Food and Agriculture Organization of the United Nations

# Crop water productivity options to achieve real water savings
## Training manual

FutureWater

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# Training manual

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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 because of population growth, economic development, land degradation and climate change. As irrigation is the largest consumer of freshwater withdrawals, solutions to reverse this trend should focus on irrigated agriculture.

Options to save water 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 review by Perry and Steduto (2017), shows that in the vast majority of cases, water saving at field scale translates into an increase in water consumption at basin scale. Yet, despite the growing and irrefutable body of evidence, false water saving technologies continue to be promoted, subsidized and implemented as a solution to water scarcity in agriculture.

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

The objectives of this training manual are to:

- introduce clear examples, questions/prompts and answers related to real water saving and water productivity;
- introduce clear examples, questions/prompts and answers related to agricultural field interventions and impacts at irrigation system and basin scale;
- instruct how to use the Real Water Saving (REWAS) software tool to estimate real water saving and water productivity at irrigation system scale, which is based off of FAO's REWAS framework outlined in the FAO (2021) report *Guidance on realizing real water savings with crop water productivity interventions*; and
- instruct how to use the Water Efficiency and Productivity (WEAP) software tool to estimate real water saving and water productivity at basin scale.

This publication was developed under the Asia-Pacific Water Scarcity Programme (WSP), a regional initiative led by the Food and Agriculture Organization of the United Nations Regional Office for Asia and the Pacific. The WSP supports countries to strengthen their capacity to manage water scarcity through an adaptive, country-led process encompassing in-depth policy and governance analyses, regional mapping of water scarcity trends, assessment of modeling capabilities, water tenure analyses, and consistent engagement with national, regional, and local governments as well as water stakeholders. As part of Phase I of the WSP, technical experts in Thailand, Viet Nam, Cambodia, Indonesia, Lao People's Democratic Republic, and Mongolia were trained to conduct water accounting in agricultural systems at different scales using tools that included Follow the Water and REal WAter Savings (REWAS).

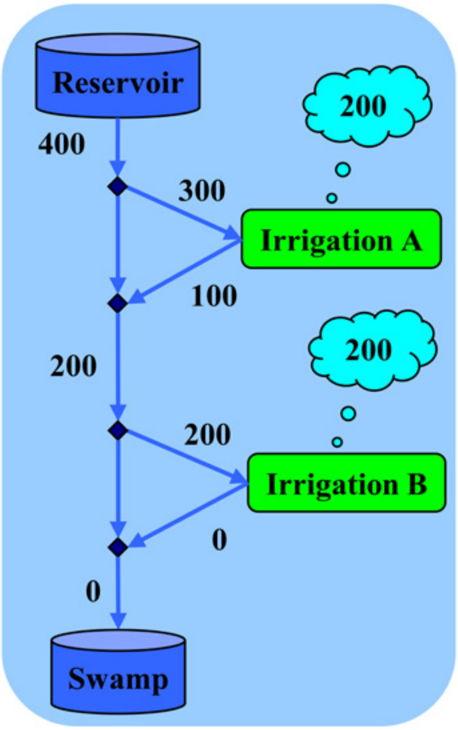
# 2. Exercise: Concepts of real water savings at basin

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

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

- a reservoir receiving water from the upstream located catchment area
- two irrigation districts (Irrigation A and Irrigation B)
- a downstream sea or lake (Swamp)

FIGURE 1
**Conceptual layout of a river basin**




Source: Authors' own elaboration.

Note: Units are million cubic metres per year (MCM/y)

### 2.1 Question: What is the irrigation efficiency of irrigation district A?

Inflow is ____________________ (MCM/y)

Water consumption is ____________ (MCM/y)

Irrigation efficiency is ____________ (percent)

### 2.2 Question: What is the irrigation efficiency of irrigation district B?

Inflow is ______________________ (MCM/y)

Water consumption is ______________________ (MCM/y)

Irrigation efficiency is ______________________ (percent)

### 2.3 Question: Why is the irrigation efficiency of irrigation district B higher than that of irrigation district A?

Answer: ____________________________________________________________

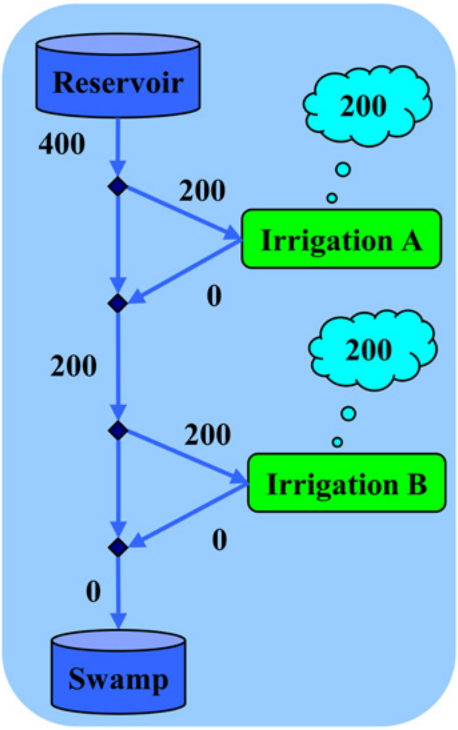
### 2.4 Question: What amount of water is consumed to produce a crop?

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

FIGURE 2
**Conceptual layout of river basin after investment in irrigation**




Source: Authors' own elaboration.

Notes. Irrigation efficiency of system A was increased by investments in the irrigation infrastructure.

Units are in million cubic metres per year (MCM/y)

### 2.5 Prompt: Do the same calculations for this new situation

Irrigation efficiency district A __________ (percent)

Irrigation efficiency district B __________ (percent)

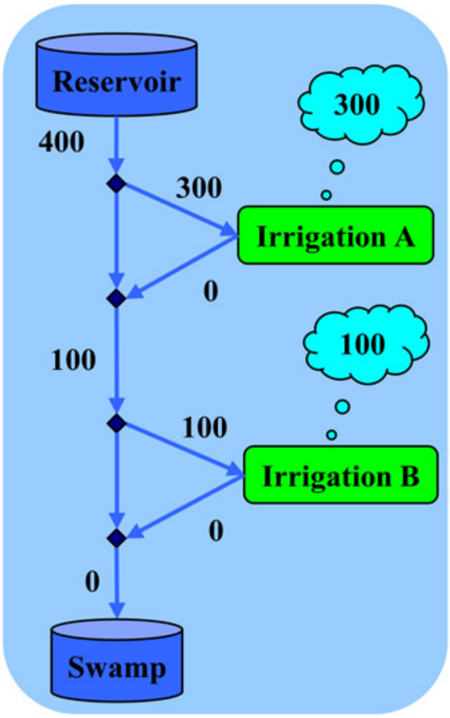
Crop evapotranspiration (total) __________ (MCM/y)

Consider farmers in irrigation district A. Considerable investments were made in increasing the efficiency 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 (See Figure 1). After the investments, this was reduced to 200 MCM/y (See Figure 2).

Clearly, farmers in irrigation district A will never accept receiving less water after making investments in the irrigation system (or more likely they will claim for more water to compensate for their investments). The new situation after the investments have been made can be seen in Figure 3.

FIGURE 3

**Conceptual layout of river basin showing the more realistic water allocation**




Source: Authors' own elaboration.

Note. Units are in million cubic metres per year (MCM/y).

### 2.6 Prompt: Do the same calculation for this new situation

Irrigation efficiency district A ____________ (percent)

Irrigation efficiency district B ____________ (percent)

Crop evapotranspiration (total) _______________ (MCM/y)

### 2.7 Prompt: Answer the same questions (2.1, 2.2, 2.3, and 2.4) for this new situation

Answer: ____________________________________________

### 2.8 Prompt: Identify the implications of this new situation for farmers in district B

Answer: ____________________________________________

### 2.9 Prompt: Identify what has changed in the amount of food produced

Answer: ____________________________________________

# 3. Follow the water exercises

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 fact part of these flows is 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**

Source: Jha, A. K., Malla, R., Sharma, M., Panthi, J., Lakhankar, T., Krakauer, N. Y., Pradhanang, S. M., Dahal, P. & Shrestha, M. L. 2016. Impact of irrigation method on water use efficiency and productivity of fodder crops in Nepal. *Climate*, 4(1): 4, doi:10.3390/cli4010004

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 3 120 kg/ha (Jha *et al.*, 2016) (See Table 1).

### 3.1 Q: Question: What do you expect to happen to 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 3 120 kg/ha (scenario A) and 2 870 kg/ha (scenario B) (See Table 1).

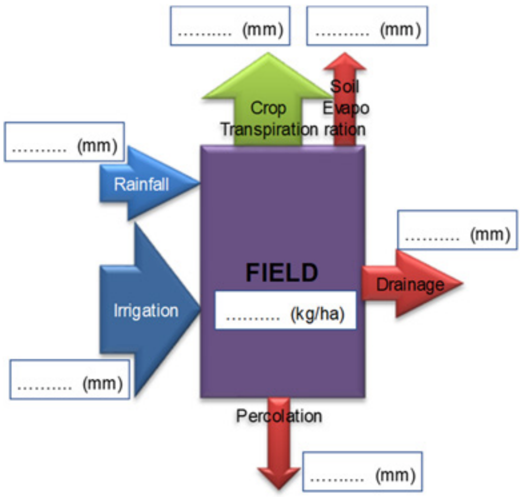
TABLE 1
**The full water balance based on the two field trials in Nepal**

| | 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 |
| Yield (kg/ha) | 3120 | 2870 |

Source: Jha, A. K., Malla, R., Sharma, M., Panthi, J., Lakhankar, T., Krakauer, N. Y., Pradhanang, S. M., Dahal, P. & Shrestha, M. L. 2016. Impact of irrigation method on water use efficiency and productivity of fodder crops in Nepal. *Climate*, 4(1): 4, doi:10.3390/cli4010004

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

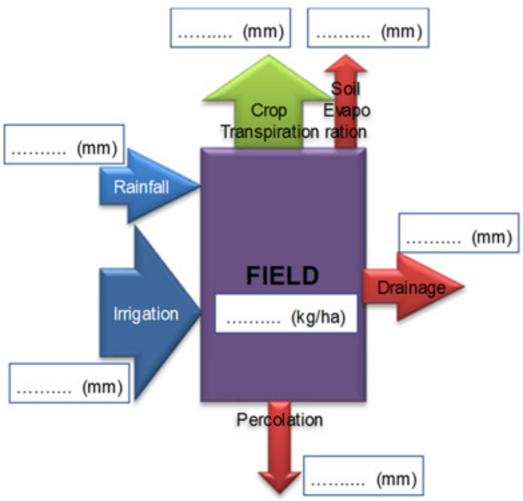
FIGURE 5
**Irrigation schematic for scenario A**




Source: Authors' own elaboration.

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

FIGURE 6
**Irrigation schematic for scenario B**




Source: Authors' own elaboration.

### 3.4 Question: What is 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)

### 3.5 Question: According to the farmer's perspective, what is the water saving when comparing 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

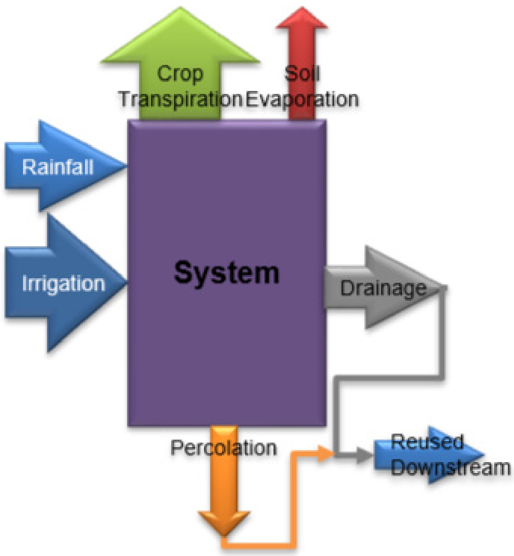
### 3.6 Question: According to the farmer's perspective, the water saving when comparing irrigation scenarios is 240 mm/season. What is the water saving relative to the total inflow A?

