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Climate Smart WATER Management
and Sustainable DEVELOPMENT
for Food and Agriculture in East Africa

TOOLBOX MANUAL



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and Sustainable DEVelopment
for Food and Agriculture in East Africa

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1.

1. Introduction

Managing water in East African basins implies the sustainable use of agricultural water while looking at its nexus with food and energy. In many East-African areas (e.g. Ethiopian Low and Highlands, Blue Nile River, Upper Tana River, White Nile River, Victoria Lake riparian areas and others), the benefits of agricultural resources are endangered by reduction of agricultural productivity and agricultural systems efficiency.

The WATDEV project (watdev.eu), under the EU DeSIRA programme, developed a Toolbox with the aim to support local stakeholders (mainly decision-makers) in water planning in agriculture to meet food and nutritional needs, raise incomes and increase employment opportunities, while protecting the environment and reducing inequalities.

The Toolbox has two-level user options: Basic and advanced.

The basic level has predefined scenarios that the user can take a closer look at and is able to create customized scenarios based on the predefined scenarios.

In the advanced option, users can upload their own scenarios.

More complex changes such as adding new study areas can only be done by Toolbox Administrators.



2. Overview of the Toolbox

The Toolbox is a visualization tool to study the results of an integrated modelling system which combines dynamic catchment-scale model to multicriteria analysis.

The main idea of the Toolbox is to help in discussions between different stakeholder groups and to give option to try different directions in decision making.

The Toolbox is at the moment applied to 4 study areas: Sharqia in Egypt, Gezira in Sudan, Koga in Ethiopia, and Hola/Bura in Kenya. The application for these study areas was based on a participatory process between different stakeholder groups in developing scenarios of Best Management Practices (BMPs), selecting Key Performance Indicators (KPIs) and assigning them weights based on development objectives.

Physical KPIs are based on model results, while socio-economic KPIs are calculated inside the Toolbox based on assumptions on socioeconomic conditions (e.g. crop price, farming costs, BMP investment and operational costs, etc.).

Main KPIs of different sectors are shown in [Figure 1: Main Key Performance Indicators \(KPIs\)](#), below.

The Toolbox has two-level user options: **basic** and **advanced**. In addition, there is an **administration level** with broader rights.

The **basic** level has predefined scenarios that the user can take a closer look at.

In the **advanced** option user can add own scenarios and save Multi-Criteria Analysis (MCA) configurations.

The **administration level** is able to manage toolbox-wide MCA assumptions and manage both study areas and model runs.

The current version of the Toolbox contains detailed scenarios of BMP application for each project study area. All these scenarios describe the steady-state situation in which BMP has been implemented several years.

Scaling the Toolbox to other areas requires a new application of the integrated model to that area. At a general level, modeling can be done using global data of weather, soil types, land cover or land use, and elevation map of the area. Global data are available from several open data bases (e.g. <https://swat.tamu.edu/data/>). The reliability of the modeling will improve if more accurate local data is available. However, information from local experts is desirable to determine intervention objectives, select appropriate BMPs to achieve these objectives, adjust socioeconomic assumptions to local conditions, and select the importance of different KPIs.

Advanced and admin users can add new crops and KPIs into the Toolbox.

When an advanced or admin user uploads a new scenario, the toolbox will ask the user to identify the new crop codes and provide its regular name. Admin users are then able to set default values for these crops in the MCA. Advanced users are able to store their values in their personal workspaces. In the advanced option there are instructions for creating own management scenarios.

Figure 1: Main Key Performance Indicators (KPIs)

	Sector	Key Performance Indicator
Model results (processed)	Crop	• Crop Yield • Irrigation water use (& efficiency) • Fertilizer (N, P) use (& efficiency) • Carbon sequestration in crop
	Soil	• Erosion • Soil organic carbon • Soil nutrients (N, P)
Post-processing (Toolbox)	Water	• Groundwater recharge • Nitrate in groundwater • Nitrate in surface water
	Economy	• Benefit- and Price-cost ratio • Household net farm income • Technical and economic water use efficiency

3. Modelling

The WATDEV toolbox results come from an integrated mathematical catchment scale model which describes plant growth and water transport in a river basin or command area by using physically-based equations. The simulation area is divided into spatial components.

