

FAO's Water Scarcity Program

Training Manual: Crop Water Productivity Options to Achieve Real Water Savings



REPORT

199

CLIENT

FAO

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DATE

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FutureWater Report 199

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1 Introduction, Relevance, Target Audience

Increased water use has led to water scarcity in many Asian countries. This trend will continue as the gap between water demand and supply is projected to increase by factors such as population growth and economic development and environmental factors as land degradation and climate change. Solutions to revert this trend should focus on irrigated agriculture as irrigation is the largest consumer of freshwater withdrawals.

Options to save water therefore tend to focus on irrigation, specifically, improved irrigation techniques (such as drip irrigation, sprinkler, pressurized systems) are promoted as legitimate means of increasing water efficiency and “saving water” for other uses (such as domestic use and the environment). However, a growing body of evidence, including a key report by FAO (Perry and Steduto, 2017) shows that in the vast majority of cases, water “savings” at field scale translate into an increase in water consumption at basin scale. Yet despite the growing and irrefutable body of evidence, false “water savings” technologies continue to be promoted, subsidized and implemented as a solution to water scarcity in agriculture.

This training manual provides clear examples, questions, and do-it-yourself guidance for exploring and detecting real water savings versus local savings.

The objectives of this training manual is:

- Introduce clear examples, questions and answers about real water savings and water productivity.
- Introduce clear examples, questions and answers about agricultural field interventions and impacts at irrigation system and basin scale.
- Learn how to use the REWAS tool to estimate real water savings and water productivity at irrigation system scale.
- Learn how to use the WEAP tool to estimate real water savings and water productivity at basin scale.

2 Exercise: Concepts of Real Water Savings at Basin

In this exercise the outdated concept of “irrigation efficiencies” will be discussed and that alternatives should be used to evaluate irrigation systems.

We start using a conceptual river basin that simplifies the situation found in many drier regions in Asia (Figure 1):

- reservoir receiving water from the upstream located catchment
- two irrigation districts
- downstream a sea or lake

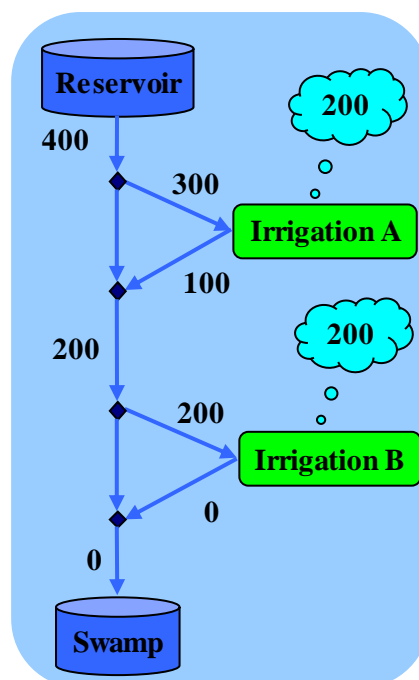


Figure 1. Conceptual river basin layout. Units are MCM (million cubic meter) per year.

2.1 Q: Calculate the irrigation efficiency of irrigation district A

Inflow is (MCM/y)

Water consumption is (MCM/y)

Irrigation efficiency is (%)

2.2 Q: Calculate the irrigation efficiency of irrigation district B:

Inflow is (MCM/y)

Water consumption is (MCM/y)

Irrigation efficiency is (%)

2.3 Q: Why is the irrigation efficiency of irrigation district B higher compared to A?

Answer:

2.4 Q: Calculate the amount of water that is consumed to produce crop

(for this example we assume that all water that is consumed by the crop (evapotranspiration) will be converted to yield):

Crop evapotranspiration (total) (MCM/y)

Since the irrigation district A has a somewhat low efficiency (67%) compared to district B, it was decided to invest in irrigation district A to increase its efficiency. The new situation can be seen in Figure 2

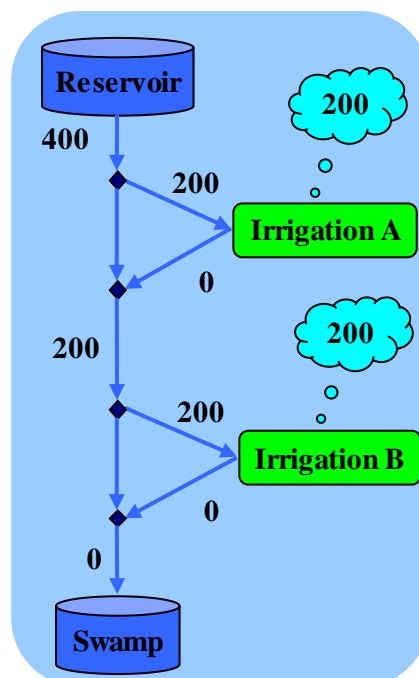


Figure 2. Same as Figure 1, but irrigation efficiencies of system A increased by investments in the irrigation infrastructure.

2.5 Answer the same questions for this new situation:

Irrigation efficiency district **A** (%)
Irrigation efficiency district **B** (%)
Crop evapotranspiration (total) (MCM/y)

Consider a farmer in irrigation district A. Quite some investments were made in increasing the efficiencies of the system (either by the farmers or the irrigation/water user association). Before the investments were made the irrigation district received 300 MCM/y (Figure 1). After investments this was reduced to 200 MCM/y (Figure 2). It is clear that farmers will never accept such a reduction in water allocation after investment done by them.

So, it is quite sure that irrigation district A will never accept receiving less water after those investments (or more likely they would claim for more water to pay back their investments). The new situation after investments can be seen in Figure 3.

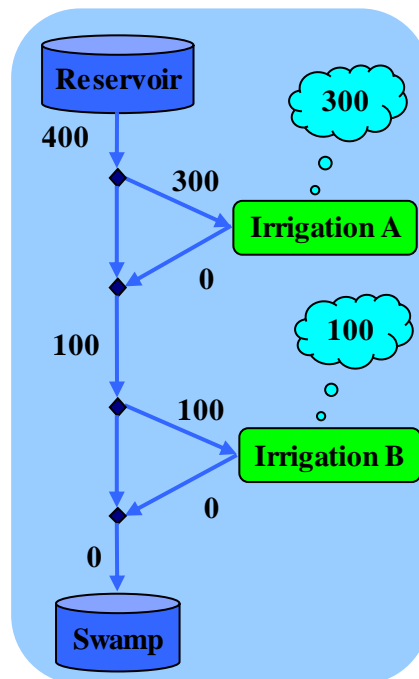


Figure 3. Same as Figure 2, but here with the more realistic water allocation.

2.6 Answer the same questions for this new and more realistic situation:

Irrigation efficiency district **A** (%)
Irrigation efficiency district **B** (%)
Crop evapotranspiration (total) (MCM/y)

2.7 Discuss what will be the implications of this new situation for farmers in district **A**:

Answer:

2.8 Discuss what will be the implications of this new situation for farmers in district **B**:

Answer:

2.9 Discuss what has changed in the amount of food produced:

Answer:

3 Exercise: Follow the water

In irrigation systems water inflows are rainfall and irrigation, and water outflows are soil evaporation, crop transpiration, drainage and percolation. Consider a farmer in an irrigation system. According to a farmer's perspective drainage and percolation flows are water losses, but in reality part of these flows are recoverable. We have selected a rice irrigation system of 25 hectares in the Kavrepalanchok district, Nepal to evaluate the water flows and crop yields.



Figure 4. Rice irrigation system of 25 hectares in the Kavrepalanchok district, Nepal.

The irrigation system consists of rice fields separated by soil bunds. The irrigation method is surface irrigation. The management practices of each field inside the system are assumed to be the same. Rainfall during the cropping season between July and November is 707 mm/season (Funk et al., 2015). Typical irrigation application is 270 mm/season and the rice yield is 3120 kg/ha (Jha et al., 2016).

3.1 Q: What do you expect with the rice yield if the irrigation application is reduced?

- ☐ Same rice yield
- ☐ Higher rice yield
- ☐ Lower rice yield

A study (Jha et al., 2016) reported results of two irrigation application scenarios: 270 mm/season (scenario A); and 30 mm/season (scenario B). According to the field trials rice yields for those scenarios were 3120 kg/ha (scenario A) and 2870 kg/ha (scenario B).

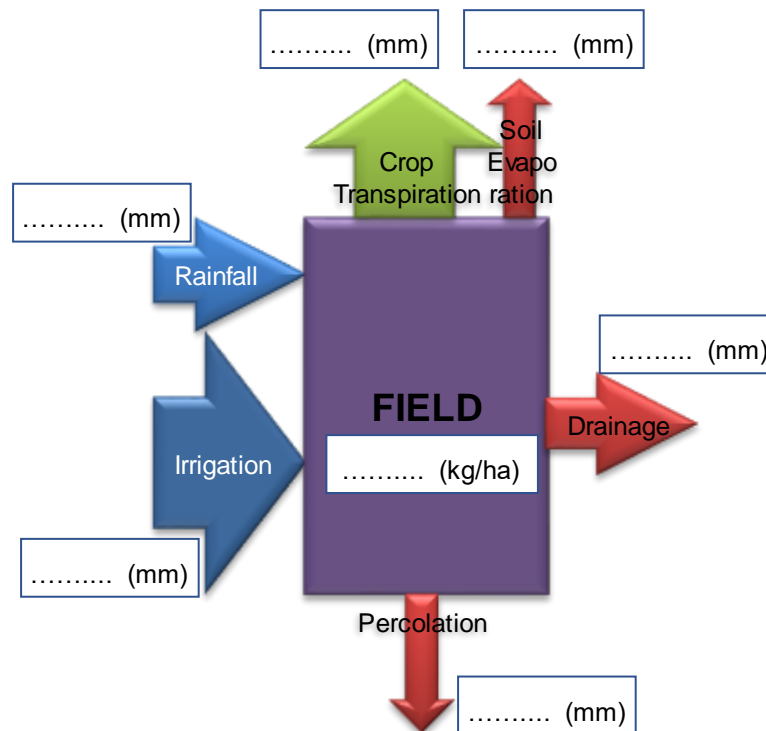
3.2 Q: Why is the rice yield reduced with lower irrigation application?

Answer:

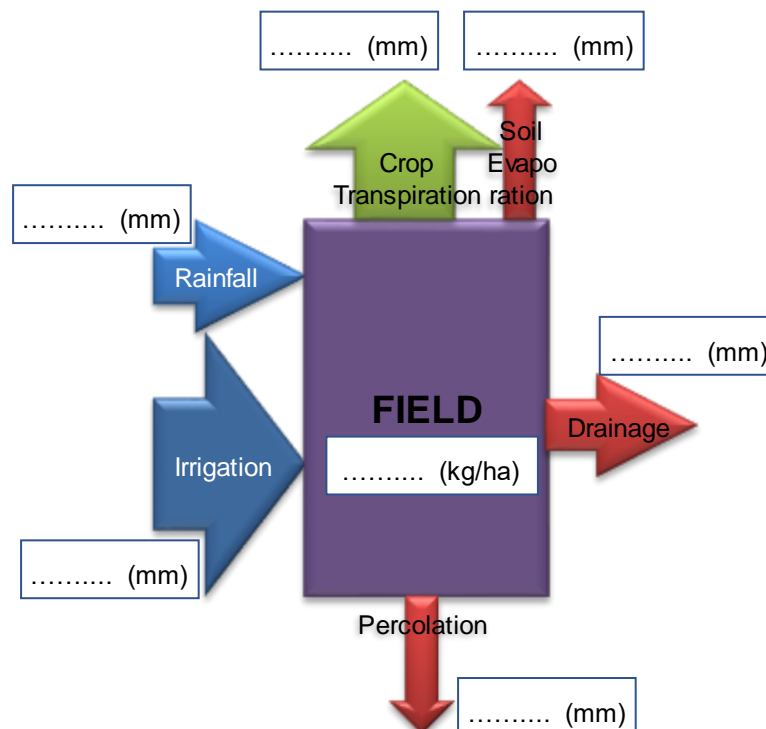
The full water balance based on the two field trials are as following:

	A	B
Precipitation (mm/season)	707	707
Irrigation (mm/season)	270	30
Crop Transpiration (mm/season)	212	192
Soil Evaporation (mm/season)	172	154
Drainage (mm/season)	349	198
Percolation (mm/season)	244	193
<i>Yield (kg/ha)</i>	<i>3120</i>	<i>2870</i>

3.3 Put the numbers in the schematic below for scenario **A**



3.4 Put the numbers in the schematic below for scenario **B**



3.5 Q: Calculate the total inflow and the total outflow for each irrigation application scenario:

Total inflow A is (mm/season)

Total outflow A is (mm/season)

Total inflow B is (mm/season)

Total outflow B is (mm/season)

3.6 Q: According to the farmer's perspective, obtain the water savings between irrigation application A and irrigation application B:

☐ 240 mm/season

☐ 202 mm/season

☐ 220 mm/season

☐ 18 mm/season

☐ 20 mm/season

☐ 10 mm/season

3.7 Q: According to the farmer's perspective, the water savings between irrigation scenarios is 240 mm/season. Obtain the water savings relative to the total inflow A:

Water savings is..... %

According to the farmer's perspective, drainage and percolation flows are water losses. However, drainage and percolation flows are reused downstream (Figure 5). In fact, a fraction of drainage and percolation flows may be recoverable for a specific user. The fraction which is recoverable depends on soil characteristics, existing infrastructure (e.g. pumps and canals) and management aspects (e.g. opening and closing control gates/valves).