Water savings is ______________ percent

According to the farmer's perspective, drainage and percolation flows are water losses. However, drainage and percolation flows are reused downstream (Figure 7). 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 7

**The water flows in an irrigation system**

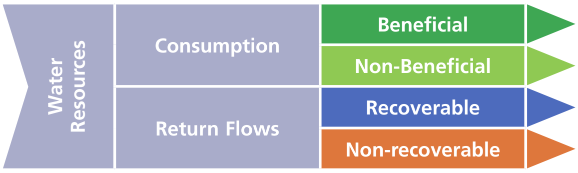



Source: Authors' own elaboration.

Note. Drainage and percolation flows are reused downstream

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

### 3.7 Question: According to the field trials, what are the beneficial, non-beneficial, recoverable, and non-recoverable flows for irrigation application A and irrigation application B?




| A (mm/season) | B (mm/season) |
|---|---|
| | |
| | |
| | |
| | |

### 3.8 Question: What is the non-beneficial flow saving comparing irrigation application A and irrigation application B?

The Non-beneficial flow savings is: ________________ mm/season

### 3.9 Question: What is the non-recoverable flow saving comparing irrigation application A and irrigation application B?

The Non-beneficial flow savings is: ________________ mm/season

### 3.10 Question: What is the real water saving comparing 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

### 3.11 Question: The real water saving comparing irrigation scenarios is 58 mm/season. What is the real water saving relative to the total inflow A?

Real water savings is ________________ percent

# 4. Water productivity exercises

Water productivity was evaluated for a rice irrigation system of 1 000 hectares located in Nghe An province in the north central coastal region of Viet Nam. Rainfall during the cropping season between February and June is 2.11 $Mm^3$/season (Funk *et al.*, 2015). A study (Hong and Yabe, 2017) reported two irrigation application scenarios: 9.10 $Mm^3$/season (scenario A) and 1.82 $Mm^3$/season (scenario B). According to field trials, rice production for those scenarios was 5.24 Mkg (scenario A) and 3.81 Mkg (scenario B) (see Table 2).

TABLE 2

**The full water balance based on the two field trials in Viet Nam**

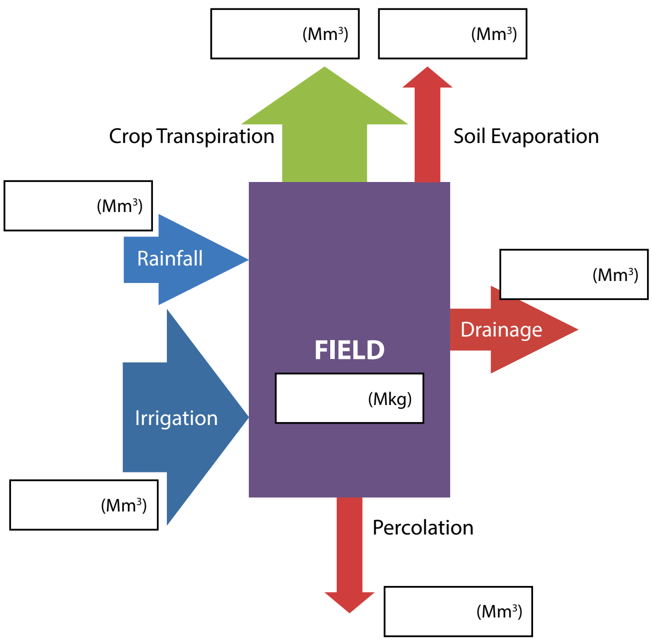
| | A | B |
|---|---|---|
| Precipitation ($Mm^3$/season) | 2.11 | 2.11 |
| Irrigation ($Mm^3$/season) | 9.10 | 1.82 |
| Crop Transpiration ($Mm^3$/season) | 4.03 | 2.42 |
| Soil Evaporation ($Mm^3$/season) | 1.63 | 1.30 |
| Drainage ($Mm^3$/season) | 3.21 | 0.10 |
| Percolation ($Mm^3$/season) | 2.34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

Please change to: Adapted from Hong, N. B. & Yabe, M. 2017. Improvement in irrigation water use efficiency: a strategy for climate change adaptation and sustainable development of Vietnamese tea production. *Environment, Development and Sustainability*, 19(4): 1247–1263. doi:10.1007/s10668-016-9793-8

### 4.1 Prompt: Put the numbers in the schematic below for scenario A

FIGURE 8

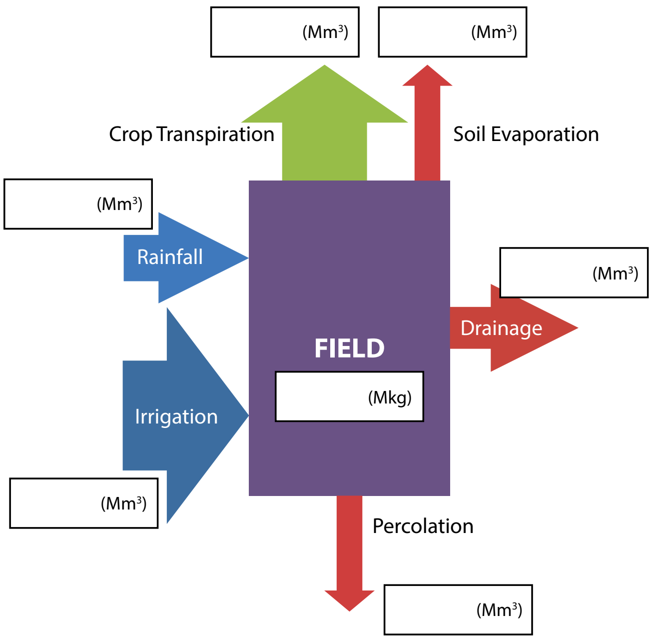
**Irrigation schematic for scenario A (exercise 1)**




Source: Authors' own elaboration.

### 4.2 Prompt: Put the numbers in the schematic below for scenario B

FIGURE 9
**Irrigation schematic for scenario B (exercise 2)**




Source: Authors' own elaboration.

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. Prompt: 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 is ______ $Mm^3$/season

In scenario B, the amount of water consumed to obtain the rice production is ______ $Mm^3$/season

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

In scenario A, the amount of rice produced is __________ Mkg/season

In scenario B, the amount of rice produced is __________ Mkg/season

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

In scenario A, the water productivity for rice is __________ $kg/m^3$

In scenario B, the water productivity for rice is __________ $kg/m^3$

### 4.6 Prompt: Determine the amount of rice produced in scenario A and in scenario B:

Answer: ____________________________________________

### 4.7 Prompt: Determine the amount of rice produced in scenario A and in scenario B:

Answer: ____________________________________________

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

Answer: ____________________________________________

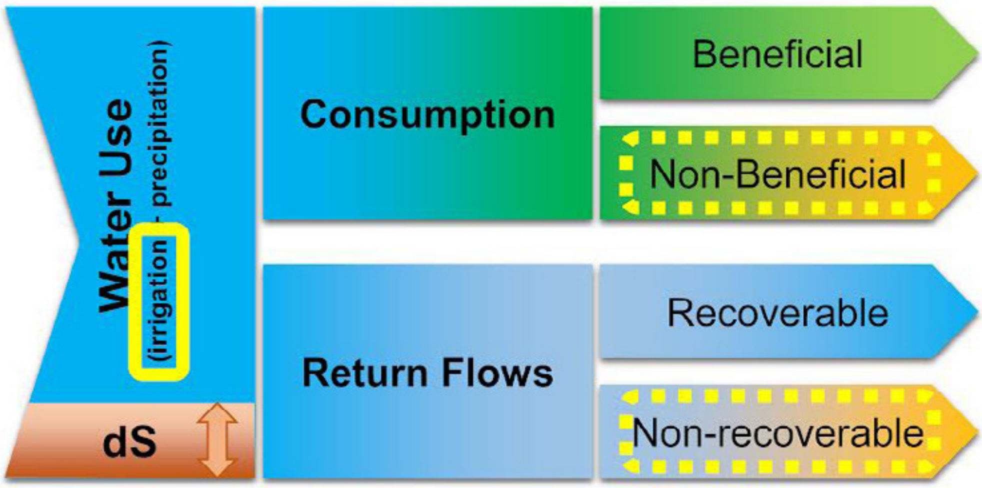
# 5. Introducing real water savings in agriculture

The main objective of real water saving (REWAS) in agriculture is to assess quickly the impact of field-scale crop–water interventions on basin-scale water saving. 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 saving case will be summarized here. A study from Nepal (Jha *et al*., 2016) reported that by reducing irrigation applications, a 75 percent water savings was achieved. However, the study failed to use the Follow the Water principle as it was assumed that all return flows were losses, whereas in reality 80 percent of those return flows are recovered by downstream users. This suggests that the study's reported water saving referred only to the irrigation application (box outlined in solid yellow in Figure 10), whereas the focus should have been on the non-recoverable return flows and non-beneficial consumptions.

Using the REWAS tool it is evident that the claimed water saving of 75 percent is not true from a basin perspective and the real water saving at basin scale is much smaller and is in the order of about 6 percent (see Figure 11).

FIGURE 10
**The Follow the Water approach as applied in the REWAS software tool**




Source: Adapted from Van Opstal, J., Droogers, P., Kaune, A., Steduto, P. and Perry, C. 2021. *Guidance on realizing real water savings with crop water productivity interventions.* FAO Water Reports 46. Wageningen, FAO and FutureWater. https://doi.org/10.4060/cb3844en; Perry, C. 2011. Accounting for water use: terminology and implications for saving water and increasing production. *Agric. Water Manag.* 98(12): 1840–1846. https://doi.org/10.1016/j.agwat.2010.10.002

FIGURE 11
**Screenshot from the REWAS tool analysing real water saving for the Nepal case**

| 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%** |

Source: Authors' own elaboration.

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 Kaune *et al.* (2020).

# 6. REal WAter Savings (REWAS) software tool start guide

Open the REWAS software tool in the excel file called: **REWAS_v8.xlsm**

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

## 6.1 Inserting input data in the REWAS interface

The input data interface in REWAS is shown in Figure 12. 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 Kaune *et al.* (2020). Also, the area of the irrigation system and the recoverable flow fraction can be manually inserted. More information about the recoverable flow fraction can be found in Kaune *et al.* (2020).

FIGURE 12

**REWAS input data: field data, irrigation area and reuse parameters.**

If needed, click to import AquaCrop Results | Ref | A | B

| 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 | (%) | | | |

Source: Authors' own elaboration.

## 6.2 Obtaining results using the REWAS software tool

The output results of the REWAS software tool are separated at field (FIELD) and system (SYSTEM) levels. 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 13. The water saving is determined comparing a reference scenario and different intervention scenarios (e.g. intervention A and intervention B). The different components of water accounting, corresponding to real water saving at system scale and the water productivity are calculated. In Figure 14, the intermediate results using REWAS are 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.

FIGURE 13
**Output results at field level and system level**

| RESULTS | | | | |
|---|---|---|---|---|
| | | Scenario | | |
| | | Reference | Intervention A | Intervention B |
| **RESULTS FIELD** | Units | | | |
| Consumption, beneficial BC | (mm) | | | |
| Consumption, non-beneficial NBC | (mm) | | | |
| Return flows | (mm) | | | |
| Storage change CS | (mm) | | | |
| Water productivity WP | (kg/m$^2$) | | | |
| Apparent water saving 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 flowsnon-recoverable NRF | (MCM) | | | |
| Storage change CS | (MCM) | | | |
| Water productivity WP | (kg/m$^2$) | | | |
| Real water saving RWS | (MCM) | | | |
| **Percentage of real water savings %RWS** | **%** | | | |

Source: Authors' own elaboration.