In a watershed, each component represents a sub-catchment delineated based on water flow into river branches. In a command area, each component represents an irrigation block (or group of blocks) with the same water source. Each sub-catchment or irrigation block is then divided into calculation units called Hydrologically Representative Units (HRUs), which can be thought of as representative fields, based on the crop or other vegetation cover, soil type and elevation. Thus, a field representing a specific crop located in a specific sub-catchment area is one calculation unit or HRU. The structure is the same as in the SWAT (Soil Water Assessment Tool) model ([SWAT | Soil & Water Assessment Tool](#)).

The model simulates crop growth and production, crop water and nutrient (N, P) use and stress, soil water and nutrient processes, and soil erosion and nutrient mobilization.

The equations of plant growth are based on the SWAT model, but users seeking more detail in plant growth can use improved equations taken from the DSSAT crop model (Decision Support System for Agrotechnology Transfer; [DSSAT.net - Official Home of the DSSAT Cropping Systems Model](#)). In areas where groundwater is of great importance, it is possible to implement the advanced groundwater model ModFlow ([MODFLOW 6: USGS Modular Hydrologic Model | U.S. Geological Survey](#)).

In the WATDEV Toolbox there are ready-made modelled scenarios for BMP scenarios for river basins in Egypt, Ethiopia, Kenya and Sudan. The BMPs for each study site consist of local adaptations of changes to cropping practices such as crop selection and fertilization (Egypt, Ethiopia, Sudan); addition of permanent crops (Egypt, Ethiopia, Kenya); or improved water management at the field and system scales (all sites). The model can either assume a steady state condition or trees planted small and growing up. In the steady state assumption, the user get the long-term view of the BMP. In the planted assumption, the user the actual income covers the first 10 years in Multi-Criteria analysis. In the Toolbox there is an option to view the model metadata, which explains basics of the scenario.

Scenarios for each country were developed together with stakeholders to answer questions that are specific to that region. Detailed descriptions of modelling will be later published by doctoral thesis works (by end of 2027) and the summarized data will be available via Toolbox.