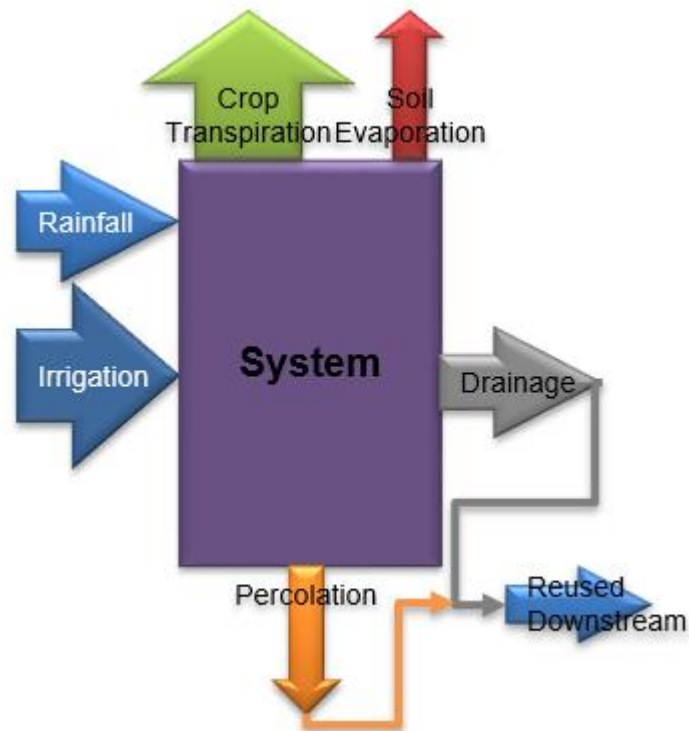


Figure 5. Following the water in an irrigation system. Drainage and percolation flows are reused downstream.

According to field trails in the rice irrigation system in Nepal, 80% of the drainage and 80% of the percolation is recoverable for irrigation. The remaining flow (20% of the drainage and 20% of the percolation) is not recoverable.

3.8 Q: According to the field trails, obtain the Beneficial, Non-beneficial, Recoverable, and Non-recoverable flows for irrigation application A and irrigation application B:

			A (mm/season)	B (mm/season)
Water Resources	Consumption	Beneficial		
		Non-Beneficial		
	Return Flows	Recoverable		
		Non-recoverable		

3.9 Q: Obtain the Non-beneficial flow savings between irrigation application A and irrigation application B:

The Non-beneficial flow savings is:mm/season

3.10 Q: Obtain the Non-recoverable flow savings between irrigation application A and irrigation application B:

The Non-recoverable flow savings is:mm/season

3.11 Q: Obtain the real water savings between irrigation application A and irrigation application B?

- | | |
|--|---------------------------------------|
| <input type="checkbox"/> 240 mm/season | <input type="checkbox"/> 18 mm/season |
| <input type="checkbox"/> 40 mm/season | <input type="checkbox"/> 20 mm/season |
| <input type="checkbox"/> 220 mm/season | <input type="checkbox"/> 58 mm/season |

3.12 Q: The real water savings between irrigation scenarios is 58 mm/season. Obtain the real water savings relative to the total inflow A:

Real water savings is..... %

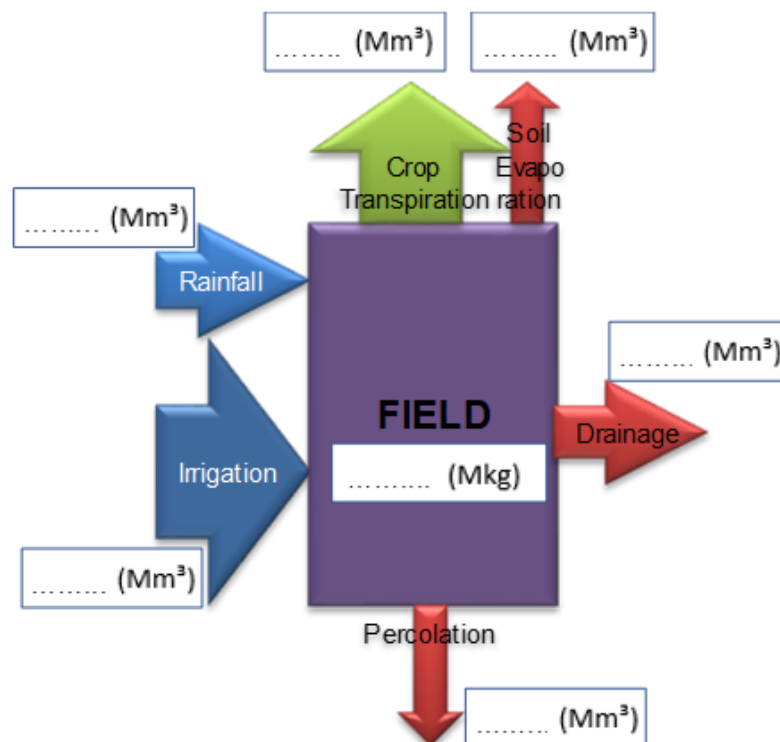
4 Exercise: Water productivity

For a rice irrigation system of 1000 hectares located in Nghe An province in the north central coastal region of Vietnam the water productivity was evaluated. Rainfall during the cropping season between February and June is 2.11 Mm³/season (Funk et al., 2015). A study (Hong and Yabe, 2017) reported two irrigation application scenarios: 9.10 Mm³/season (scenario A); and 1.82 Mm³/season (scenario B). According to field trials rice production for those scenarios were 5.24 Mkg (scenario A) and 3.81 Mkg (scenario B).

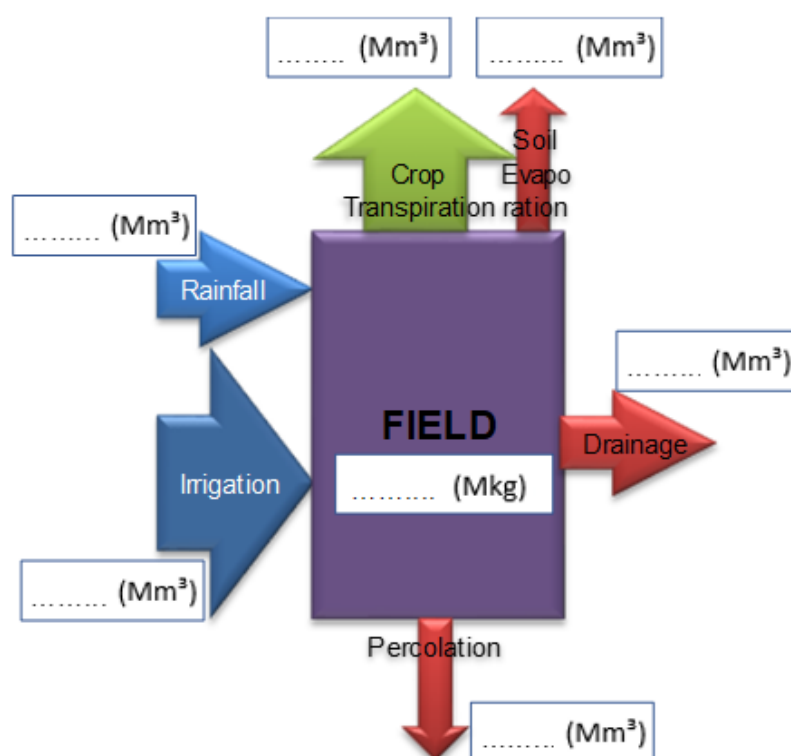
The full water balance based on the two field trials are:

	A	B
Precipitation (Mm ³ /season)	2.11	2.11
Irrigation (Mm ³ /season)	9.10	1.82
Crop Transpiration (Mm ³ /season)	4.03	2.42
Soil Evaporation (Mm ³ /season)	1.63	1.30
Drainage (Mm ³ /season)	3.21	0.10
Percolation (Mm ³ /season)	2.34	0.11
Rice production (Mkg/season)	5.24	3.81

4.1 Put the numbers in the schematic below for scenario A



4.2 Put the numbers in the schematic below for scenario B



The **water productivity** of a crop is the ratio between the amount of crop produced and the amount of water consumed to obtain such production.

4.3 Determine the amount of water consumed to obtain the rice production in scenario A and in scenario B:

In scenario A, the amount of water consumed to obtain the rice production isMm³/season

In scenario B, the amount of water consumed to obtain the rice production isMm³/season

4.4 Determine the amount of rice produced in scenario A and in scenario B:

In scenario A, the amount of rice produced isMkg/season

In scenario B, the amount of rice produced isMkg/season

4.5 Q: Determine the water productivity of rice for scenario A and scenario B

In scenario A, the water productivity for rice iskg/m³

In scenario B, the water productivity for rice iskg/m³

4.6 Q: Why is the water productivity of scenario B higher to water productivity of scenario A?

Answer:

4.7 Q: Which irrigation application scenario would the rice farmer prefer to use? Why?

Answer:

4.8 Q: Assume a high cost for irrigation water. Which irrigation application scenario would the rice farmer prefer to use now? Why?

Answer:

5 Introducing REWAS

The main objective of REWAS is to assess quickly the impact of field scale crop-water interventions on basin scale water savings. The REWAS approach is to “Follow the Water”. In other words, drainage, runoff and percolation to the groundwater are in many cases considered as “losses”, ignoring the fact that this water is used by downstream users. So, claiming that a reduction in drainage, runoff and percolation at a field saves water is incorrect as downstream reuse should be considered.

To briefly introduce what can be done with REWAS a typical water savings case will be summarized here. A study from Nepal (Jha, 2016) reported that by reducing irrigation applications, 75% water savings were achieved. However, the study failed to use the “Follow the Water” principle as it was assumed that at all Return Flows were losses, while in reality 80% of those Return Flows are Recovered by downstream users. Figure 6 indicates that the study reported water savings referred only to the irrigation application (solid yellow box in the Figure), while the focus should have been on the Recoverable Return Flows and Non-Beneficial Consumptions.

Using the REWAS tool (Figure 7) it is evident that the claimed water savings of 75% are not true from a basin perspective and the real water savings at basin scale are much smaller and are in the order of around 6%.

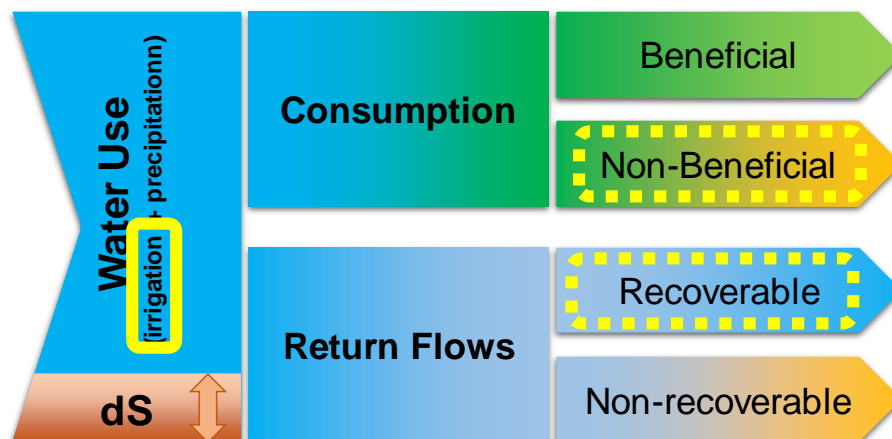


Figure 6. The approach of “Follow the Water” as applied in the REWAS tool. The solid yellow box indicates on which water savings were reported: change in irrigation reduction. The dotted yellow boxes shows where real water savings can be achieved.

INPUT DATA			
		Scenario	
		Reference	Intervention A
FIELD	Units		
Rainfall	(mm)	910	910
Irrigation	(mm)	217	54
Crop Transpiration	(mm)	720	720
Soil Evaporation	(mm)	43	0
Drainage	(mm)	182	122
Percolation	(mm)	182	122
RECOVERABLE FLOW FRACTION			
Recoverable drainage fraction RD	(%)	80%	80%
Recoverable percolation fraction RP	(%)	80%	80%
RESULTS			
		Scenario	
		Reference	Intervention A
Percentage of Real Water Savings	(%)	-	6%

Figure 7. Screenshot from the REWAS tool analysing real water savings for the Nepal case.

REWAS is developed in Microsoft Excel to enhance usability, reach, transparency, transferability of data input and output. Input data can be obtained from studies, field trials, measurements, ground observations or remote sensing. REWAS output is based on proven concepts of water accounting, and the appropriate water terminology, as promoted by FAO globally (FAO, 2013).