FIGURE 14
**Intermediate results at field and system level**

| INTERMEDIATE RESULTS | | | | |
|---|---|---|---|---|
| | | Scenario | | |
| | | Reference | Intervention A | Intervention B |
| **FIELD** | Units | | | |
| Inflow total | (mm) | | | |
| Outflow total | (mm) | | | |
| | | | | |
| **SYSTEM** | | | | |
| Rainfall | (MCM) | | | |
| Irrigation | (MCM) | | | |
| Crop transpiration | (MCM) | | | |
| Soil evaporation | (MCM) | | | |
| Drainage | (MCM) | | | |
| Percolation | (MCM) | | | |
| Production | (Mkg) | | | |
| | | | | |
| Drainage total | (MCM) | | | |
| Drainage recoverable | (MCM) | | | |
| Drainage non-recoverable | (MCM) | | | |
| Percolation total | (MCM) | | | |
| Percolation recoverable | (MCM) | | | |
| Percolation non-recoverable | (MCM) | | | |
| | | | | |
| Inflow total | (MCM) | | | |
| Outflow total | (MCM) | | | |

Source: Authors' own elaboration.

# 7. Real water savings at irrigation system level using the REWAS software tool

Let's assume the following scenarios (reference scenario and field intervention A) in a wheat irrigation system of 5 000 hectares in Iran (Islamic Republic of). Insert the values in the REWAS interface as shown in Figure 15 and Figure 16.

FIGURE 15

**Input data using REWAS (input data) in Iran (Islamic Republic of)**

| 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 |

Source: Authors' own elaboration.

FIGURE 16

**Input data: size of the irrigation system and recoverable flow fractions in Iran (Islamic Republic of)**

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

Source: Authors' own elaboration.

In Figure 17, 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.

FIGURE 17
**IIntermediate results using REWAS tool: field level and system level in Iran (Islamic Republic of)**

| INTERMEDIATE RESULTS | | | |
|---|---|---|---|
| | | Scenario | |
| | | Reference | Intervention A |
| **FIELD** | Units | | |
| Inflow Total | (mm) | 621 | 261 |
| Outflow Total | (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 |
| | | | |
| Drainage total | (MCM) | 6.0 | 0.8 |
| Drainage recoverable | (MCM) | 4.2 | 0.5 |
| Drainage non-recoverable | (MCM) | 1.8 | 0.2 |
| PercolationTotal | (MCM) | 2.8 | 0.6 |
| Percolation recoverable | (MCM) | 1.9 | 0.4 |
| Percolation non-recoverable | (MCM) | 0.8 | 0.2 |
| | | | |
| Inflow total | (MCM) | 31 | 13 |
| Outflow total | (MCM) | 31 | 13 |

Source: Authors' own elaboration.

In Figure 18 the water accounting and water productivity results at field level and real impact at system level are shown. The percentage of real water saving is 10 percent, and not 26 percent. The percentage of water saving is much lower than expected because of the influence of recoverable flows. The water productivity in intervention A (1.36 kg/m$^3$) is higher than the reference (1.19 kg/m$^3$). 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.

FIGURE 18
**Results at field level and system level in Iran (Islamic Republic of)**

| RESULTS | | | |
|---|---|---|---|
| | | Scenario | |
| | | Reference | Intervention A |
| **RESULTS FIELD** | Units | | |
| 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 | ($kg/m^2$) | 1.19 | 1.36 |
| Apparent water saving FWS | (mm) | | 163 |
| **Percentage of apparent water savings %FWS** | **%** | **-** | **26%** |
| | | | |
| **RESULTS AT SYSTEM LEVEL** | | | |
| 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 | ($kg/m^2$) | 1.19 | 1.36 |
| Real water saving RWS | (MCM) | - | 3.0 |
| **Percentage of real water savings %RWS** | **%** | **-** | **10%** |

Source: Authors' own elaboration.

# 8. Install the Water Evaluation and Planning (WEAP) software tool and obtain a free license

The Stockholm Environment Institute (SEI), which developed the Water Evaluation and Planning software tool (WEAP), provides free WEAP licenses for non-profit, governmental or academic organizations 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
- Provide the required information
- When you receive an email with your WEAP forum password, record these so you will remember them

| | |
|---|---|
| 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 your user name and the registration code below to remind you of them.

| | |
|---|---|
| User Name: | |
| Registration Code for WEAP: | |

# 9. WEAP in one hour

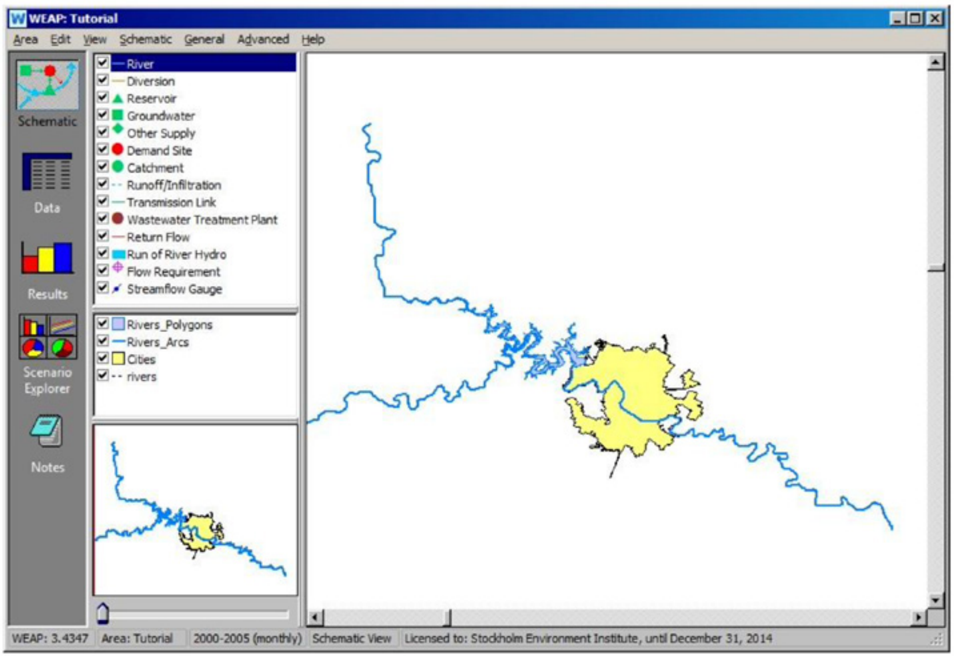
This section was copied and pasted (with some modifications) from the Water Evaluation and Planning software tool (WEAP) tutorial created in 2016 by the Stockholm Environment Institute (SEI).

## 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 in Figure 19—with blue lines for rivers and a solid yellow organic shape for the city.

FIGURE 19
**Step 1: Screen showing the beginning of the WEAP tutorial**




Source: Stockholm Environment Institute. n.d. *Water Evaluation And Planning (WEAP).* [Accessed 29 March 2020]. https://www.weap21.org/index.asp?action=8

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).

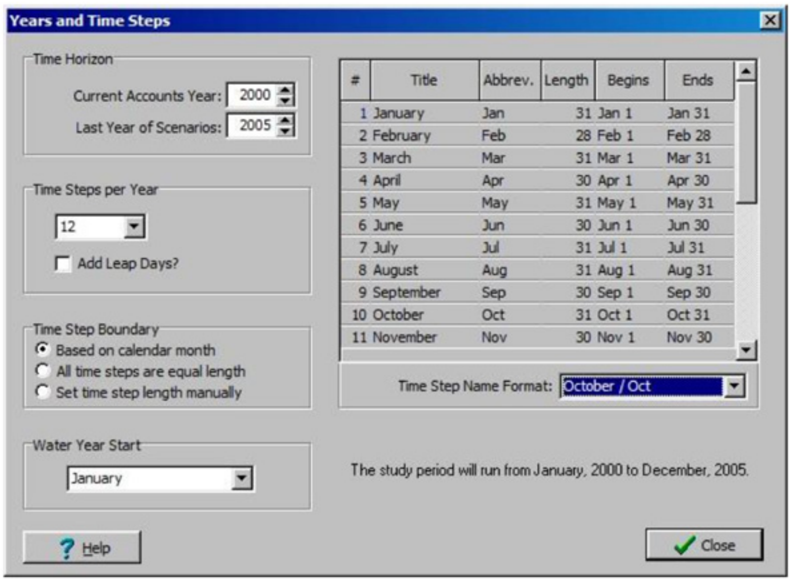
## 9.2. Set the general parameters

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 Figure 20). Keep the default (SI units) for now.

FIGURE 20

**Screen showing the "General" menu options in Step 2**




Source: Stockholm Environment Institute. n.d. *Water Evaluation And Planning (WEAP).* [Accessed 29 March 2020]. https://www.weap21.org/index.asp?action=8

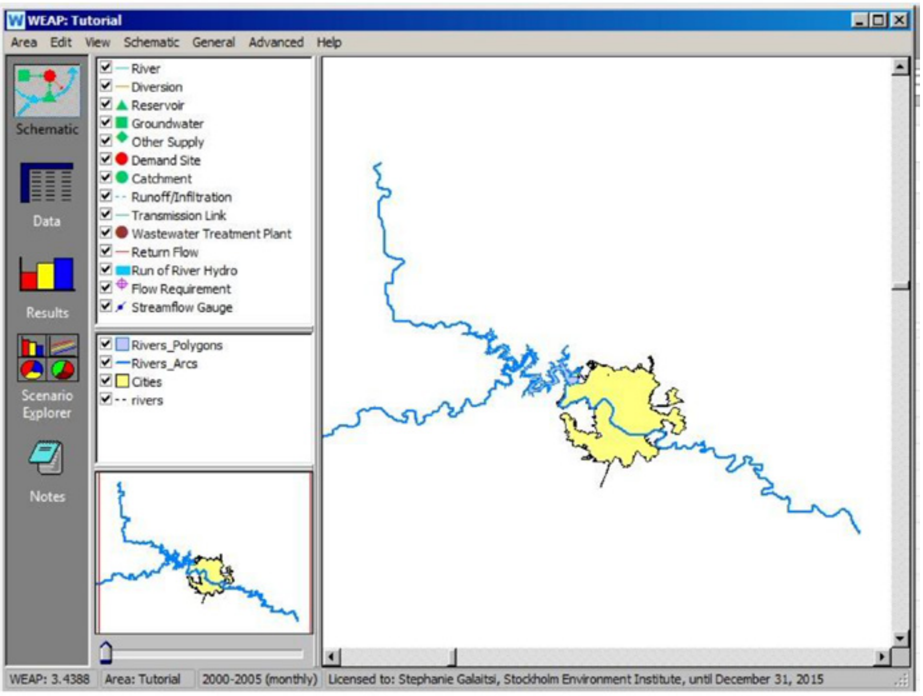
## 9.3 Entering elements into the schematic

**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.

FIGURE 21

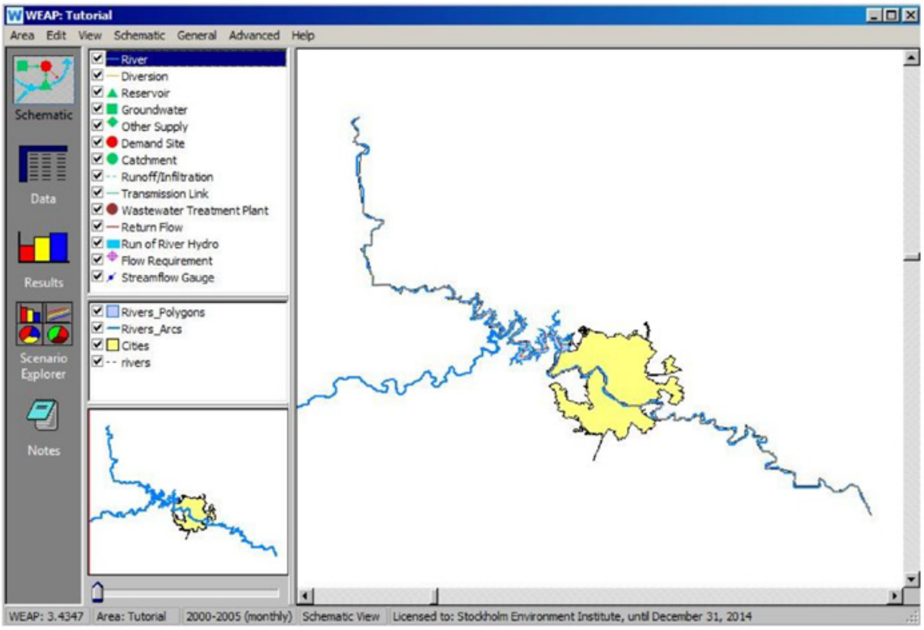
**Screen showing the river in Step 3**




Source: Stockholm Environment Institute. n.d. *Water Evaluation And Planning (WEAP).* [Accessed 29 March 2020]. https://www.weap21.org/index.asp?action=8

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) are sufficient. Double click to end drawing the river. You do not need to draw a river on the branch coming horizontally from the left.