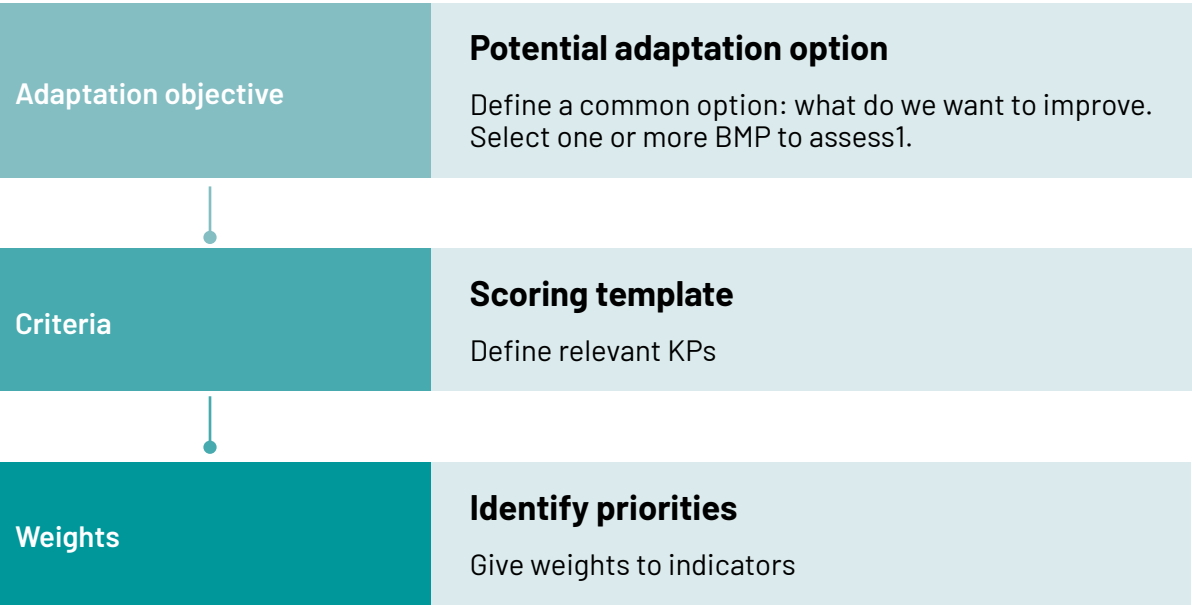
4. Multi-Criteria Analysis

Improving irrigated farming is a complex process as different stakeholders may have conflicting or parallel interests, and there may be multiple improvement objectives without clear optimal solution. Multi-Criteria Analysis (MCA) is a tool to help choose between different adaptation options under complex conditions, and therefore an essential part of the Toolbox.

MCA consists of a set of systematic procedures for designing, evaluating, and selecting decision alternatives based on conflicting criteria. MCA can also be used as a discussion support tool in cases where different end-user groups have different interests. Each adaptation option is analysed in relation to agree upon criteria. Criteria can be weighted if some criteria are considered more important than others. The MCA design workflow is shown in [Figure 2: Workflow of multicriteria analysis](#).

KPIs were selected – involving stakeholders at different levels – in the early workshops of the project. Biophysical KPIs are based on the results of the integrated models. Socio-economical KPIs are based on assumptions of BMP investment costs, labour costs, material costs, crop market prices, etc. Some of these KPIs, such as benefit-cost ratio or net farm income, also include results from the integrated model (e.g., crop yield). Default weights for KPIs are based on expert opinions collected in regional participatory workshops. All these values can be changed/adapted in the Toolbox. Finally, the Toolbox shows a diagram in which normalized KPIs for baseline and BMP scenarios are compared.