Details about underlying equations, theory and concepts of REWAS are explained in more detail in the *Technical Document: REWAS the REal Water Savings tool*.

6 REWAS start guide

Open REWAS tool in the excel document called: REWAS_v8.xlsm

Select the sheet called: Main. Follow the next sections to understand the REWAS interface.

6.1 Inserting input data in REWAS interface

In Figure 8 the input data interface in REWAS is shown. The user can manually insert data values in the assigned cells for different scenarios (reference, intervention A and intervention B). For each field intervention the crop transpiration, soil evaporation, drainage and percolation may vary. These changes can be obtained from field trials. Instead of using data from field trials the user can import AquaCrop results by clicking on the green arrow for each scenario. Steps on how to import AquaCrop results are described in the *Technical Document: REWAS the REal WATER Savings tool*. Also, the area of the irrigation system and the recoverable flow fraction can be manually field in. More information about the recoverable flow fraction can be found in the *Technical Document: REWAS the REal Water Savings tool*.

If needed, click to import AquaCrop Results				
INPUT DATA				
		Scenario		
		Reference	Intervention A	Intervention B
FIELD	Units			
Rainfall	(mm)			
Irrigation	(mm)			
Crop Transpiration	(mm)			
Soil Evaporation	(mm)			
Drainage	(mm)			
Percolation	(mm)			
Yield	(kg/ha)			
SYSTEM				
Area	(ha)			
RECOVERABLE FLOW FRACTION				
Recoverable drainage fraction RD	(%)			
Recoverable percolation fraction RP	(%)			

Figure 8. REWAS input data: Field data, irrigation area and reuse parameters. If required, data can be imported from FAO AquaCrop.

6.2 Obtaining results in REWAS

The output results of the REWAS tool are separated at field (FIELD) and system (SYSTEM) level. The units of the output variables are in mm at field level and MCM at system level according to the area of the irrigation system (defined in the input variables). The output results are shown in Figure 9. The water savings are determined between a reference scenario and different intervention scenarios (e.g. intervention A and intervention B). The different components of water accounting, corresponding real water savings at system scale and the water productivity is calculated. In Figure 10, the interface of intermediate results in REWAS is shown. Inflows and outflows at field and system scale are determined. At system scale the intermediate results for drainage and percolation volumes for recoverable flow fractions are obtained.

RESULTS				
		Scenario		
		Reference	Intervention A	Intervention B
RESULTS FIELD				
Consumption, beneficial BC	(mm)			
Consumption, non-beneficial NBC	(mm)			
Return flows	(mm)			
Storage change CS	(mm)			
Water Productivity WP	(kg/m ³)			
Apparent Water Savings FWS	(mm)			
Percentage of Apparent Water Savings %FWS	(%)			
RESULTS SYSTEM				
Consumption, beneficial BC	(MCM)			
Consumption, non-beneficial NBC	(MCM)			
Return flows, recoverable RF	(MCM)			
Return flows, non-recoverable NRF	(MCM)			
Storage change CS	(MCM)			
Water Productivity WP	(kg/m ³)			
Real Water Savings RWS	(MCM)			
Percentage of Real Water Savings %RWS	(%)			

Figure 9. REWAS output results at field level (units in mm) and system level (units in MCM), and water productivity indicator to evaluate real water savings for different intervention scenarios.

INTERMEDIATE RESULTS				
		Scenario		
		Reference	Intervention A	Intervention B
FIELD				
InflowTotal	(mm)			
OutflowTotal	(mm)			
SYSTEM				
Rainfall	(MCM)			
Irrigation	(MCM)			
Crop Transpiration	(MCM)			
Soil Evaporation	(MCM)			
Drainage	(MCM)			
Percolation	(MCM)			
Production	(Mkg)			
DrainageTotal	(MCM)			
DrainageRecoverable	(MCM)			
DrainageNonRecoverable	(MCM)			
PercolationTotal	(MCM)			
PercolationRecoverable	(MCM)			
PercolationNonRecoverable	(MCM)			
Inflow Total	(MCM)			
Outflow Total	(MCM)			

Figure 10. Intermediate results in REWAS. At system scale the intermediate results for drainage and percolation volumes for recoverable and non-recoverable flows is shown.

7 Real water Savings at irrigation system using REWAS

Let's assume the following scenarios (reference scenario and field intervention A) in a wheat irrigation system of 5000 hectares in Iran. Insert the values in REWAS as shown in Figure 11 and Figure 12.

INPUT DATA			
		Scenario	
		Reference	Intervention A
FIELD	Units		
Rainfall	(mm)	171	171
Irrigation	(mm)	450	90
Crop Transpiration	(mm)	382	185
Soil Evaporation	(mm)	65	50
Drainage	(mm)	119	15
Percolation	(mm)	55	11
Yield	(kg/ha)	5320	3200

Figure 11. Input data for REWAS (INPUT DATA) in Iran.

SYSTEM			
Area	(ha)	5000	5000
RECOVERABLE FLOW FRACTION			
Recoverable drainage fraction RD	(%)	70%	70%
Recoverable percolation fraction RP	(%)	70%	70%

Figure 12. INPUT DATA: Size of the irrigation system (5000ha) and recoverable flow fractions in Iran.

In Figure 13 intermediate results for total inflows and total outflows are shown at field and system level. Intermediate calculations are made to convert the units of water (from mm to MCM) and crop production (from kg/ha to Mkg), and to obtain recoverable flows from drainage and percolation.

INTERMEDIATE RESULTS			
		Scenario	
		Reference	Intervention A
FIELD			
InflowTotal	(mm)	621	261
OutflowTotal	(mm)	621	261
SYSTEM			
Rainfall	(MCM)	8.6	8.6
Irrigation	(MCM)	22.5	4.5
Crop Transpiration	(MCM)	19.1	9.3
Soil Evaporation	(MCM)	3.3	2.5
Drainage	(MCM)	6.0	0.8
Percolation	(MCM)	2.8	0.6
Production	(Mkg)	26.6	16.0
DrainageTotal	(MCM)	6.0	0.8
DrainageRecoverable	(MCM)	4.2	0.5
DrainageNonRecoverable	(MCM)	1.8	0.2
PercolationTotal	(MCM)	2.8	0.6
PercolationRecoverable	(MCM)	1.9	0.4
PercolationNonRecoverable	(MCM)	0.8	0.2
Inflow Total	(MCM)	31	13
Outflow Total	(MCM)	31	13

Figure 13. INTERMEDIATE RESULTS for REWAS tool: FIELD, SYSTEM in Iran.

In Figure 14 the water accounting and water productivity results at field level and real impact at system level are shown. The percentage of real water savings is 10%, and not 26%. The percentage of water savings is much lower than expected due to the influence of recoverable flows. The water productivity in intervention A (1.36 kg/m³) is higher than the reference (1.19 kg/m³). This means that even though in intervention A the crop production is lower than in the reference, the water consumed in intervention A is much lower than the water consumed in the reference scenario.

RESULTS			
		Scenario	
		Reference	Intervention A
RESULTS FIELD			
Consumption, beneficial BC	(mm)	382	185
Consumption, non-beneficial NBC	(mm)	65	50
Return flows	(mm)	174	26
Storage change CS	(mm)	0.0	0.0
Water Productivity WP	(kg/m ³)	1.19	1.36
Apparent Water Savings FWS	(mm)	-	163
Percentage of Apparent Water Savings %FWS	(%)	-	26%
RESULTS SYSTEM			
Consumption, beneficial BC	(MCM)	19.1	9.3
Consumption, non-beneficial NBC	(MCM)	3.3	2.5
Return flows, recoverable RF	(MCM)	6.1	0.9
Return flows, non-recoverable NRF	(MCM)	2.6	0.4
Storage change CS	(MCM)	0.0	0.0
Water Productivity WP	(kg/m ³)	1.19	1.36
Real Water Savings RWS	(MCM)	-	3.0
Percentage of Real Water Savings %RWS	(%)	-	10%

Figure 14. RESULTS for REWAS tool: RESULTS FIELD and RESULTS SYSTEM in Iran.

8 Install WEAP and obtain free license

The developer of WEAP (SEI) provides free WEAP licenses for non-profit, governmental or academic organization based in a developing country. To acquire this free license a two steps approach is needed. **The process may take up to two days.** FOLLOW THESE STEPS CAREFULLY.

8.1 Register at the WEAP forum

- Go to: <http://www.weap21.org/index.asp?action=8>
- Fill the required information
- You will receive an email with your WEAP forum password
- Write down below

Email address used:	
Password for WEAP forum:	

8.2 Obtain Free License

- Log into your WEAP forum account:
 - <http://www.weap21.org/index.asp?action=102>
- Obtain the license by clicking:
 - <http://www.weap21.org/index.asp?action=65>
- Write down below

User Name:	
Registration Code for WEAP:	

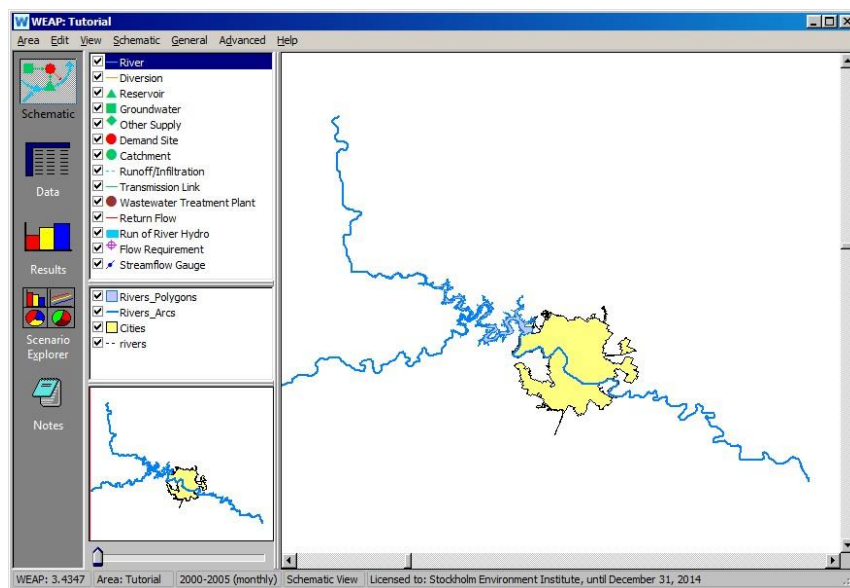
9 WEAP in one hour

This section is a copy and paste (with some modifications) of the WEAP Tutorial by SEI, 2016.

9.1 Setting General Parameters

We are now going to proceed with learning how to navigate through WEAP and its functionalities. For the remaining exercises in this tutorial we will be using a pre-defined Area called “Tutorial.”

To open this Area, on the Main Menu, go to Area and select “Open.” You should see a list of Areas that includes “Tutorial”—select this Area. You should now see the Schematic as shown below—with blue lines for rivers and a yellow polygon for the city.



If you do not see this, go to the Area Menu, select “Revert to Version” and choose the version named “Starting Point for ‘WEAP in One Hour’ module” (it will have a date and time before the title).

9.2 Set the General Parameters

Once the Area opens, use the “General” menu to set Years and Time Steps.

Set the Current Accounts Year to 2000 and the Last Year of Scenarios to 2005. Set the Time Steps per year to 12. Set the Time Step Boundary to “Based on calendar month” and starting in January (see below) Keep the default (SI units) for now.

Years and Time Steps

Time Horizon

Current Accounts Year: 2000

Last Year of Scenarios: 2005

Time Steps per Year

12

☐ Add Leap Days?

Time Step Boundary

☒ Based on calendar month

☐ All time steps are equal length

☐ Set time step length manually

Water Year Start

January

#	Title	Abbrev.	Length	Begins	Ends
1	January	Jan	31	Jan 1	Jan 31
2	February	Feb	28	Feb 1	Feb 28
3	March	Mar	31	Mar 1	Mar 31
4	April	Apr	30	Apr 1	Apr 30
5	May	May	31	May 1	May 31
6	June	Jun	30	Jun 1	Jun 30
7	July	Jul	31	Jul 1	Jul 31
8	August	Aug	31	Aug 1	Aug 31
9	September	Sep	30	Sep 1	Sep 30
10	October	Oct	31	Oct 1	Oct 31
11	November	Nov	30	Nov 1	Nov 30

Time Step Name Format: October / Oct

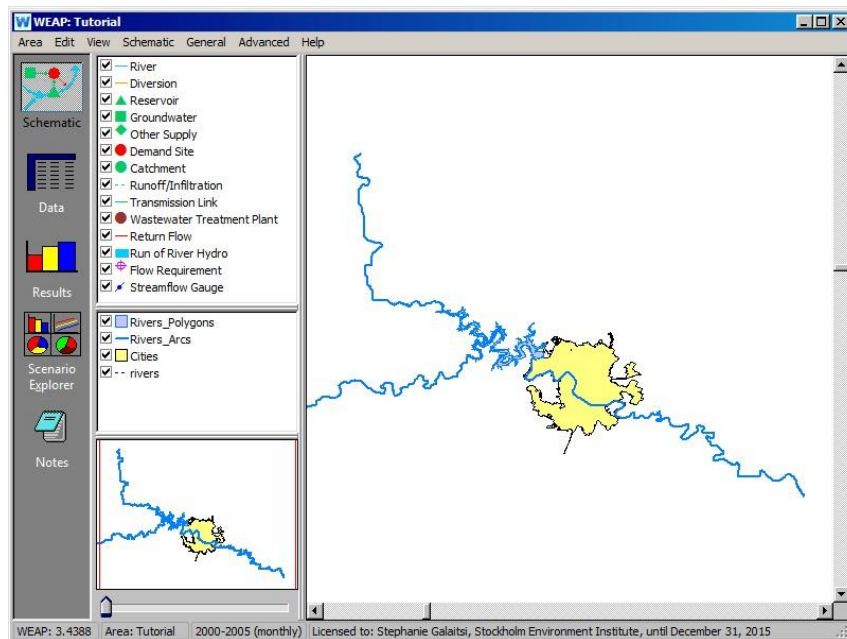
The study period will run from January, 2000 to December, 2005.