FIGURE 22
**Screen showing the river in Step 4**

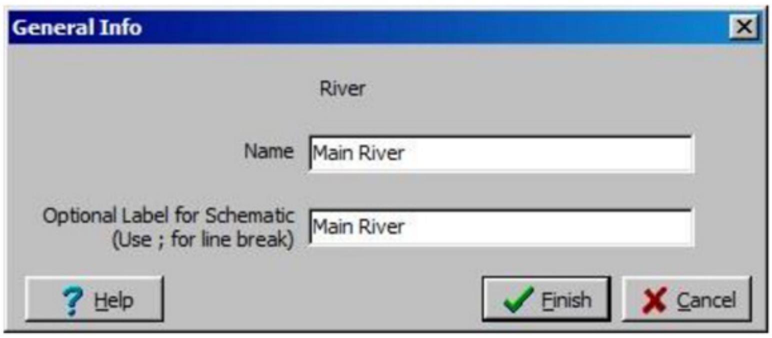



Source: Stockholm Environment Institute. n.d. *Water Evaluation And Planning (WEAP).* [Accessed 29 March 2020]. https://www.weap21.org/index.asp?action=8

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

Name the river "Main River."

FIGURE 23
**Screen showing the naming feature in WEAP in Step 5**




Source: Stockholm Environment Institute. n.d. *Water Evaluation And Planning (WEAP).* [Accessed 29 March 2020]. https://www.weap21.org/index.asp?action=8

## 9.4. Enter data for the Main River

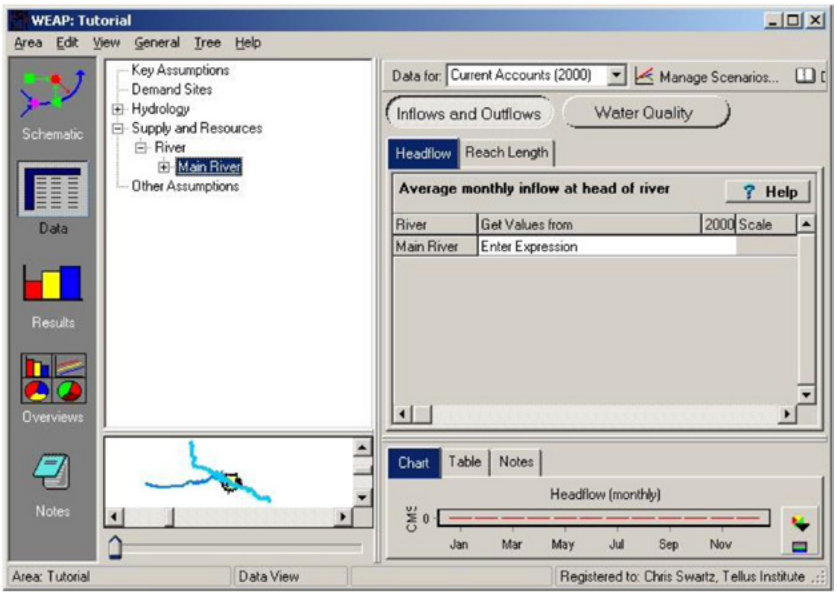
There are two ways to navigate to the data entry section of WEAP to enter data for the Main River.

1) Right-click on the Main River and select Edit data and any item in the list (Figure 24).

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 (Figure 25).

FIGURE 24

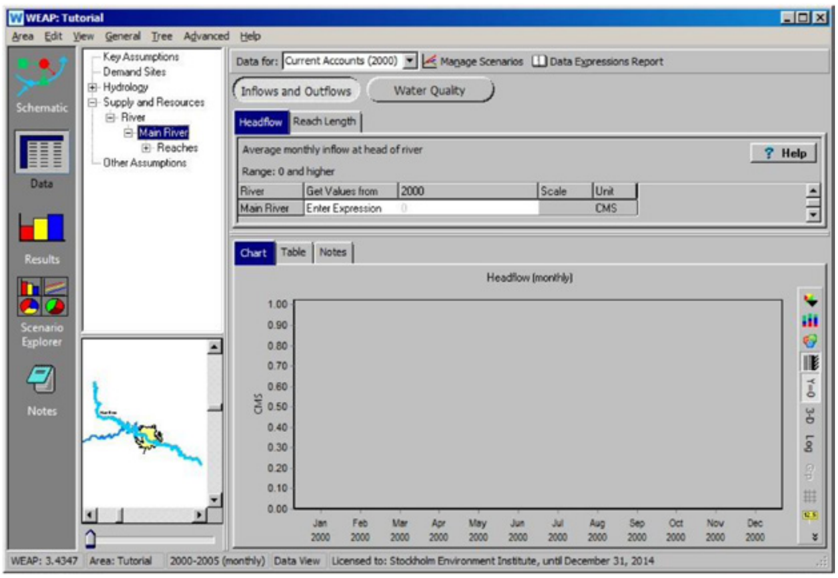
**Screen showing data editing feature for the Main River in Step 6**




Source: Stockholm Environment Institute. n.d. *Water Evaluation And Planning (WEAP).* [Accessed 29 March 2020]. https://www.weap21.org/index.asp?action=8

FIGURE 25

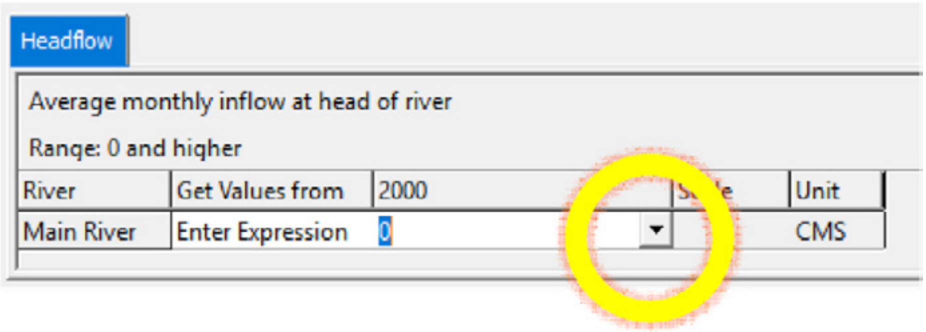
**Screen showing additional data editing categories for the Main River in Step 7**




Source: Stockholm Environment Institute. n.d. *Water Evaluation And Planning (WEAP).* [Accessed 29 March 2020]. https://www.weap21.org/index.asp?action=8

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 labelled "2000" in the data input window to view a pull- down menu icon (the small arrow) (Figure 26).

FIGURE 26
**Screen showing inflow input feature in Step 8**




Source: Stockholm Environment Institute. n.d. *Water Evaluation And Planning (WEAP).* [Accessed 29 March 2020]. https://www.weap21.org/index.asp?action=8

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

Use the Monthly Time–Series Wizard to enter the following data series: Monthly Flow (CMS) (Figure 27).

FIGURE 27
**Monthly–Series Wizard feature in Step 9**

| | |
|---|---|
| Jan | 12 |
| Feb | 7 |
| Mar | 11 |
| Apr | 17 |
| May | 80 |
| Jun | 136 |
| Jul | 45 |
| Aug | 32 |
| Sep | 38 |
| Oct | 18 |
| Nov | 9 |
| Dec | 7 |

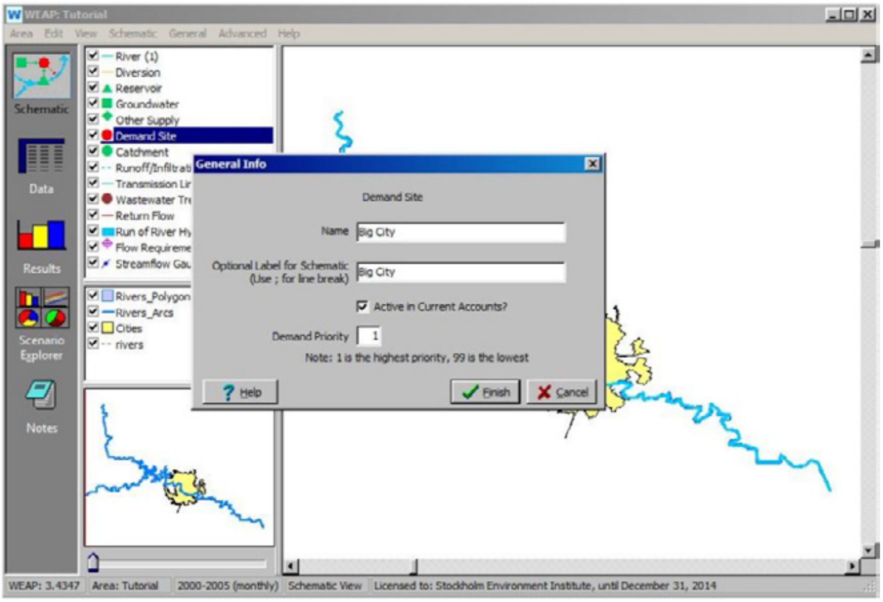
Source: Stockholm Environment Institute. n.d. *Water Evaluation And Planning (WEAP).* [Accessed 29 March 2020]. https://www.weap21.org/index.asp?action=8

## 9.5. Enter data for the Main River

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 (Figure 28).

FIGURE 28
**Screen showing Big City in WEAP tutorial Step 10**



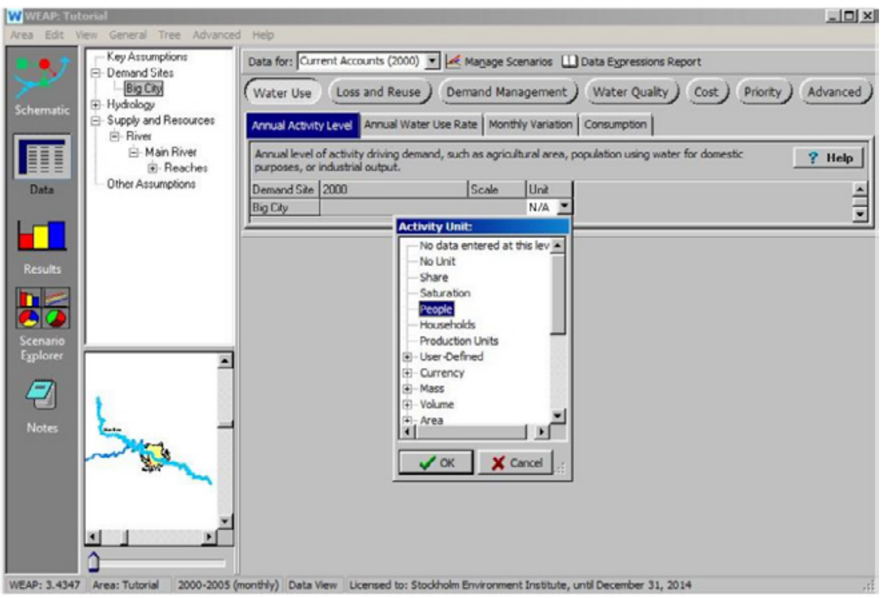

Source: Stockholm Environment Institute. n.d. *Water Evaluation And Planning (WEAP).* [Accessed 29 March 2020]. https://www.weap21.org/index.asp?action=8

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" (Figure 29).