Figure 2: Workflow of multicriteria analysis



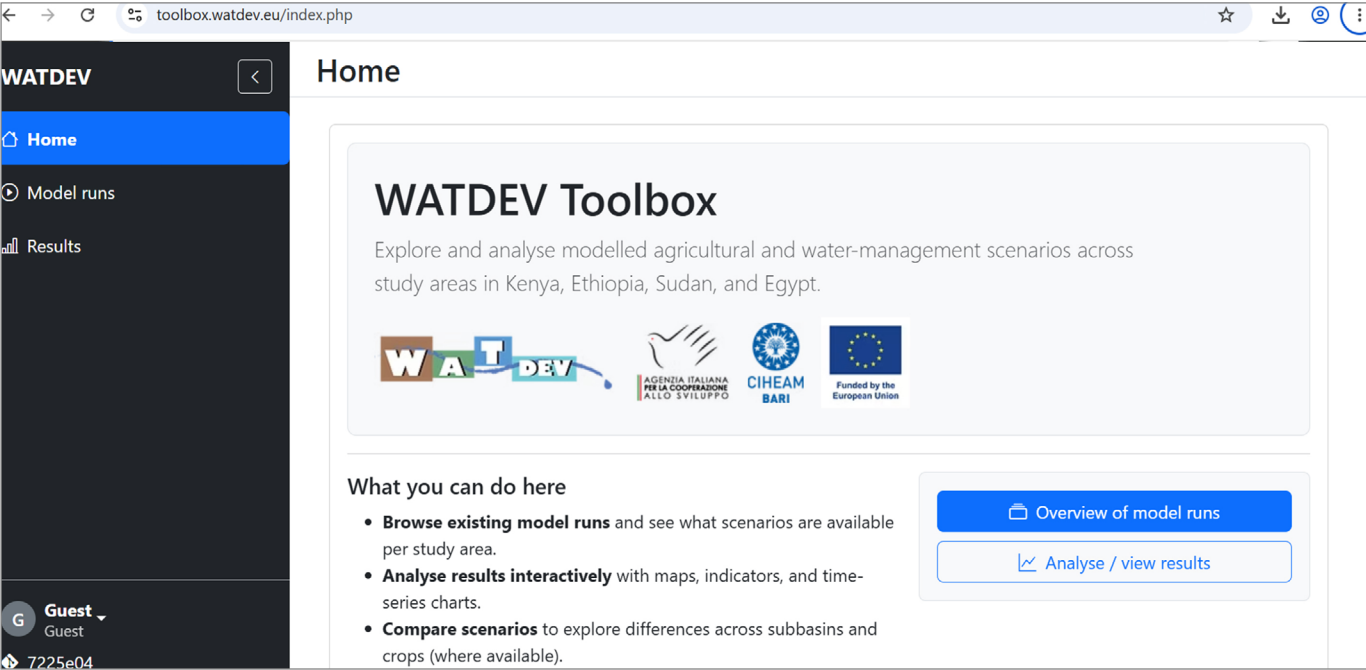
5. Basic options

5.a. Results visualization

The WATDEV Toolbox is available at <https://toolbox.watdev.eu>

The link opens the home page of the Toolbox (Figure 3: Homepage of the WATDEV Toolbox). In the bottom left corner, there is an option to log in as a user (via GitHub account: <https://github.com/>). On the left side panel there are options to have a look of current model runs for different management options in different countries. The results are illustrated and analyzed in the results section.

Figure 3: Homepage of the WATDEV Toolbox



A blank page will be open in the Results section. The same page is accessed from the button “Analyze/view results”. The map of the desired catchment area can be displayed by selecting the area in the top panel, under ‘study area’ (Figure 4: Subbasin dashboard). The boundary of the selected area is drawn on the map. With the slider “Opacity” it is possible to make the river basin area more transparent. Below the map, there is a horizontal panel from which it is possible to choose either a background map or a satellite image for the map. In the right panel there are options for default datasets/scenarios of management options. The modeled results can be selected from metrics (Figure 6: Option to select crops. The arrow shows where to choose the sub-catchment), and the crop of interest from crops. Default shows KPI per crop type per sub basin. After each scenario there is a small logo, which opens the metadata

page. There is more detailed information about the scenario on that page.

In the Visualization section, the user can compare the impact of different scenarios on a specific sub-catchment area. To do this, the user must first select the management option scenarios and then click on the desired sub-catchment area on the map (Figure 5: Modelled scenario outputs. The arrow shows where to choose the sub-catchment). Results can be compared as a line graph over time, or as bar graphs for different crops and metrics (Figure 7: Visualisation of the scenarios).

There is also an option to mix and match scenarios under the button ‘Manage custom scenarios’. Pressing this will open a window where the basic (?) user can give the new scenario a name and describe its content. Then the user selects an existing BMP and assigns it to the desired subbasin. The scenario is visible in ‘Databases/scenarios’ under ‘Custom scenarios’ (Figure 8: Custom scenarios)