[? Help](#) [Close](#)

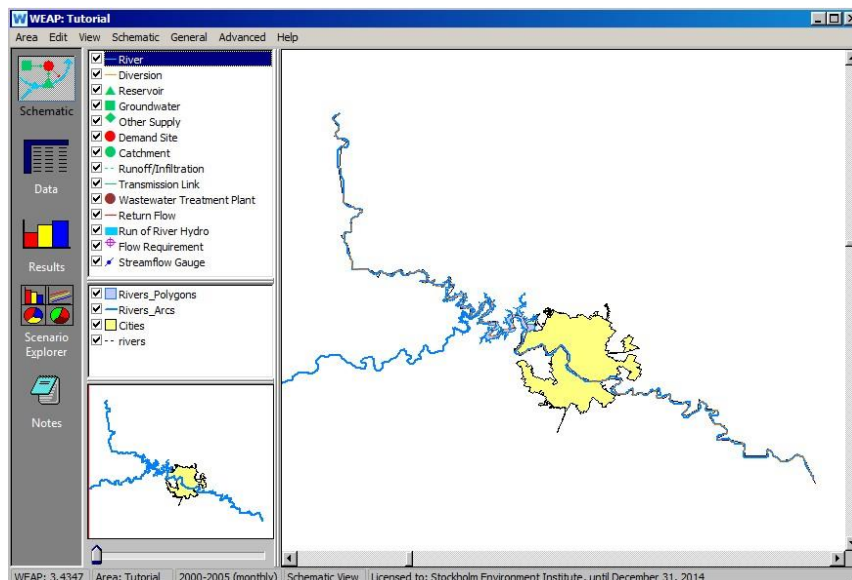
9.3 Entering Elements into the Schematic

Draw a River

Click on the “River” symbol in the Element window and hold the click (YES: KEEP YOUR LEFT MOUSE BUTTON DOWN!!) as you drag the symbol over to the map. Release the click when you have positioned the cursor over the upper left starting point of the main section of the river. Move the cursor, and you will notice a line being generated from that starting point.



Follow roughly the main river, drawing from the upstream (upper left) to the downstream (lower right), clicking once to end each segment that you draw. There is no need to follow the river in all details. About 20 clicks (=segments) is sufficient. Double click to end drawing the river. You do not need to draw a river on the branch coming horizontally from the left.



When you double click to finish drawing the river, a dialog box appears for naming the river (see below).

Name the river "Main River."

General Info

River

Name: Main River

Optional Label for Schematic (Use ; for line break): Main River

Buttons: ? Help, Finish, Cancel

9.4 Enter Data for the Main River

There are two ways to navigate to the data entry section of WEAP to enter data for the Main River.

- 1) Right-click on the Main River and select Edit data and any item in the list.
- 2) Switch to the Data view by clicking on the Data symbol on the left of the main screen. Select: *Supply and Resources/ River /Main River* in the Data tree. You may have to click on the “plus sign” icon beside the Supply and Resources branch in order to view all of the additional branches below it in the tree.

WEAP: Tutorial

Area Edit View General Tree Help

Schematic

Data

Results

Overviews

Notes

Key Assumptions

Demand Sites

Hydrology

Supply and Resources

River

Main River

Other Assumptions

Data for: Current Accounts (2000) Manage Scenarios...

Inflows and Outflows Water Quality

Headflow Reach Length

Average monthly inflow at head of river Help

River	Get Values from	Scale
Main River	Enter Expression	2000

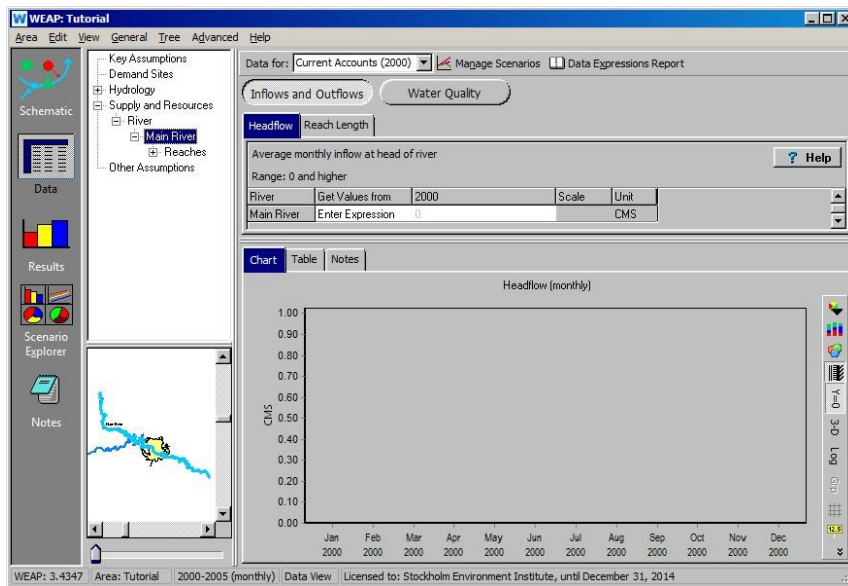
Chart Table Notes

Headflow (monthly)

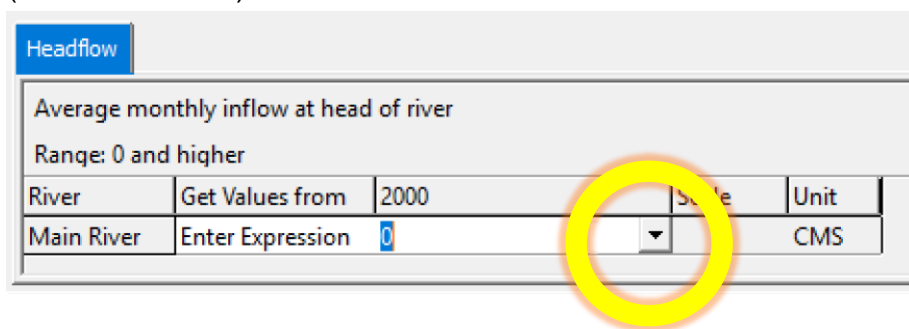
0 100

Jan Mar May Jul Sep Nov

Area: Tutorial Data View Registered to: Chris Swartz, Tellus Institute



The "Inflows and Outflows" window should be open - if it isn't, click on the appropriate button. Click on the "Headflow" tab. Click on the area just beneath the bar labeled "2000" in the data input window to view a pull-down menu icon (the small arrow).



Select the "Monthly Time-Series Wizard" from the drop--down menu.

Use the Monthly Time Series Wizard to enter the following data series: Month Flow (CMS)

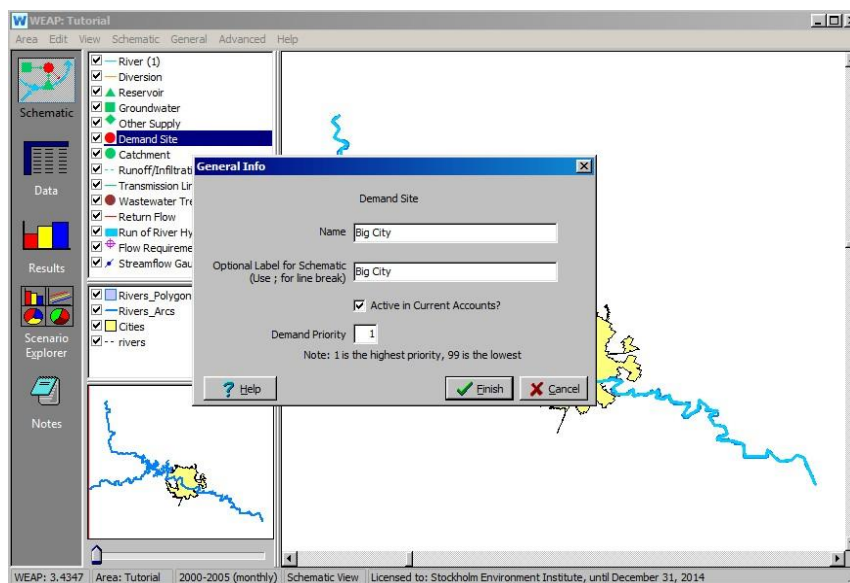
Jan	12
Feb	7
Mar	11
Apr	17
May	80
Jun	136
Jul	45
Aug	32
Sep	38

Oct	18
Nov	9
Dec	7

9.5 Create an Urban Demand Site and Enter the Related Data

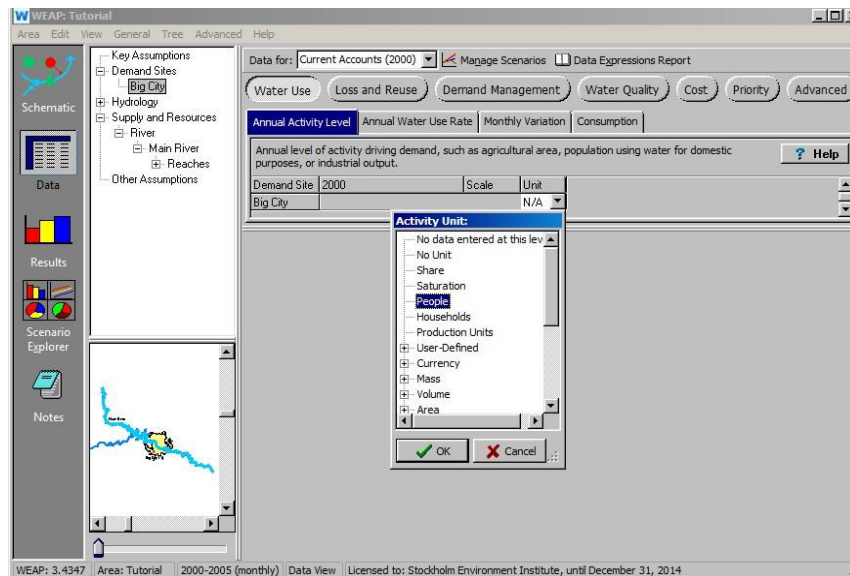
Creating a demand node is similar to the process you used to create a river. Return to the Schematic view and pull a demand node symbol onto the schematic from the Element window, releasing the click when you have positioned the node on the left bank of the river (facing downstream) in the yellow area that marks the city's extent.

Enter the name of this demand node as "Big City" in the dialog box, and set the demand priority to 1.

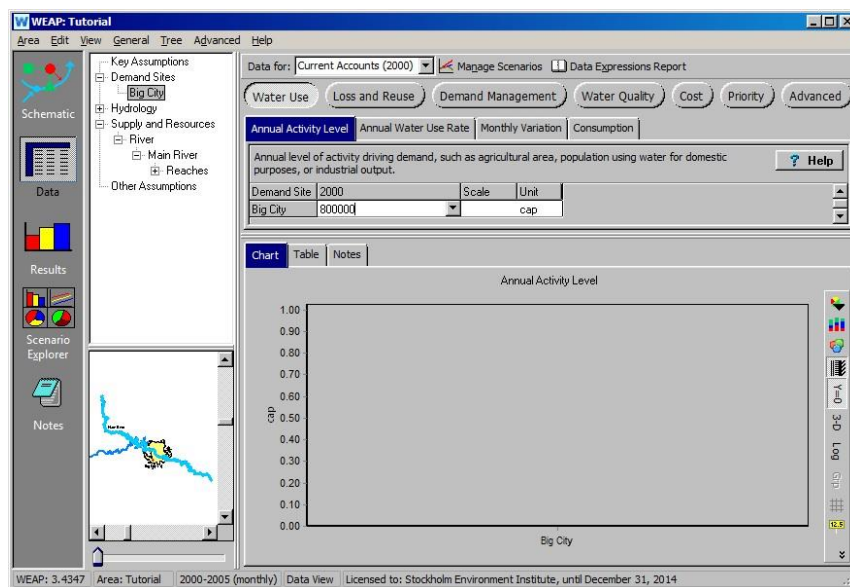


Right click on the Big City demand site and select "Edit data" and "Annual Activity Level." This is the alternative way to edit data, rather than clicking on the "Data" view icon on the side bar menu and searching through the data tree.