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

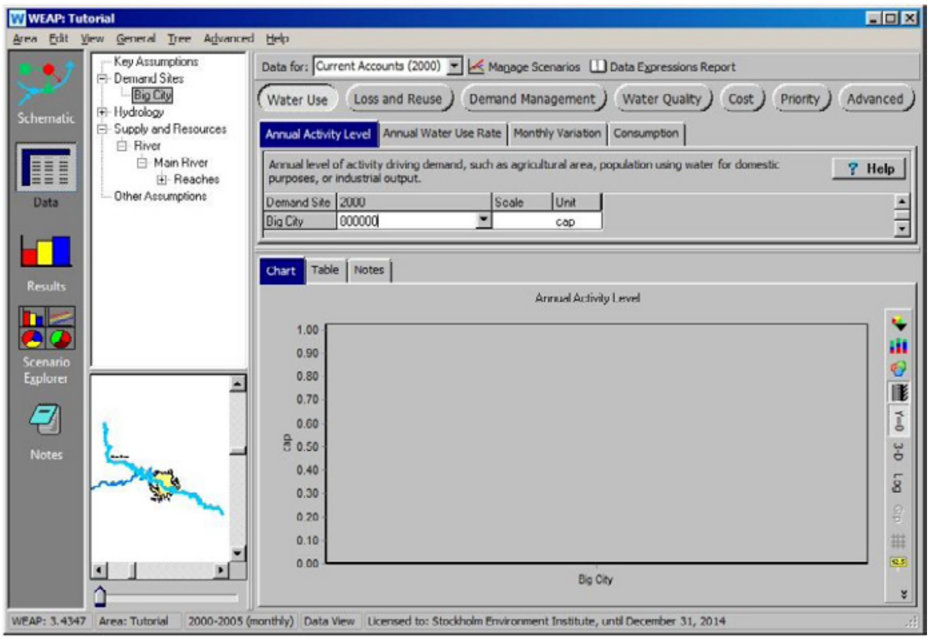
FIGURE 29
**Screen showing unit selection feature in Step 11**




Source: Stockholm Environment Institute. n.d. *Water Evaluation And Planning (WEAP).* [Accessed 29 March 2020]. https://www.weap21.org/index.asp?action=8

In the space under the field labelled “2000”, enter the Annual Activity Level as 800 000 (Figure 30).

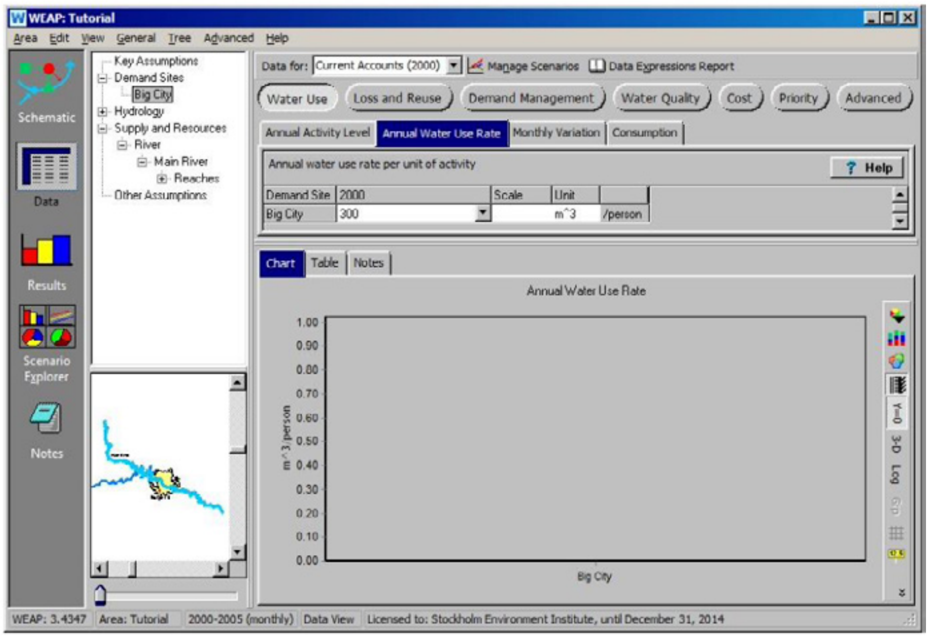
FIGURE 30
**Screen showing annual activity level selection in Step 12**




Source: Stockholm Environment Institute. n.d. *Water Evaluation And Planning (WEAP).* [Accessed 29 March 2020]. https://www.weap21.org/index.asp?action=8

Next, click on the "Annual Water Use Rate" tab and enter 300 under the year 2000 (Figure 31).

FIGURE 31
**Screen showing annual water use rate selection in Step 13**




Source: Stockholm Environment Institute. n.d. *Water Evaluation And Planning (WEAP).* [Accessed 29 March 2020]. https://www.weap21.org/index.asp?action=8

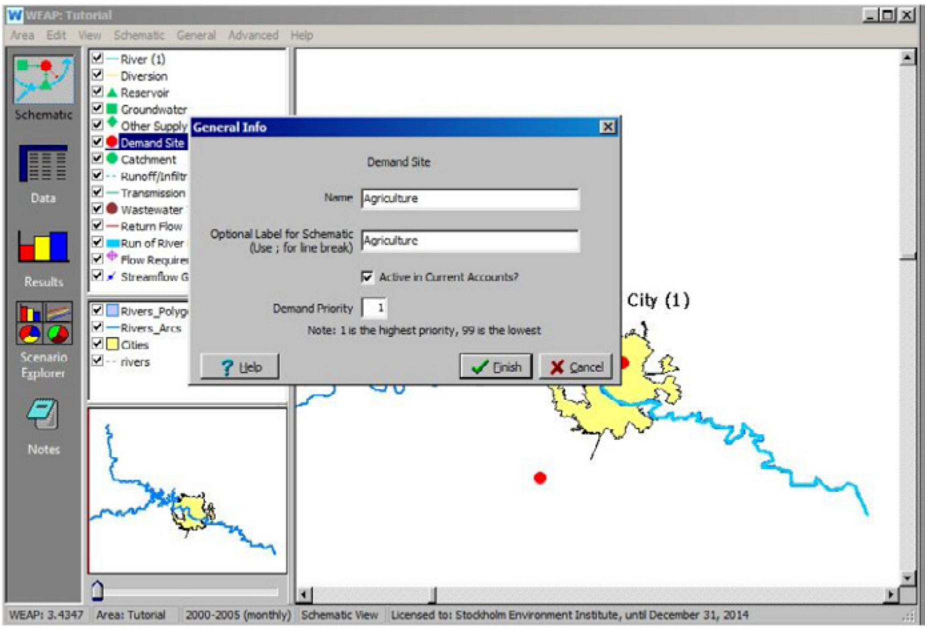
Finally, click on the "Consumption" tab and enter 15. Note that the units are preset to "percent."

## 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 Figure 32).

FIGURE 32
**Screen showing Agriculture in WEAP tutorial in Step 14**



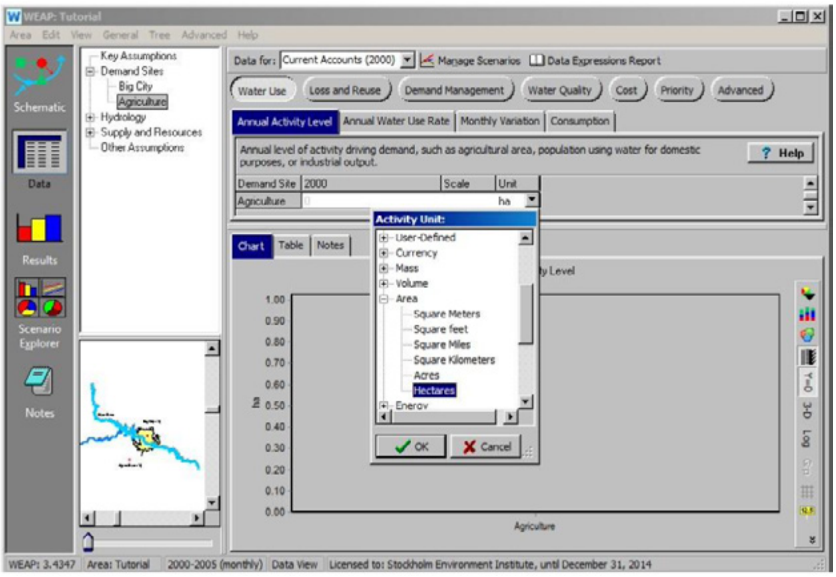

Source: Stockholm Environment Institute. n.d. *Water Evaluation And Planning (WEAP).* [Accessed 29 March 2020]. https://www.weap21.org/index.asp?action=8

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) (Figure 33).

*Annual activity level* *100 000 hectares*

*Annual water use rate* *3 500* $m^3$*/hectare*

FIGURE 33
**Screen showing selections for annual activity level and annual water use rate in Step 15**



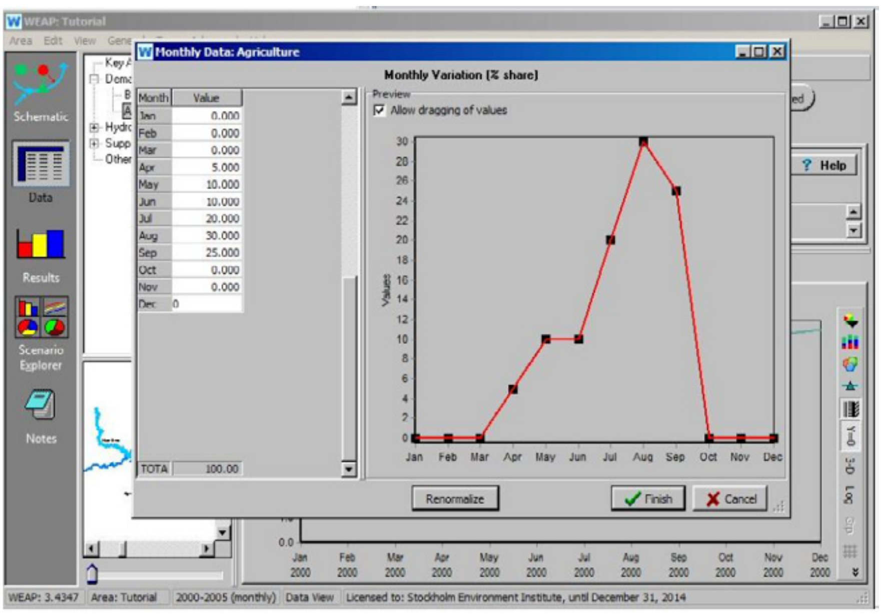

Source: Stockholm Environment Institute. n.d. *Water Evaluation And Planning (WEAP).* [Accessed 29 March 2020]. https://www.weap21.org/index.asp?action=8

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.) (Figure 34).

Monthly variation:

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

FIGURE 34
**Screen showing monthly variation in water use for Agriculture in Step 16**




Source: Stockholm Environment Institute. n.d. *Water Evaluation And Planning (WEAP).* [Accessed 29 March 2020]. https://www.weap21.org/index.asp?action=8

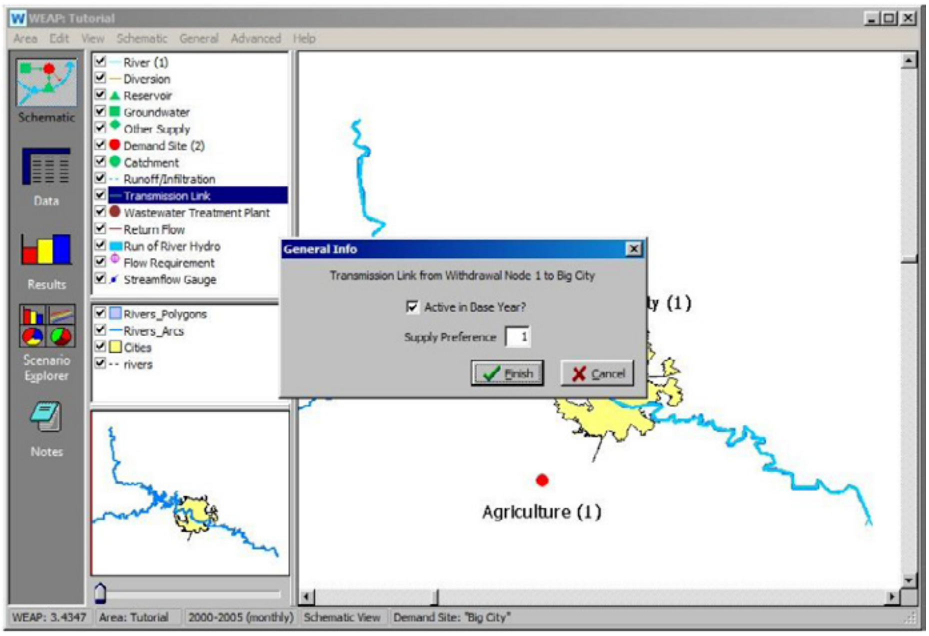
Finally, click on the Consumption tab and enter 90.