Figure 4: Subbasin dashboard

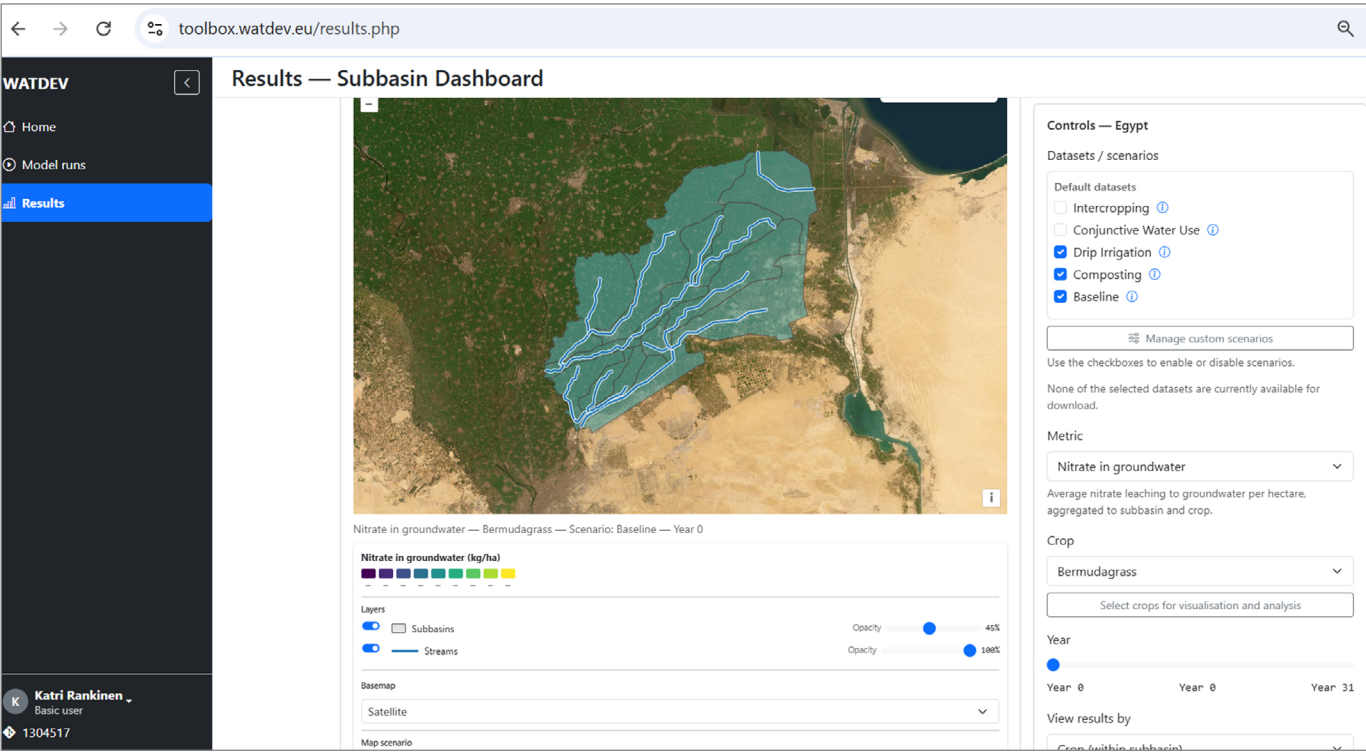


Figure 5: Modelled scenario outputs. The arrow shows where to choose the sub-catchment