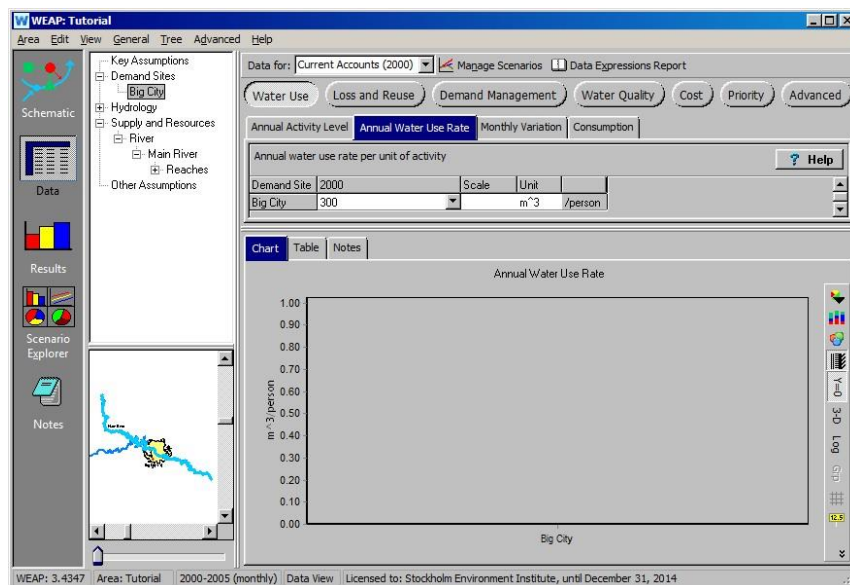
You must first select the units before entering data. Click on the "N/A" under Unit in the Annual Activity level tab. Pull down the arrow that appears, select "People", and click "OK."



In the space under the field labeled “2000”, enter the Annual Activity Level as 800,000.



Next, click on the "Annual Water Use Rate" tab and enter 300 under the year 2000.

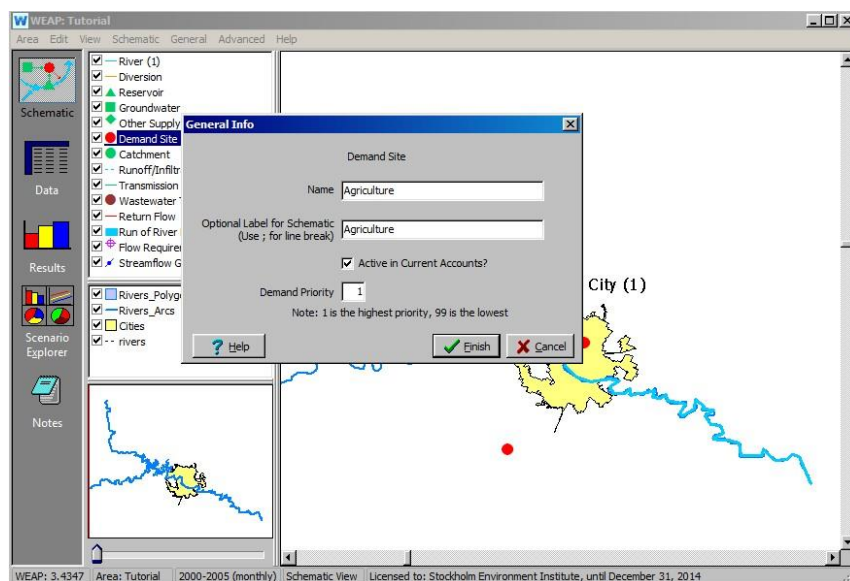


Finally, click on the "Consumption" tab and enter 15. Note that the units are pre- set to "percent."

9.6 Create an Agriculture Demand Site

Pull another demand node symbol into the project area and position it on the other side of the Main River opposite and downstream of Big City.

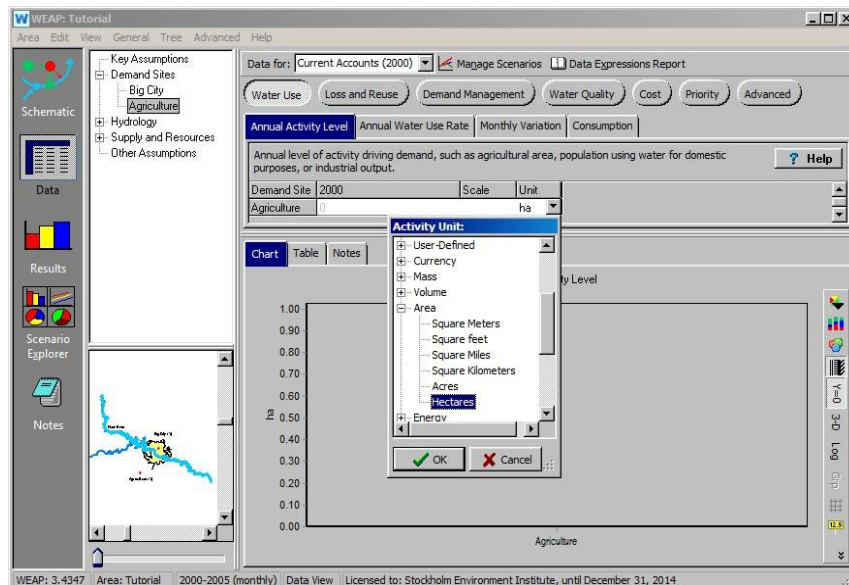
Name this demand node "Agriculture", and set the demand priority to 1.



In the same manner as for Big City, enter the Annual Activity Level and Annual Water Use Rate in the Data View for the Agriculture demand site after first selecting "hectares" as the units (you may have to click on the "plus" sign to the left in the tree in order to see all of the options for area units).

Annual Activity Level 100,000 hectares

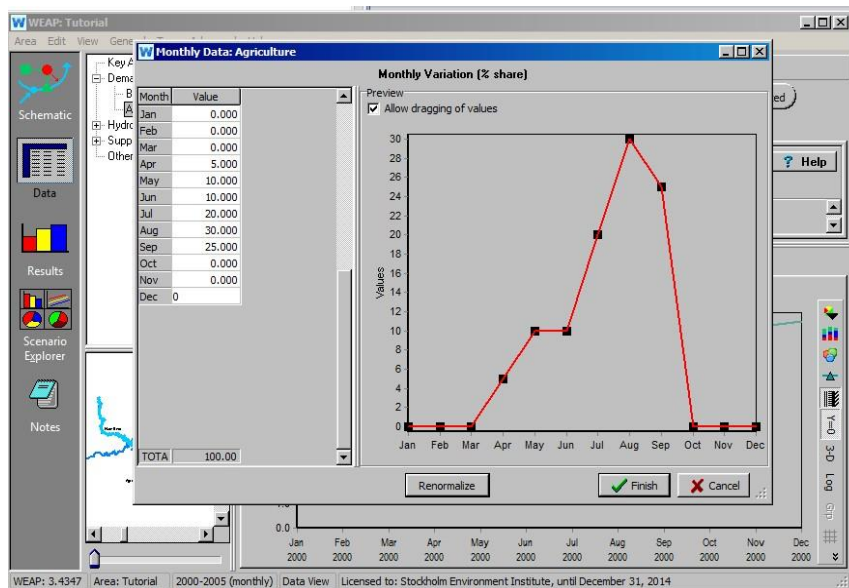
Annual Water Use rate 3,500 m³/hectare



Select the Monthly Variation tab and the Monthly Time Series Wizard to enter the data below for the monthly variation in the water use rate (small arrow at the right of the Input Box).

Monthly Variation:

- 5% in April
- 10% in May and June
- 20% in July
- 30% in August
- 25% in September
- 0% for the rest of the year

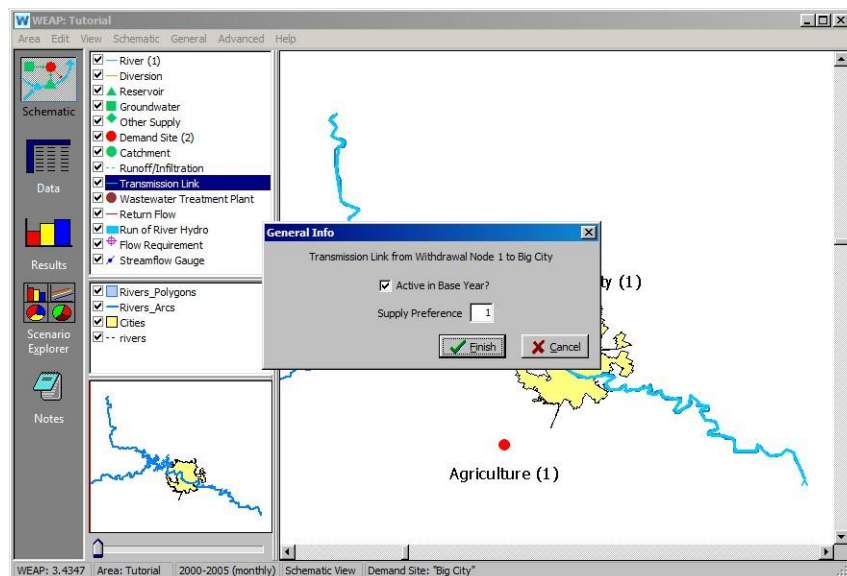


Finally, click on the Consumption tab and enter 90.

9.7 Connect the Demand with a Supply

You now need to tell WEAP how demand is satisfied; this is accomplished by connecting a supply resource to each demand site. Return to the Schematic view and create a Transmission Link from the Main River to Big City and to Agriculture. Do this by dragging the Transmission Link first to a position on the river, releasing the click, then pulling the link to Big City and double clicking on this demand node. Do the same for Agriculture, but start the Transmission Link downstream of the one created for Big City.

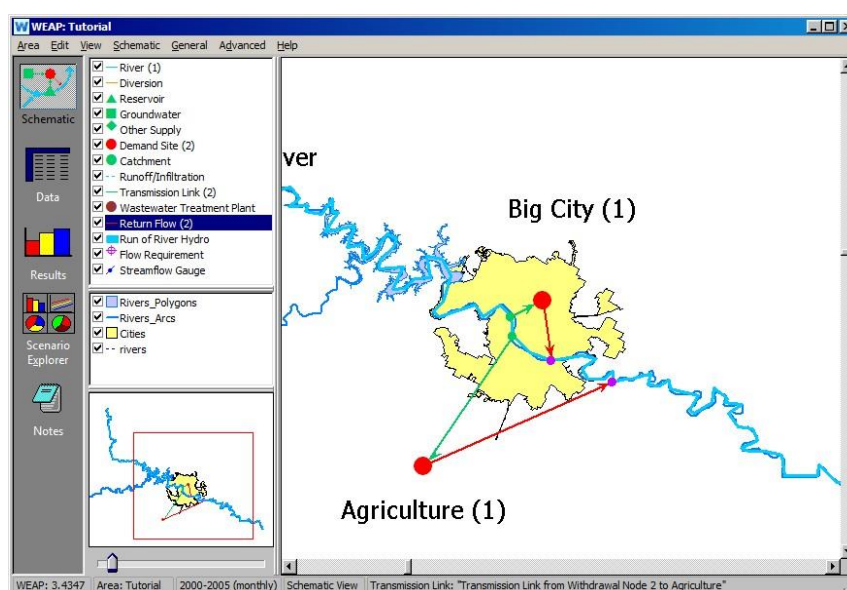
Select a Supply Preference of 1 for each Transmission Link.



9.8 Create Return Flow Links

Now create a Return Flow from Big City to the Main River. Do the same for Agriculture to the Main River. Follow the same "drag and release" procedure as for the Transmission Links.

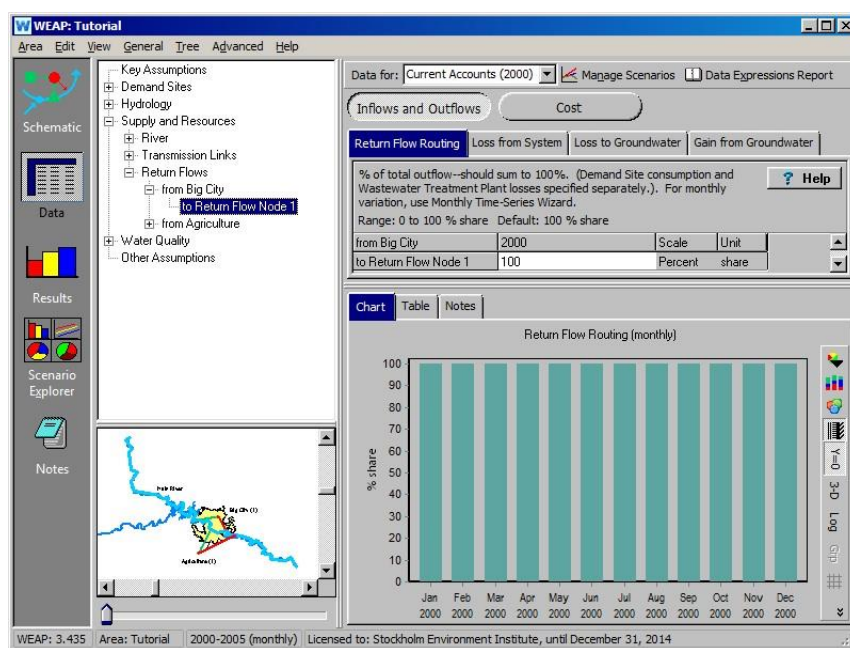
The return flow for the urban demand site should be positioned downstream of the agriculture withdrawal point. In the flow direction, the sequence should be: withdrawal for Big City, withdrawal for Agriculture, return from Big City, return from Agriculture.