## 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 (Figure 35).

Select a supply preference of 1 for each transmission link.

FIGURE 35
**Step 17: Screen showing transmission link for Big City**




Source: Stockholm Environment Institute. n.d. *Water Evaluation And Planning (WEAP).* [Accessed 29 March 2020]. https://www.weap21.org/index.asp?action=8

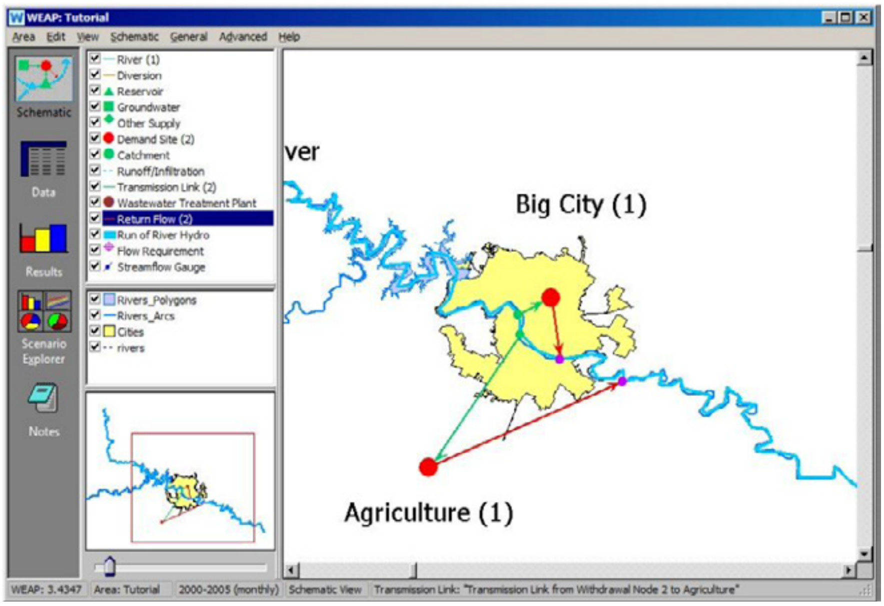
## 9.8. Create return flow links

Now create a return flow from Big City to the Main River. Do the same for Agriculture to the Main River (Figure 36). 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.

FIGURE 36

**Screen showing set up for return flows for Big City in Step 18**




Source: Stockholm Environment Institute. n.d. *Water Evaluation And Planning (WEAP).* [Accessed 29 March 2020]. https://www.weap21.org/index.asp?action=8

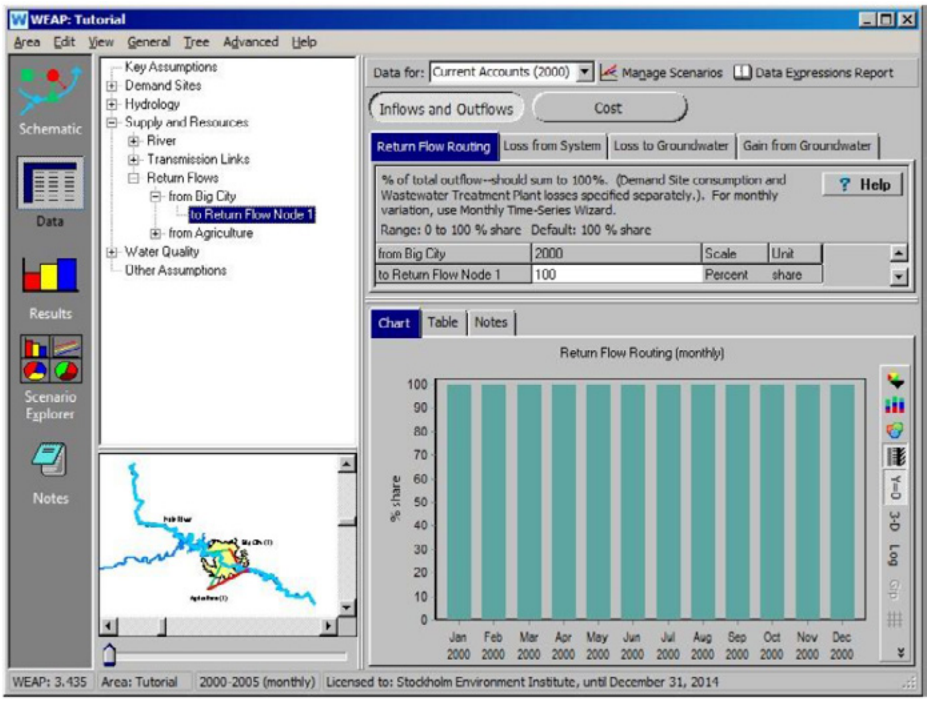
Next, set the Return Flow Routing for the Big City Return Flow (Figure 37). Do this by right-clicking on each Return Flow and selecting "edit data" and "Return Flow Routing" or by going to the Data view\ Supply and Resources\Return Flows\from Big City.

*Set the return flow routing to 100 percent.*

Do the same for the Agriculture return flow.

FIGURE 37

**Screen showing set up for return flows for Agriculture in Step 19**

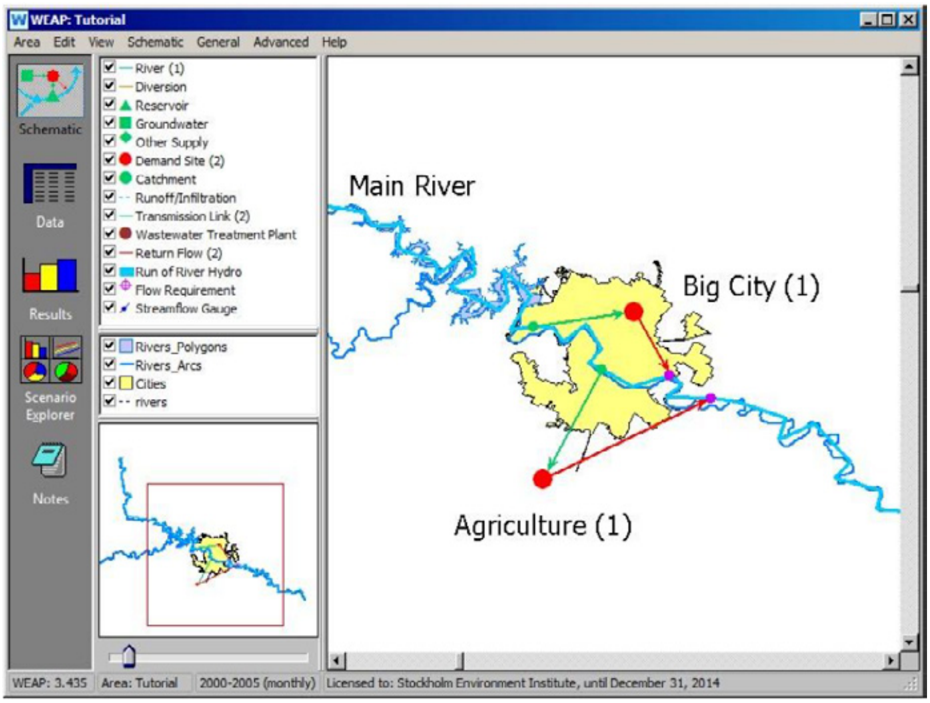



Source: Stockholm Environment Institute. n.d. *Water Evaluation And Planning (WEAP).* [Accessed 29 March 2020]. https://www.weap21.org/index.asp?action=8

## 9.9. Check your model

At this point, your model should look similar to that in Figure 38.

FIGURE 38
**Screen showing final product of the tutorial (Step 20)**



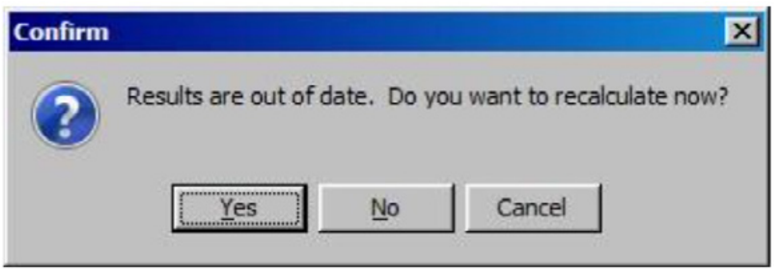

Source: Stockholm Environment Institute. n.d. *Water Evaluation And Planning (WEAP).* [Accessed 29 March 2020]. https://www.weap21.org/index.asp?action=8

## 9.10. Getting first results

*Run the model*

Click on the "Results" view to start the computation. When asked whether to recalculate, click Yes (Figure 39). 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.

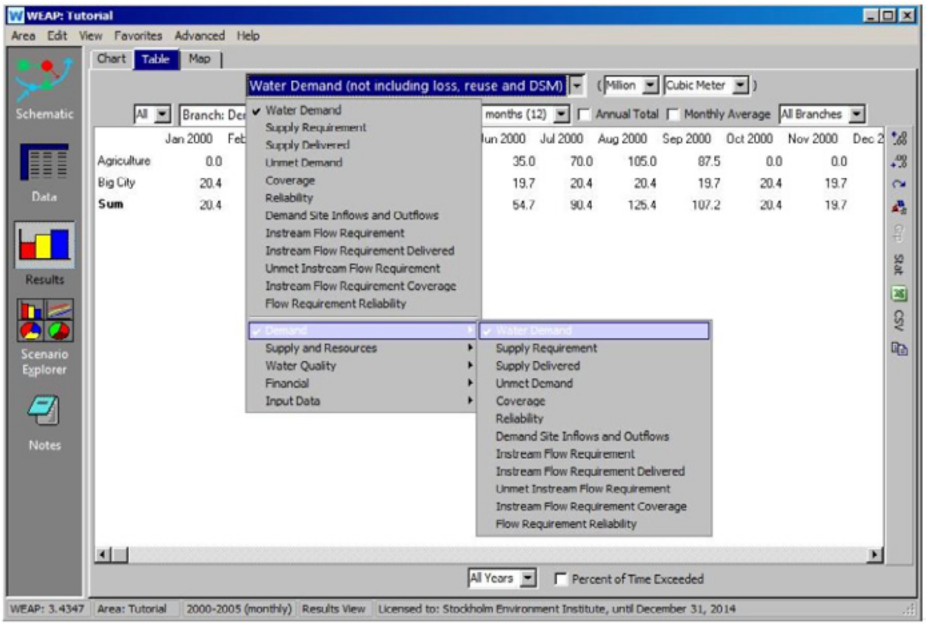
FIGURE 39
**Check your results (Step 21)**




Source: Stockholm Environment Institute. n.d. *Water Evaluation And Planning (WEAP).* [Accessed 29 March 2020]. https://www.weap21.org/index.asp?action=8

Click on the "Table" tab and select "Demand" and "Water Demand" from the primary variable pull-down menu in the upper centre of the window (see Figure 40).