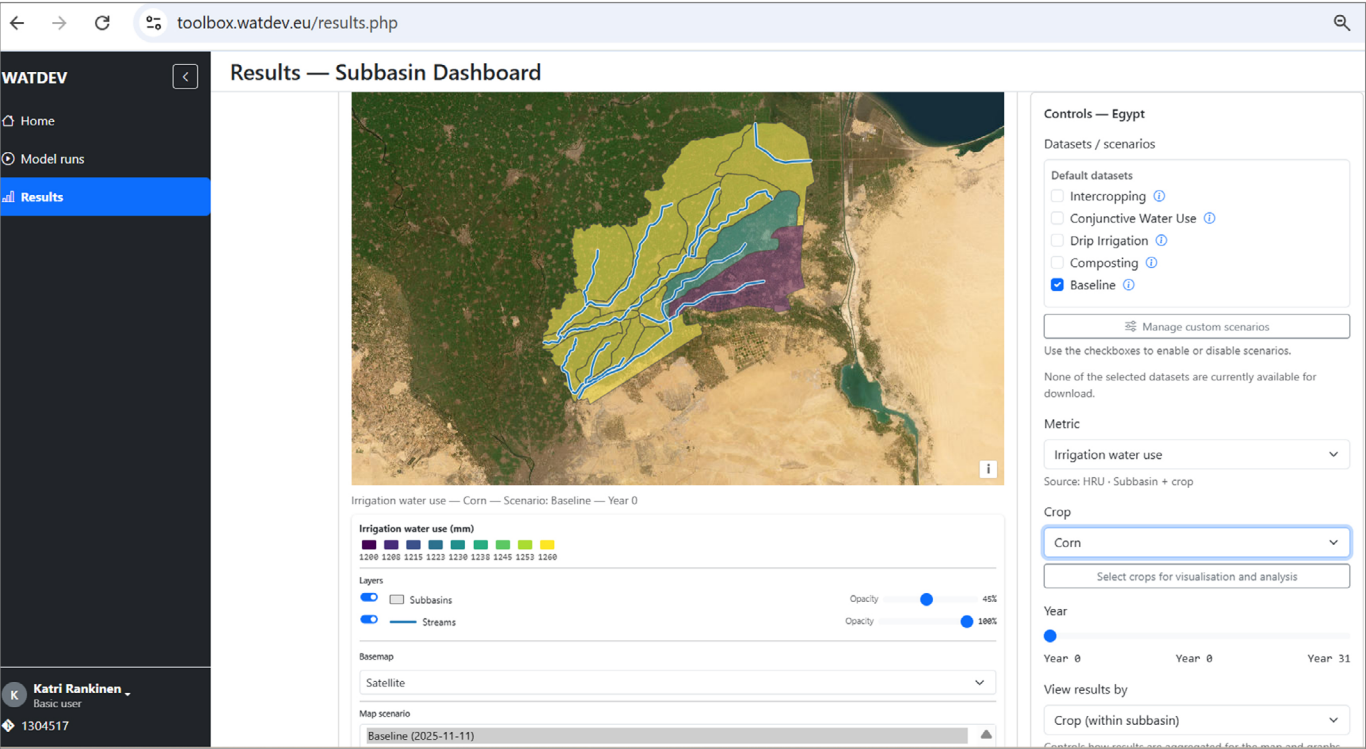


Figure 7: Visualisation of the scenarios

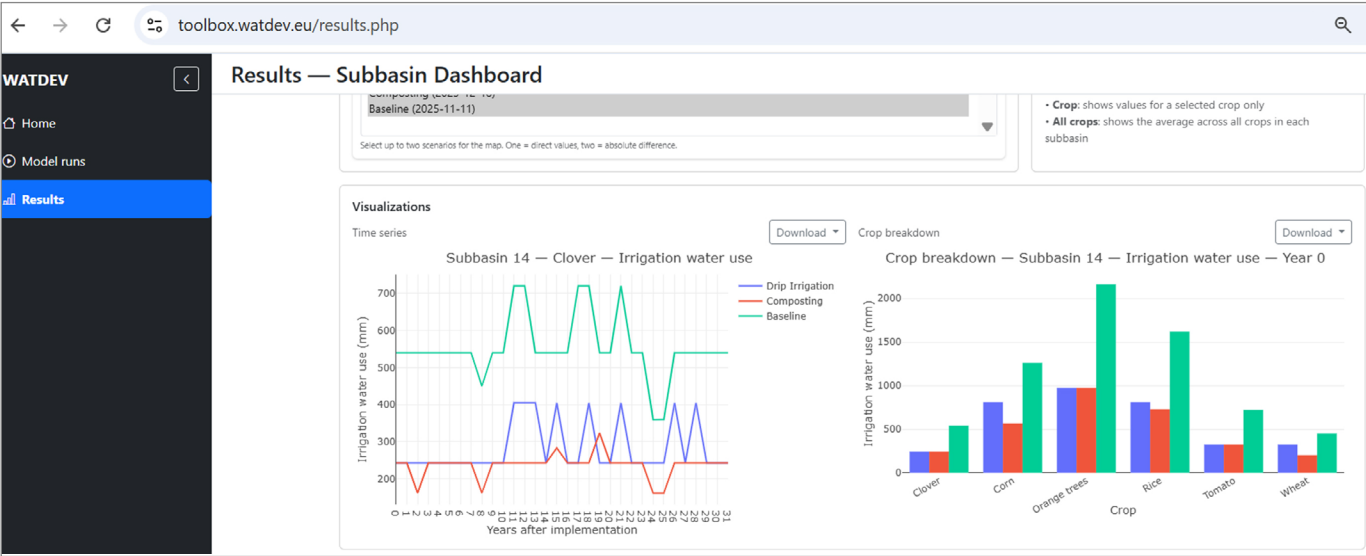