Next, set the Return Flow Routing for the Big City Return Flow. Do this by right-clicking on each Return Flow and selecting "edit data" and "Return Flow Routing" or by going to the Data view\Supply and Resources\Return Flows\from Big City.

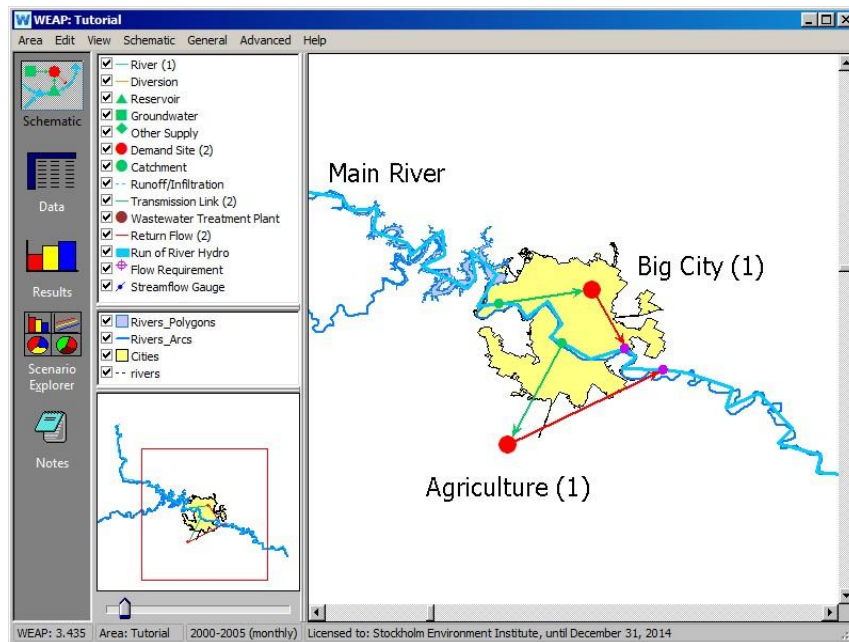
Set the Return Flow Routing to 100%.

Do the same for the Agriculture Return Flow.



9.9 Check your Model

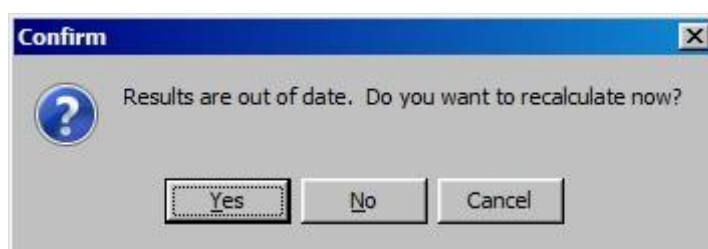
At this point, your model should look similar to the figure below.



9.10 Getting First Results

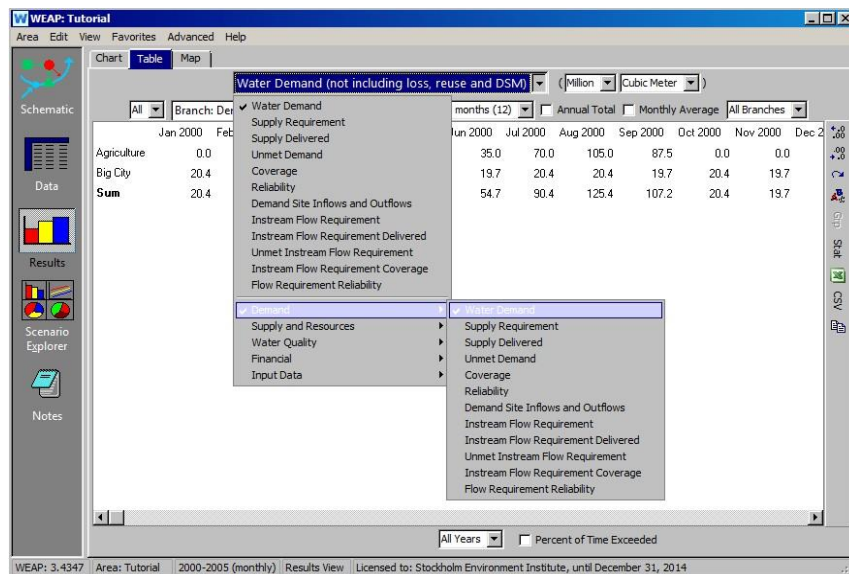
Run the Model

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 2005). When the computation is complete, the Results view will appear.



Check your Results

Click on the “Table” tab and select “Demand” and “Water Demand” from the primary variable pull-down menu in the upper center of the window (see below).

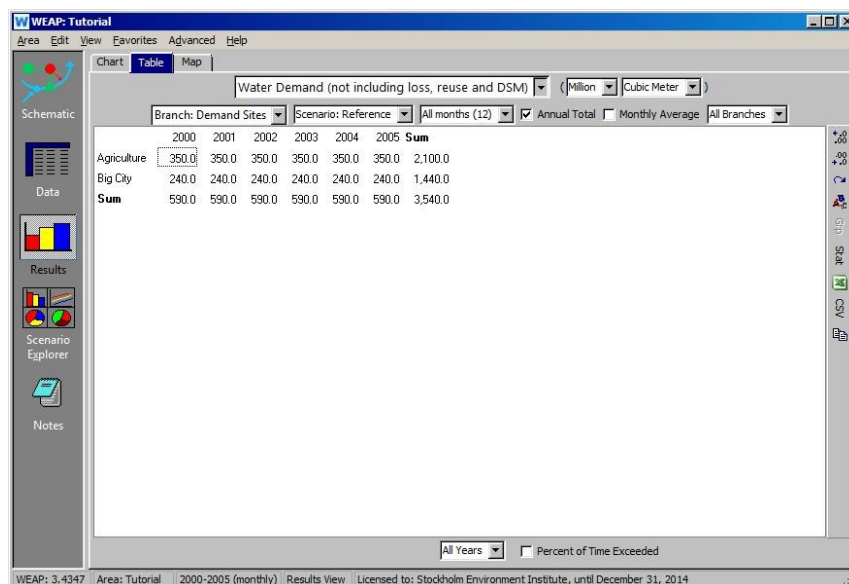


Also, click the “Annual Total” Box.

If you have entered all data as listed in previous steps, you should obtain the following annual demand values for each year (2000 to 2005) of the Reference scenario:

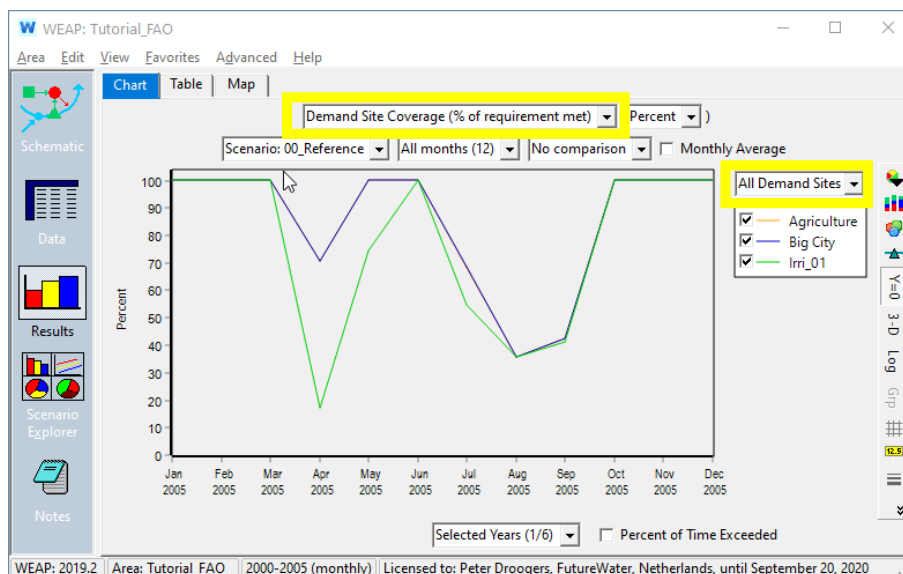
Annual Demand for Agriculture 350 M m³

Annual Demand for Urban Area 240 M m³



Look at some additional results to better understand WEAP. Some examples to explore the model are given hereafter. However, feel free to experiment by yourself.

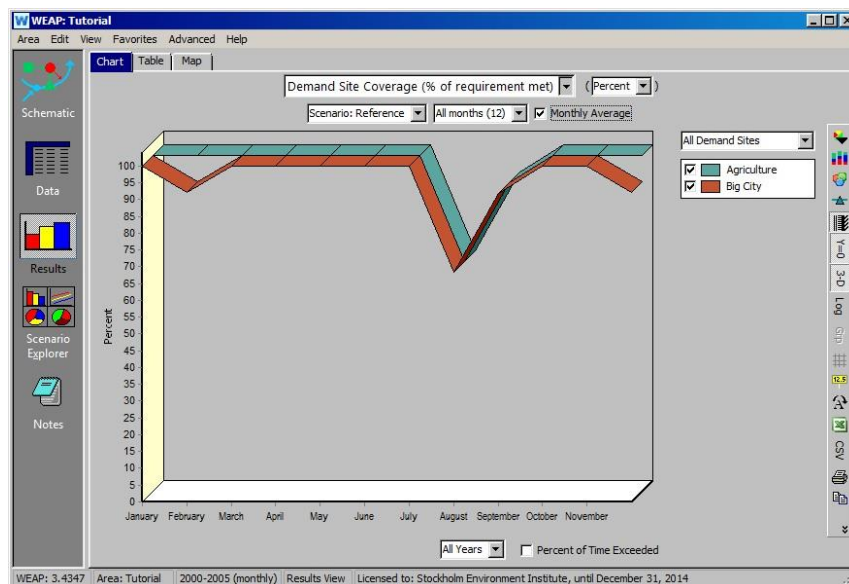
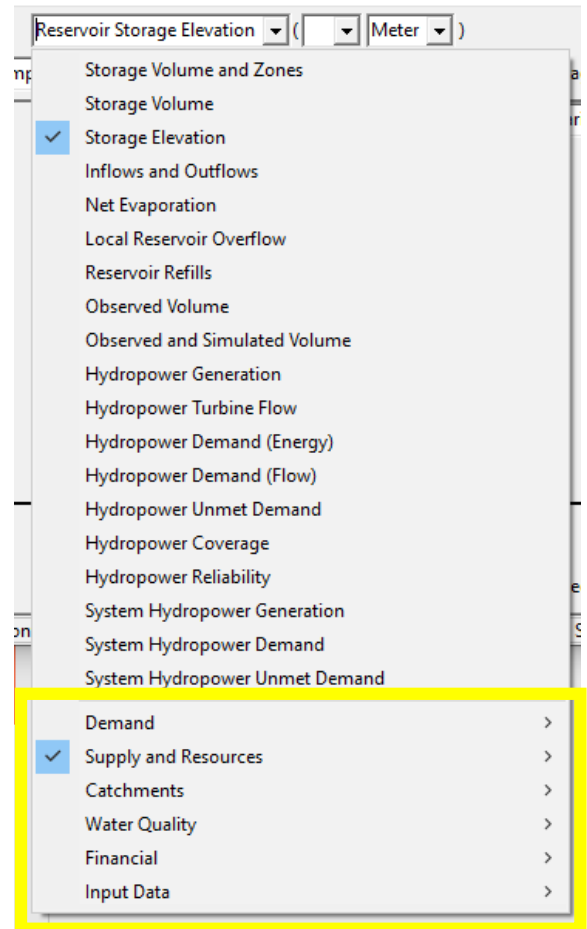
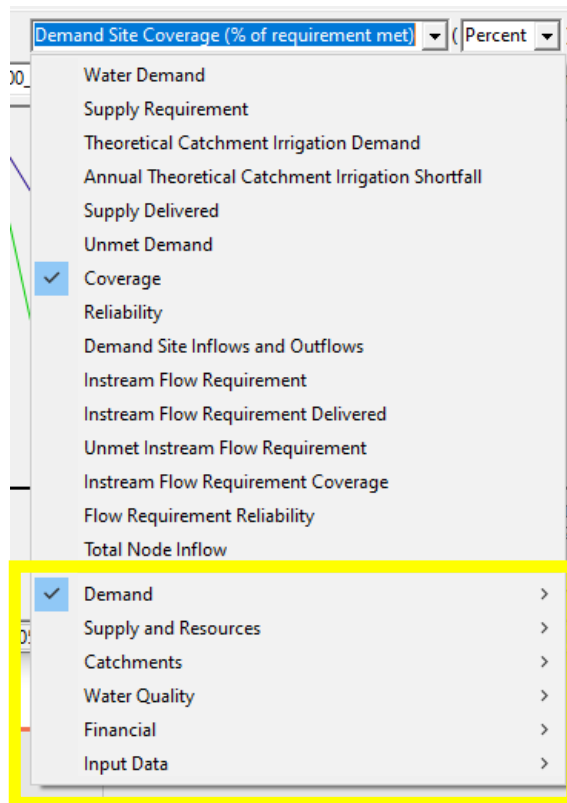
Look at the monthly Demand Coverage rates in graphical form. Click on the “Chart” tab. Select “Coverage” from the primary variable pull-down menu in the upper center of the window.