FIGURE 40
**Select water demand as a primary variable (Step 22)**



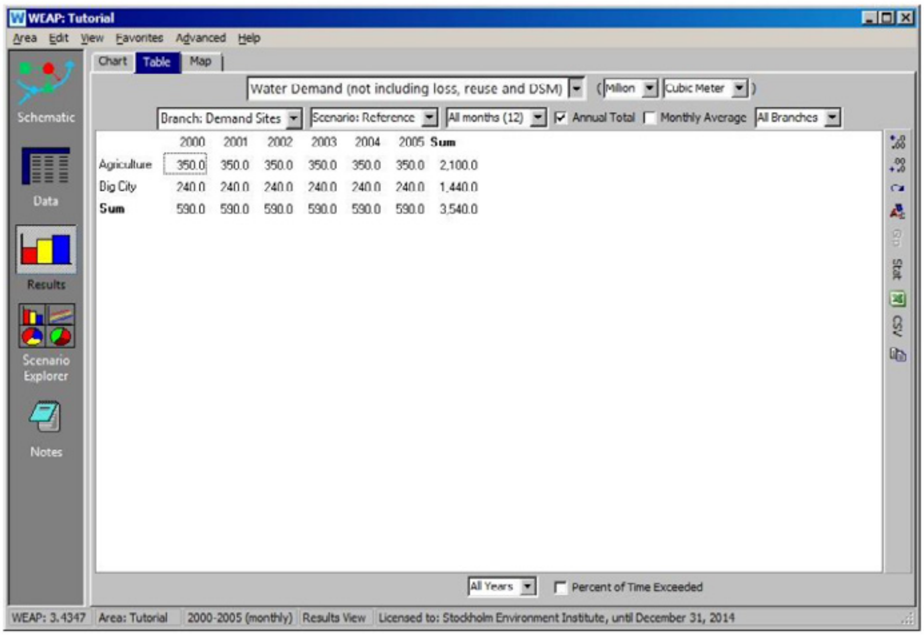

Source: Stockholm Environment Institute. n.d. *Water Evaluation And Planning (WEAP).* [Accessed 29 March 2020]. https://www.weap21.org/index.asp?action=8

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 (Figure 41):

| | |
|---|---|
| Annual demand for agriculture | 350 $Mm^3$ |
| Annual demand for urban area | 240 $Mm^3$ |

FIGURE 41
**Annual demand values for each year of the reference scenario (Step 23)**

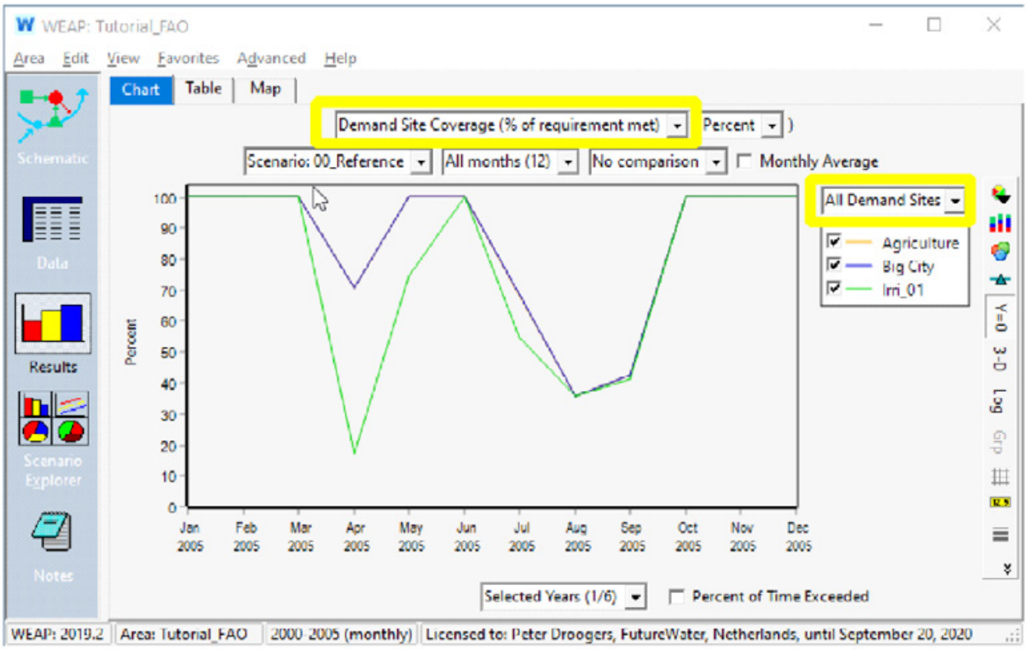



Source: Stockholm Environment Institute. n.d. *Water Evaluation And Planning (WEAP).* [Accessed 29 March 2020]. https://www.weap21.org/index.asp?action=8

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 centre of the window.

FIGURE 42
**Screen showing additional results to better understand WEAP (Step 24)**



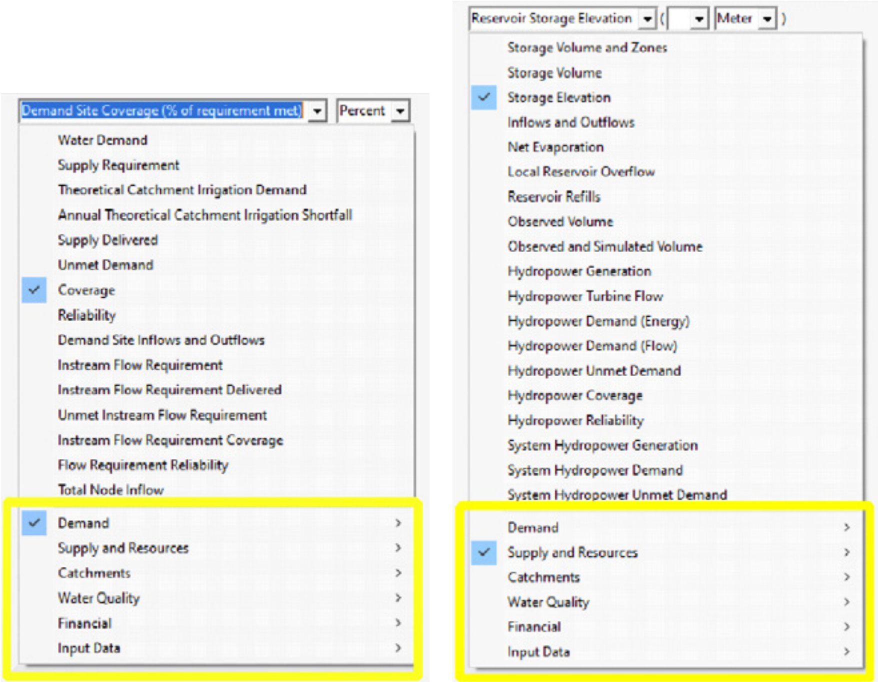

Source: Stockholm Environment Institute. n.d. *Water Evaluation And Planning (WEAP).* [Accessed 29 March 2020]. https://www.weap21.org/index.asp?action=8

WEAP can be quite overwhelming when 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 (keep the "Monthly Average" option checked). Note that the 3-D option allows the viewer to see both data sets even when they overlap. The graph should be similar to the one in Figure 43.

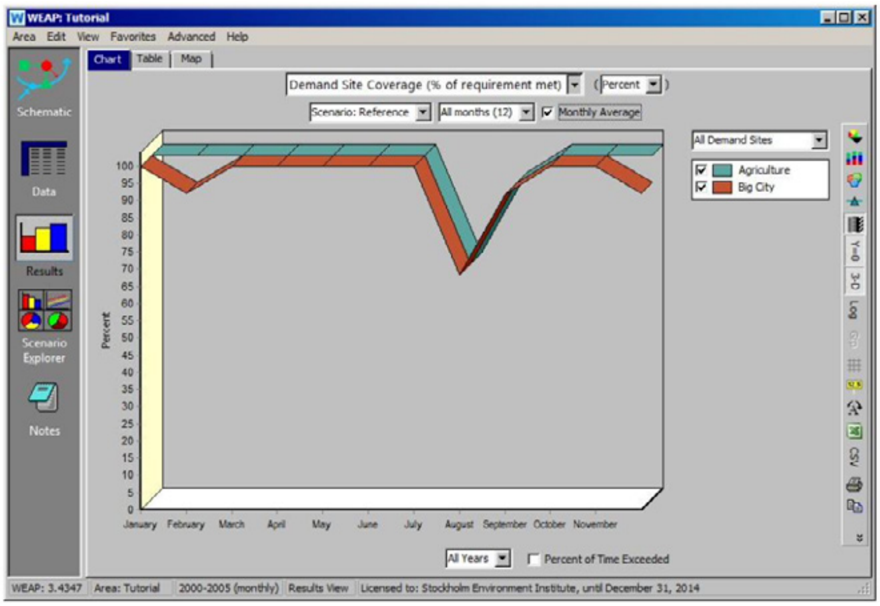
VERY IMPORTANT: The top drop-down box has a peculiar behaviour. There are six main results groups that are displayed AT THE BOTTOM of the drop-down box (Demand, Supply and Resources, Catchments, Water Quality, Financial, Input Data). Based on the group selected, the top of the drop-down box will display other possible results that can be selected as in Figure 44.

FIGURE 43
**Exploring WEAP through use of drop-down boxes (Step 24)**




Source: Stockholm Environment Institute. n.d. *Water Evaluation And Planning (WEAP).* [Accessed 29 March 2020]. https://www.weap21.org/index.asp?action=8

FIGURE 44
**Alternative results in Step 25**




Source: Stockholm Environment Institute. n.d. *Water Evaluation And Planning (WEAP).* [Accessed 29 March 2020]. https://www.weap21.org/index.asp?action=8

During the months of December and February, which have little flow in the river, Big City lacks water, and therefore demands go unmet. We modelled agriculture to only require water from March to September, so it registers 100 percent coverage in the December to February shortage because it has no water demand. Agriculture only has a shortfall in supply in the months 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 a water shortage they will have equal percentages of unmet demand, assuming they are both demanding water at that time.

# 10. Water saving at basin level using WEAP

As discussed before, the term "water saving" is somewhat misunderstood. Water saving as such is not an objective in itself. In fact, water saving is made to serve other users. Therefore, the following definition is preferred: *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 (i.e. making more water available to a downstream located town) will be explored.

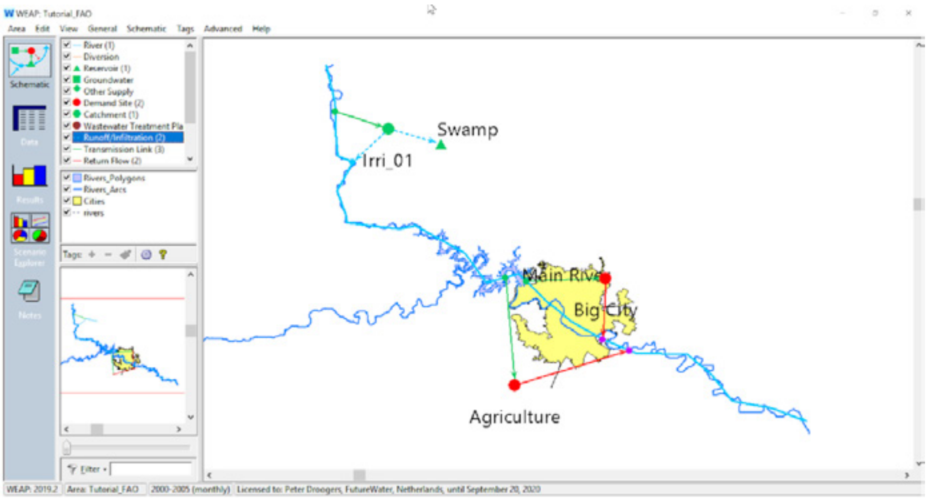
### 10.1. Expand the existing WEAP model

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 when creating a new node in WEAP: keep left mouse button down, drag the node to the desired location, release mouse button.
  - If the question, "Would you like to use the Catchment Delineation Mode" pops up answer with "No".
  - In the pop-up "Select method for calculating runoff and irrigation", select "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 be similar to that shown in Figure 45.