Figure 6: Option to select crops

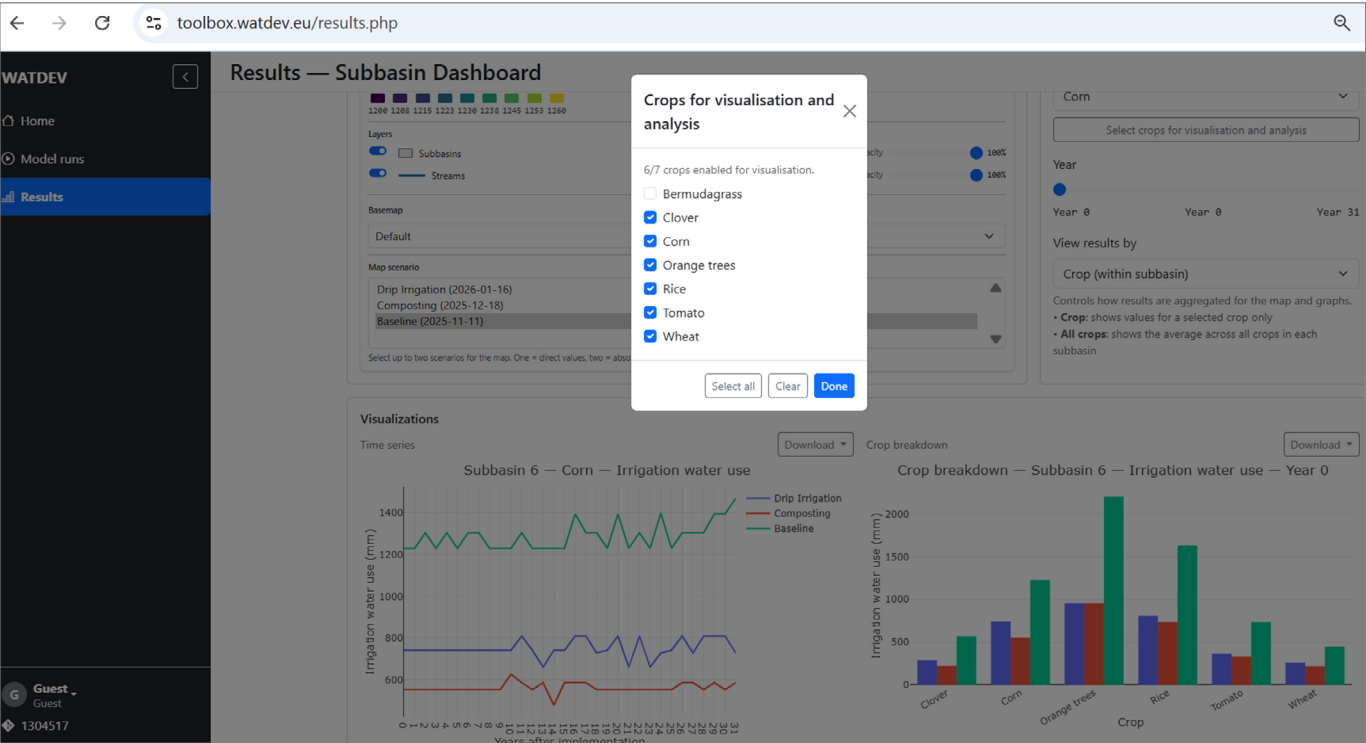
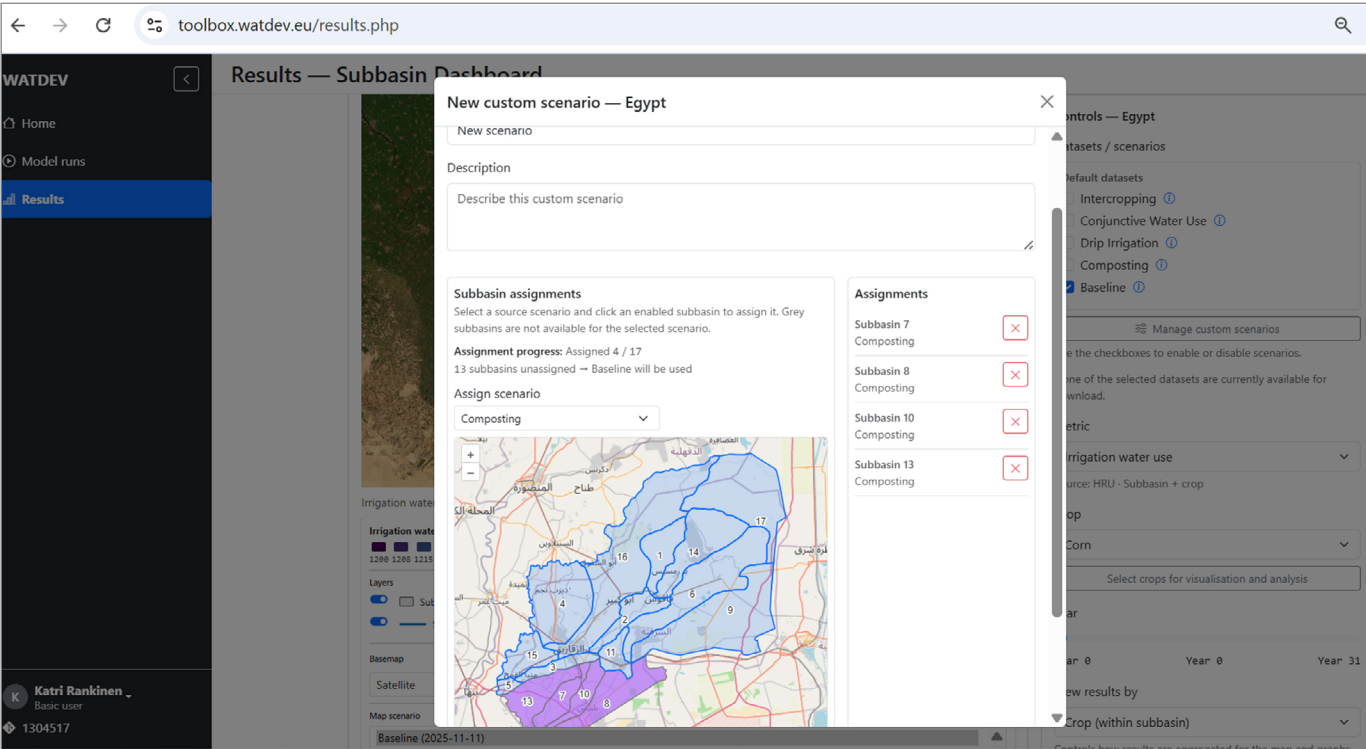