WEPA can be quite overwhelming in showing results. As a rule of thumb start at the top drop-down box to get the required result. Also the drop-down box at the right is often key to get the desired result. Explore with the other drop-down boxes to see what happens.

Format the graph by selecting the 3-D option on the right side-bar menu, and ensure that “All months” is selected in the pull-down menu above the graph (also keep the “Monthly Average” option checked). Note that the 3- D option allows the viewer to see both data sets even while they overlap. The graph should like the one below.

VERY IMPORTANT: The top drop-down box has a peculiar behavior. There are six main results groups that are displayed **AT THE BOTTOM** of the drop-down box (Demand, Supply and Resources, Catchments, Water Quality, Financial, Input Data). Based on the selected the group, the top of the drop-down will display other possible results that can be selected:



During the months of December and February, which have little flow in the river, Big City lacks water, and therefore demands go unmet. We modeled

agriculture to only require water March-September, so it registers 100% coverage in the December- February shortage because it has no water demand. Agriculture only has a shortfall in supply in the month of August and September, when the plants require the most water. Note that because Agriculture and Big City both have a supply preference of 1, when there is water shortage they will have equal percentages of unmet demand, assuming they are both demanding water at that time.

10 Water Savings at Basin Analysis using WEAP

As discussed before, the term “water savings” is somewhat incomplete. Water savings as such are not an objective in itself. In fact water savings are done to serve other users. It is therefore better to use the following definition:

Water saving is an intervention that results in incremental water being made available for an alternative beneficial use.

In this particular exercise agricultural water abstractions and consumptions will be connected to urban demand. Options to “save” water (=making more water available to a downstream located town) will be explored.

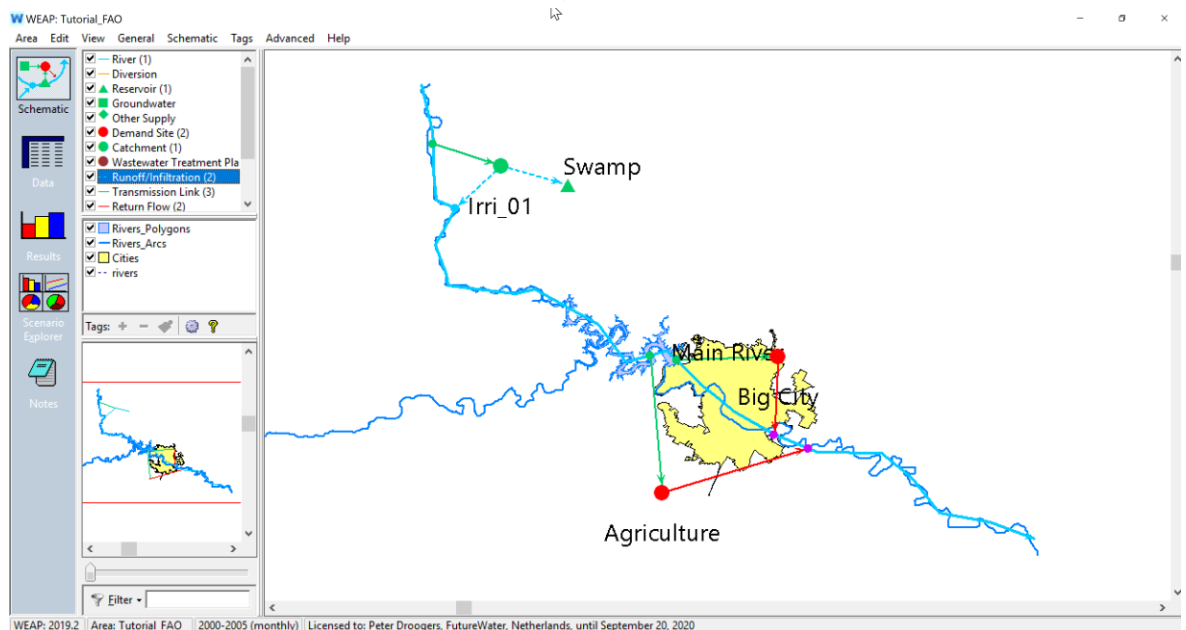
10.1 Expand the existing WEAP model

The WEAP model as developed during the “WEAP in one hour” exercise will be expanded with another agricultural demand site. The one created during that previous exercise was very simple: only hectare and m3 of irrigation demand per hectare. WEAP offers also a much more realistic irrigation demand option based on the water balance approach and calculating the irrigation demand (based on weather conditions, crop status, and soil characteristics).

- Create a new Catchment node and call it Irri_01
 - Remember on creating a new node in WEAP: keep left mouse button down, drag the node to the desired location, release mouse button.
 - If the question pops up “Would you like to use the Catchment Delineation Mode”, answer with “No”.
 - Answer in the pop-up “Select method for calculating runoff and irrigation”: “Rainfall Runoff (Soil Moisture Method)”
 - Provide a name (e.g. Irri_01).
 - Tick the box “Include Irrigated Areas”.
 - Press “Finish”.
- Add a Transmission Link from the River to the new Catchment Node. Leave the options as default and click Finish.
- Add a Runoff/Infiltration from the Catchment Node to the River.
- Add a Reservoir Node which represents a swampy area.

- Add a Runoff/Infiltration from the Catchment Node to the Swamp.

Your WEAP Area should like something like this:



Add additional data for those newly created Nodes (go to the Data View):

- > Data > Demand Sites and Catchments > Irrigation_01
 - Area: 5000 ha
 - Kc: monthly time series wizard (small pull down arrow at the right of the input box)
 - Apr: 0.5
 - May: 1.0
 - June: 1.2
 - July: 1.2
 - August: 1.0
 - September: 0.5
 - all other months: 0
 - Preferred Flow Direction: 0.8
 - Irrigation > Irrigated Area > monthly times series wizard (again, use the small pull down arrow at the right of the input box):
 - April to September: 100%
 - all other months: 0%
 - Irrigation > Lower Threshold: 80%

- Irrigation > Upper Threshold: 90%
- Climate > Precipitation > monthly time series wizard:
 - Jan – Mar: 50 mm/month
 - Apr – Sep: 0 mm/month
 - Oct – Dec: 50 mm/month
- Temperature: 20°C
- Humidity: 50%
- Cloudiness fraction: 0.5
- Latitude: 25 degrees
- > Data > Supply and Resources > Runoff and Infiltration > from Irri_01
 - to Irri_01 Runoff: 70%
 - to Swamp: 30%

The model setup and data entry has completed. Start running WEAP by pressing the Results tab.

10.2 In which month in 2005 is the highest amount of irrigation applied

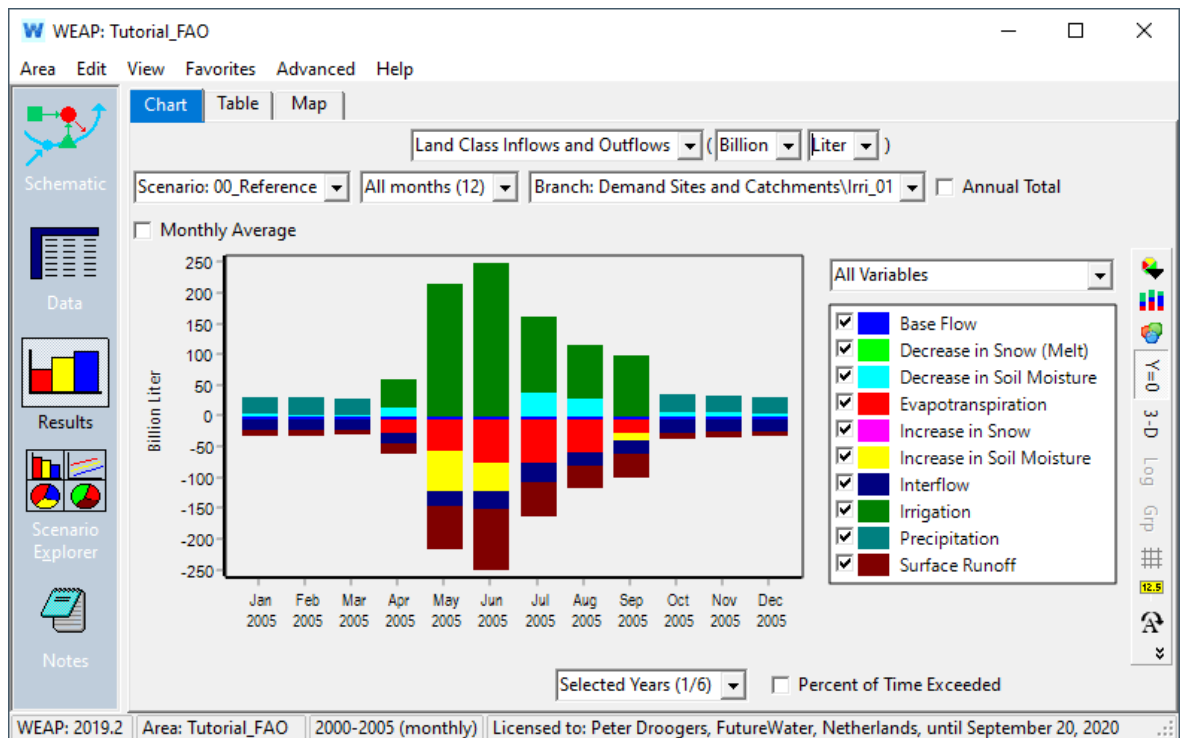
```

Month with highest irrigation ..... (month)
Irrigation amount in that month ..... (MCM/month)
Same but in mm/month ..... (mm/month)
  
```

This information can be obtained by the following steps in WEAP:

- Left: screen “Result”
- Top list box: Catchments > Land Class Inflows and Outflows
- Second top dropboxes:
 - Scenario: 00_Reference
 - All months (12)
 - Branch: Demand Sites and Catchments\Irri_01
- Bottom dropbox: Selected Years: 2005

Screen should look something like:



TIP: By selecting “Table” instead of “Chart” actual numbers are provided.

WEAP: Tutorial_FAO

Area Edit View Favorites Advanced Help

Chart Table Map

Land Class Inflows and Outflows (Billion Liter)

Scenario: 00_Reference All months (12) All Variables

Branch: Demand Sites and Catchments\Irr_i_01 Annual Total Monthly Average

	Jan 2005	Feb 2005	Mar 2005	Apr 2005	May 2005	Jun 2005	Jul 2005	Aug 2005	Sep 2005
Base Flow	-5	-5	-5	-5	-5	-5	-5	-5	-5
Decrease in Snow (Melt)	0	0	0	0	0	0	0	0	0
Decrease in Soil Moisture	5	4	4	16	0	0	40	30	
Evapotranspiration	0	0	0	-22	-53	-71	-72	-53	
Increase in Snow	0	0	0	0	0	0	0	0	
Increase in Soil Moisture	0	0	0	0	-66	-45	0	0	
Interflow	-19	-18	-18	-17	-22	-31	-30	-24	
Irrigation	0	0	0	44	214	248	121	86	
Precipitation	25	25	25	0	0	0	0	0	
Surface Runoff	-6	-6	-6	-15	-69	-95	-53	-34	