FIGURE 45
**The WEAP Area showing new catchment node (Step 26)**




Source: Stockholm Environment Institute. n.d. *Water Evaluation And Planning (WEAP).* [Accessed 29 March 2020]. https://www.weap21.org/index.asp?action=8

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

- > Data > Demand Sites and Catchments > Irri_01
  - Area: 5 000 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 percent
    - all other months: 0 percent
  - Irrigation > Lower Threshold: 80 percent
  - Irrigation > Upper Threshold: 90 percent
  - 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 percent
  - Cloudiness fraction: 0.5
  - Latitude: 25 degrees
- > Data > Supply and Resources > Runoff and Infiltration > from Irri_01
  - to Irri_01 Runoff: 70 percent
  - to Swamp: 30 percent

The model setup and data entry are complete. Start running WEAP by pressing the Results tab.

### 10.2. A brief test

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

Month with highest irrigation ____________________ (month)

Irrigation amount in that month ____________________ (MCM/month)

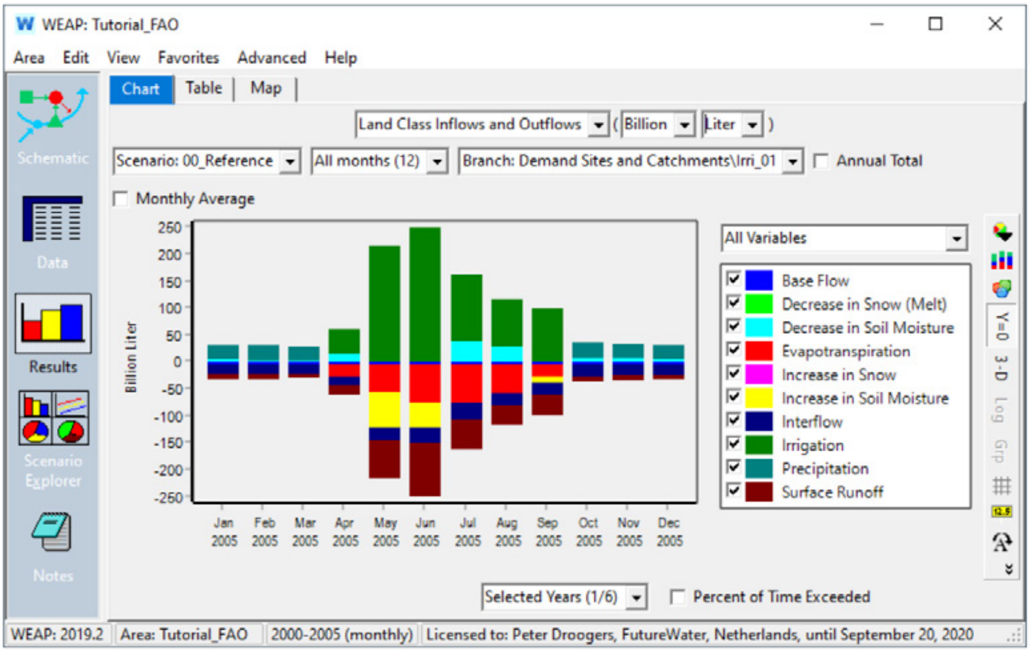
Same but in mm/month ____________________ (mm/month)

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 drop boxes:
  - Scenario: 00_Reference
  - All months (12)
  - Branch: Demand Sites and Catchments\Irri_01
- Bottom dropbox: Selected Years: 2005

Your screen should be similar to that shown in Figure 46.

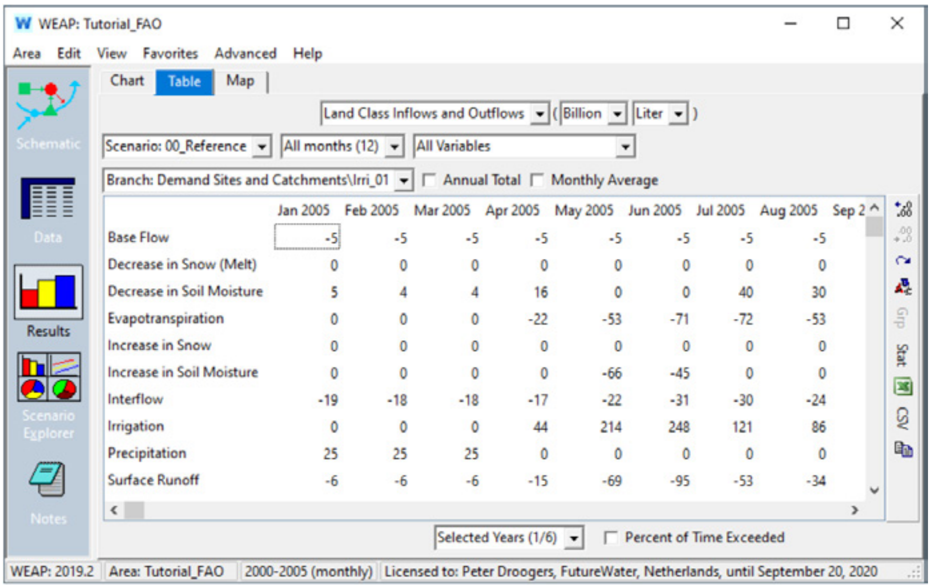
FIGURE 46
**Screen showing irrigation data in Step 27.**




Source: Stockholm Environment Institute. n.d. *Water Evaluation And Planning (WEAP).* [Accessed 29 March 2020]. https://www.weap21.org/index.asp?action=8

TIP: By selecting “Table” instead of “Chart” actual numbers are provided (Figure 47).

FIGURE 47
**Showing table with numbers provided in Step 28**




| | Jan 2005 | Feb 2005 | Mar 2005 | Apr 2005 | May 2005 | Jun 2005 | Jul 2005 | Aug 2005 | Sep 2 |
|---|---|---|---|---|---|---|---|---|---|
| Base Flow | -5 | -5 | -5 | -5 | -5 | -5 | -5 | -5 | |
| Decrease in Snow (Melt) | 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 | |

Source: Stockholm Environment Institute. n.d. *Water Evaluation And Planning (WEAP).* [Accessed 29 March 2020]. https://www.weap21.org/index.asp?action=8

### 10.3. Obtain the full water balance for the Irri_01 for the entire year 2005 using Figure 48 below:

FIGURE 48
**Full water balance table without values in Step 29**

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

Source: Authors' own elaboration.

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

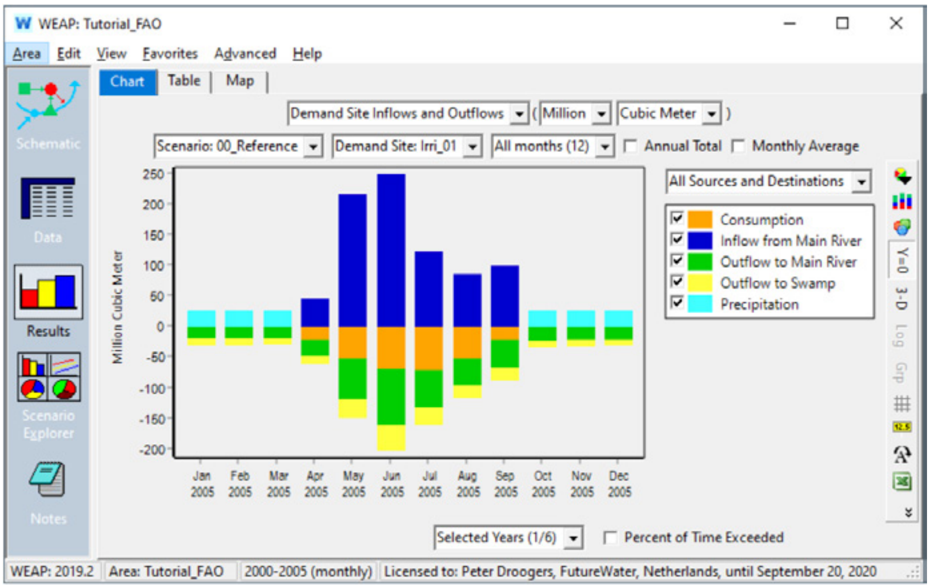
### 10.4. Fill in the water balance components using the schematic view of the irrigation system. Use the same numbers as you entered in Figure 48.

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

- Distinction between crop transpiration and soil evaporation is not calculated by WEAP. Assume that from the total evapotranspiration
  - 80 percent is crop transpiration
  - 20 percent 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 (Figure 49)

FIGURE 49

**Screenshot showing how the amount of recoverable water is obtained in Step 30.**

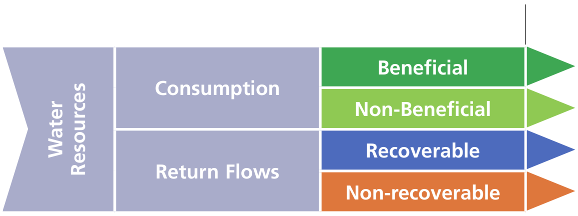



Source: Stockholm Environment Institute. n.d. *Water Evaluation And Planning (WEAP).* [Accessed 29 March 2020]. https://www.weap21.org/index.asp?action=8

## 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 Follow the Water approach

FIGURE 50

**Using the Follow the Water approach in Step 31**




| A (mm/season) | B (mm/season) |
|---|---|
| | |
| | |
| | |
| | |

Source: Authors' own elaboration.

In the past we would use the term "irrigation efficiency". For this particular situation the irrigation efficiency would be calculated as:

Evapotranspiration / irrigation applied
= 294 MCM / 810 MCM
= 37 percent

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 to 50
- less water flows down the rootzone
  - change the Root Zone Conductivity from 200 mm/month to 100 mm/month
- better water uptake by crop:
  - increase all Kc values by 10 percent
    - 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 respond to the following prompts

Compare irrigation applications for the two scenarios:

Reference: ____________________ (MCM/year)

Modernization: ____________________ (MCM/year)

Explain why the irrigation applications are different

---

It looks like we "save" a significant amount of water. The question is whether this "saving" is 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

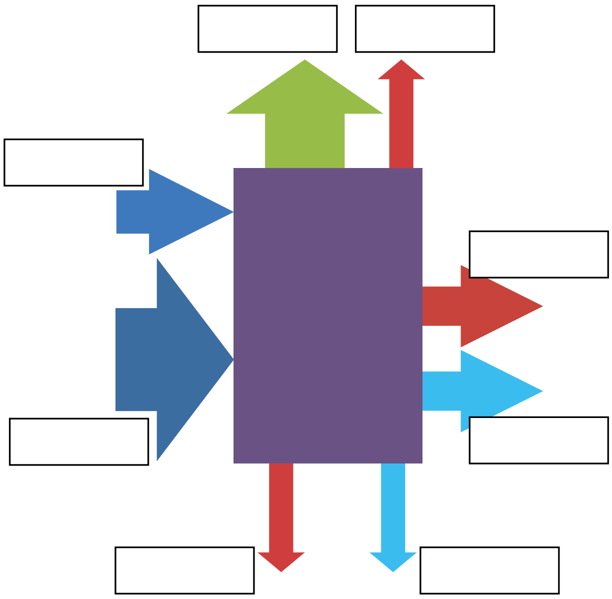
Reference: ____________________ (MCM/year)

Modernization: ____________________ (MCM/year)

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

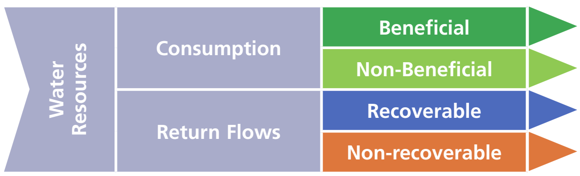
Fill in the numbers in Figure 51 and Figure 52 for the modernization scenario.

FIGURE 51
**The modernization scenario: variables to be identified**



Source: Authors' own elaboration.

FIGURE 52
**The modernization scenario: values to be added**




| A (mm/season) | B (mm/season) |
|---|---|
| | |
| | |
| | |
| | |

Source: Authors' own elaboration.

The previous exercise showed that by introducing drip irrigation no additional water was made available for use 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 MCM/y down to 580 MCM/y).

## 10.7. Discuss the results

After completing the exercises above, discuss the results to identify what happens with the downstream flows when farmers invest in drip irrigation and still receive the same amount of irrigation water.

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