Selected Years (1/6) Percent of Time Exceeded

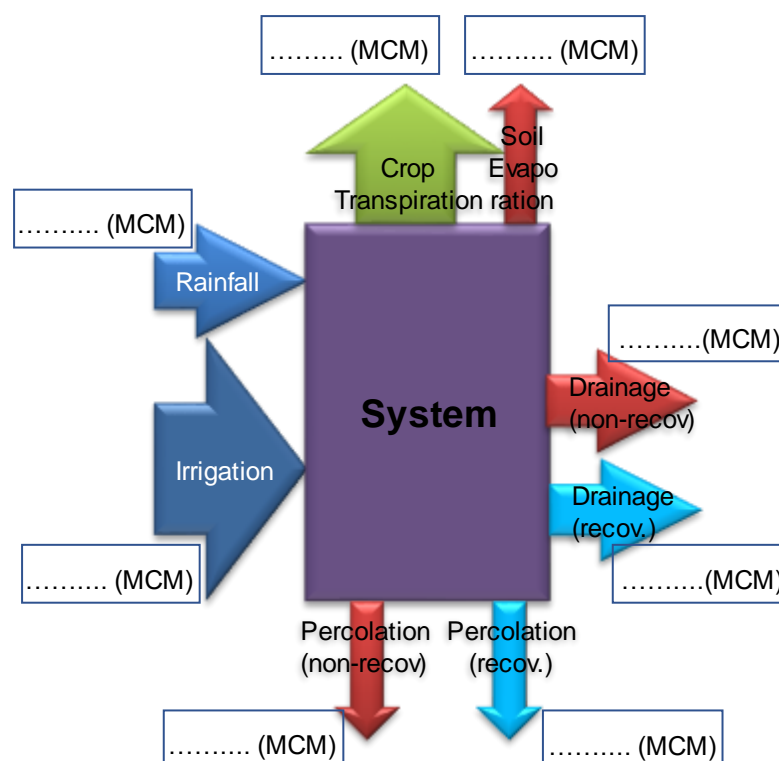
WEAP: 2019.2 Area: Tutorial_FAO 2000-2005 (monthly) Licensed to: Peter Droogers, FutureWater, Netherlands, until September 20, 2020

10.3 Obtain the full water balance for the Irri_01 for the entire year 2005 using the Table below:

INFLOWS	(MCM/y)	OUTFLOWS	(MCM/y)
Precipitation		Evapotranspiration	
Irrigation		Base Flow	
		Interflow	
		Surface Runoff	
TOTAL		TOTAL	

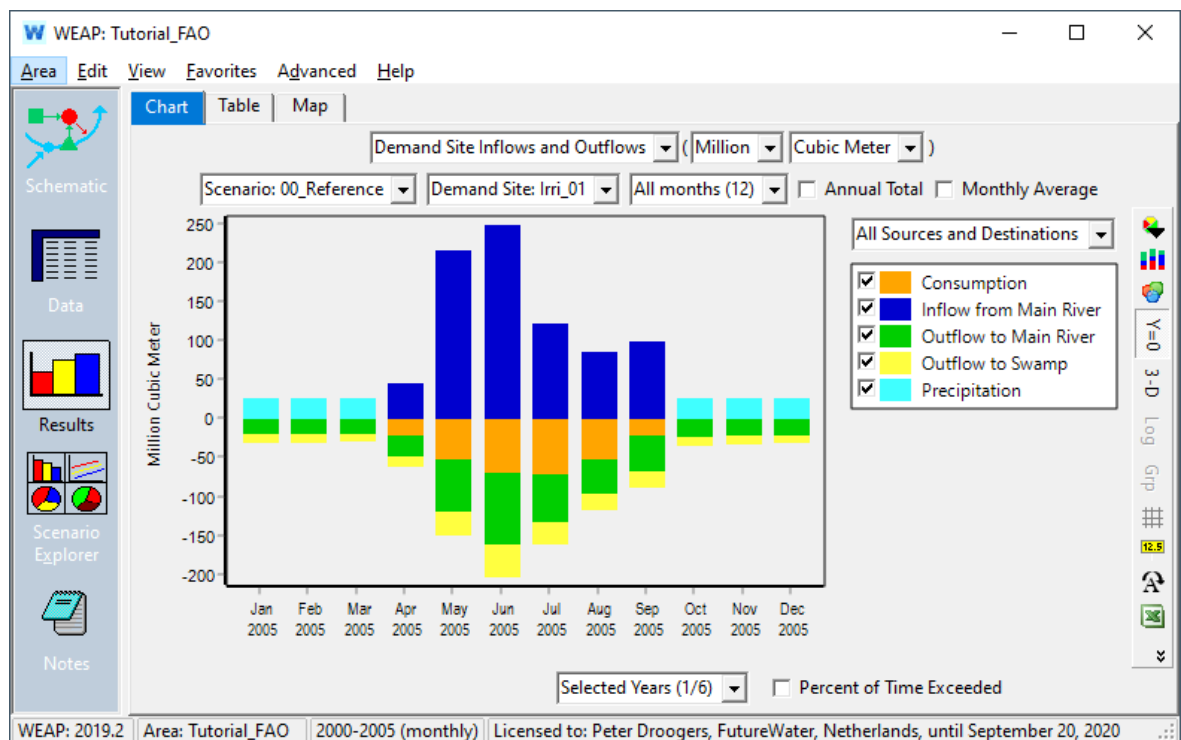
Tip: Enable “Annual Total” in WEAP (at top-right)

10.4 Fill in the water balance components using the schematic view of the irrigation system. Use the same numbers as above.

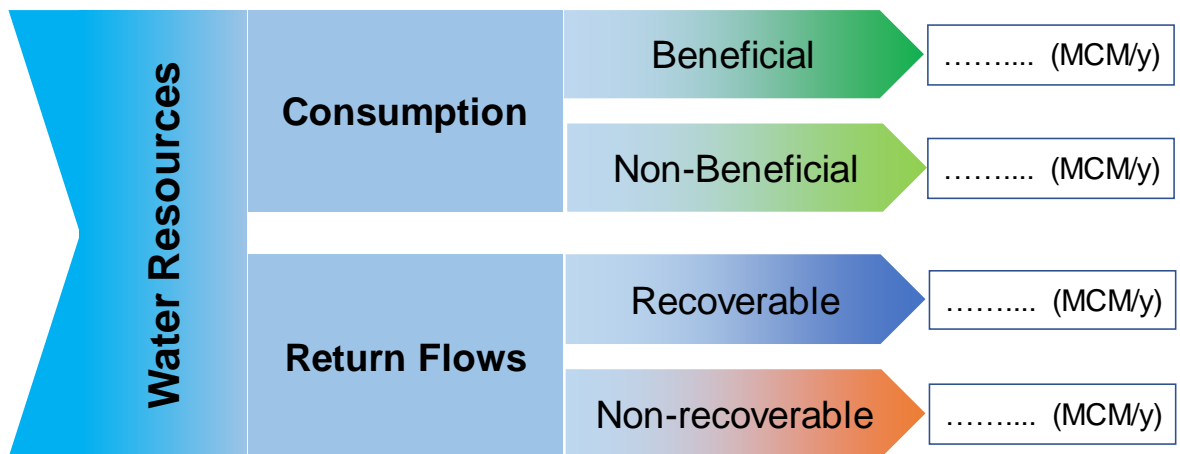


Note that some of the numbers are on different output screens in WEAP. Here some tips:

- Distinction between Crop Transpiration and Soil Evaporation is not calculated by WEAP. Assume that from the total Evapotranspiration
 - 80% is Crop Transpiration and
 - 20% Soil Evaporation.
- Drainage = Surface Runoff + Interflow
- Percolation = Base Flow
- The amount of recoverable water can be obtained from WEAP using:
 - Demand > Demand Site Inflows and Outflows (see screenshot)



10.5 As discussed earlier, we would like to follow the water. Use the results from above and fill in the four components of the



In the past we would use the term Irrigation Efficiency. For this particular situation the Irrigation Efficiency would be calculated as:

$$\begin{aligned}
 & \text{Evapotranspiration / Irrigation applied} \\
 & = 294 \text{ MCM} / 810 \text{ MCM} \\
 & = 37\%
 \end{aligned}$$

This looks very low! But from the “Follow the Water” figure we realize that most of the water is recoverable and in fact important for the downstream users.

However, decision makers might be interested in increasing the Irrigation Efficiency (ask them why??). Assume it was decided to install drip irrigation and WEAP will be used to explore the impact of introducing drip irrigation.

In WEAP this can be implemented by:

- Lower surface runoff by drip:
 - change the Runoff Resistance Factor: 2 → 50
- Less water flows down the rootzone:
 - change the Root Zone Conductivity from 200 → 100 mm/month
- Better water uptake by crop:
 - increase all Kc values by 10%
 - just add at the end of the monthly Kc time series: *1.1

Note: In WEAP this can be best done by introducing a new scenario (Data > Area > Manage Scenarios). If this is too complex, don't worry, just change the values in the normal way.

10.6 Run WEAP with those new values and answer the following questions

Compare irrigation applications for the two scenarios

Reference: (MCM/year)

Modernization: (MCM/year)

Explain why irrigation applications are different

Answer:

It looks like we “save” quite some water. The question is whether those “savings” are real. Look at the streamflow in the river downstream of the Irri_01:

> WEAP > Results > Supply and Resources > River > Streamflow

> Main River Nodes and Reaches: Below Irri_01 Runoff

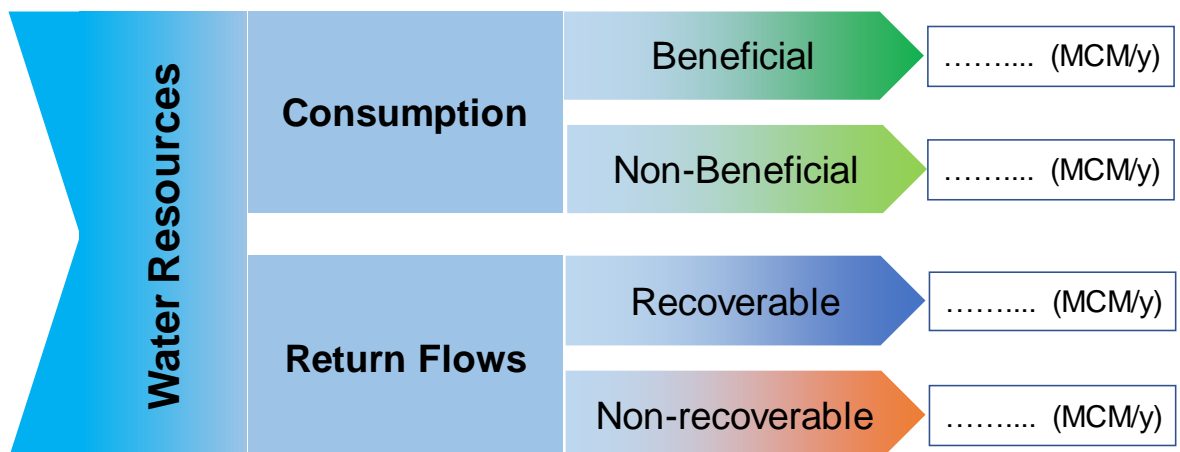
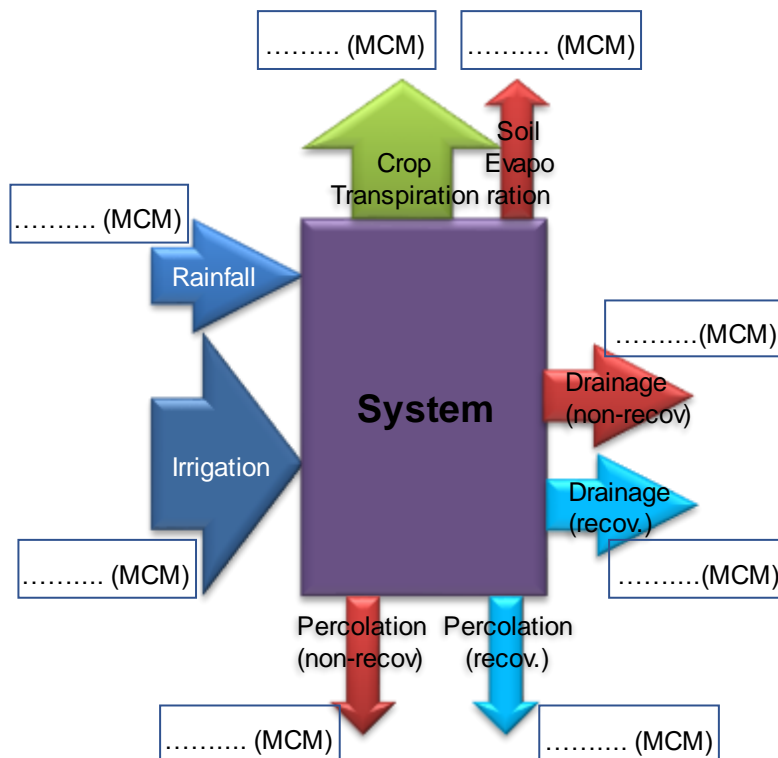
Streamflow below Irri_01

Reference: (MCM/year)

Modernization: (MCM/year)

In order to explain why there is hardly any difference in streamflow, while at the same time irrigation application has been reduced drastically, we follow the approach of “Follow the Water”.

Fill in the numbers in the two Figures below for the Modernization scenario.



The previous exercise showed that by introducing drip irrigation no additional water was made available to be used by the downstream users. In reality the situation might be even worse. Consider the farmers who used to get 810 MCM/y. After investing in drip irrigation it is very unlikely that they will accept a reduction in irrigation allocation (in our example from 810 down to 580 MCM/y).

10.7 Discuss what will happen with downstream flows if the farmers invest in drip irrigation and still receive the same amount of irrigation water.

Answer:

References

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