Figure 8: Custom scenarios



b. Multi-Criteria Analysis

Multi-Criteria Analysis becomes available by clicking the tab ‘Enable MCA’ in the rights side of the page. Four horizontal panels appear on the screen: Indicators & weights, Crop variables (Global), Variables (Global) and Scenarios in MCA.

The weights of different indicators are presented as percentages, and they can be changed in the panel on right (Figure 9: Indicators and weights in MCA). The weights are automatically normalized when the MCA is calculated, i.e. if the total sum is different than 100, weights are adjusted so that their sum is 100.

The KPIs to be displayed in the results section are selected by clicking on the box to the left of each indicator. On the right side of the indicator, the user can choose whether the indicator’s positive value will decrease or increase.

Crop variables contain prices of different crops (USD/t), but also labour costs (labour-day/ha) and material costs (USD/ha) of cultivation. These values can be freely changed. Other variables contains farm size as hectares and cost of labour days and land rental as US dollars. Finally, scenario variables contains costs for selected scenarios.

Under the global crop variables, default values for costs can be changed (Figure 10: Crop variables). Under global variables, the parameters concerning representative individual farm can be changed (Figure 11: Global variables). Parameters of different scenarios can be changed (see Figure 12: Scenarios in MCA).

When pressing “compute MCA”, the results become visible(Figure 13: Results of the MCA analysis). The variable to be illustrated can be changed in the line chart by selecting it in the panel in the upper corner.

The visualization section shows the overall MCA scores as bars. The spider chart shows the normalized value of the individual, so that the number 1 is the best reult (independent whether the best KPI value should increase or decrease).

Figure 9: Indicators and weights in MCA

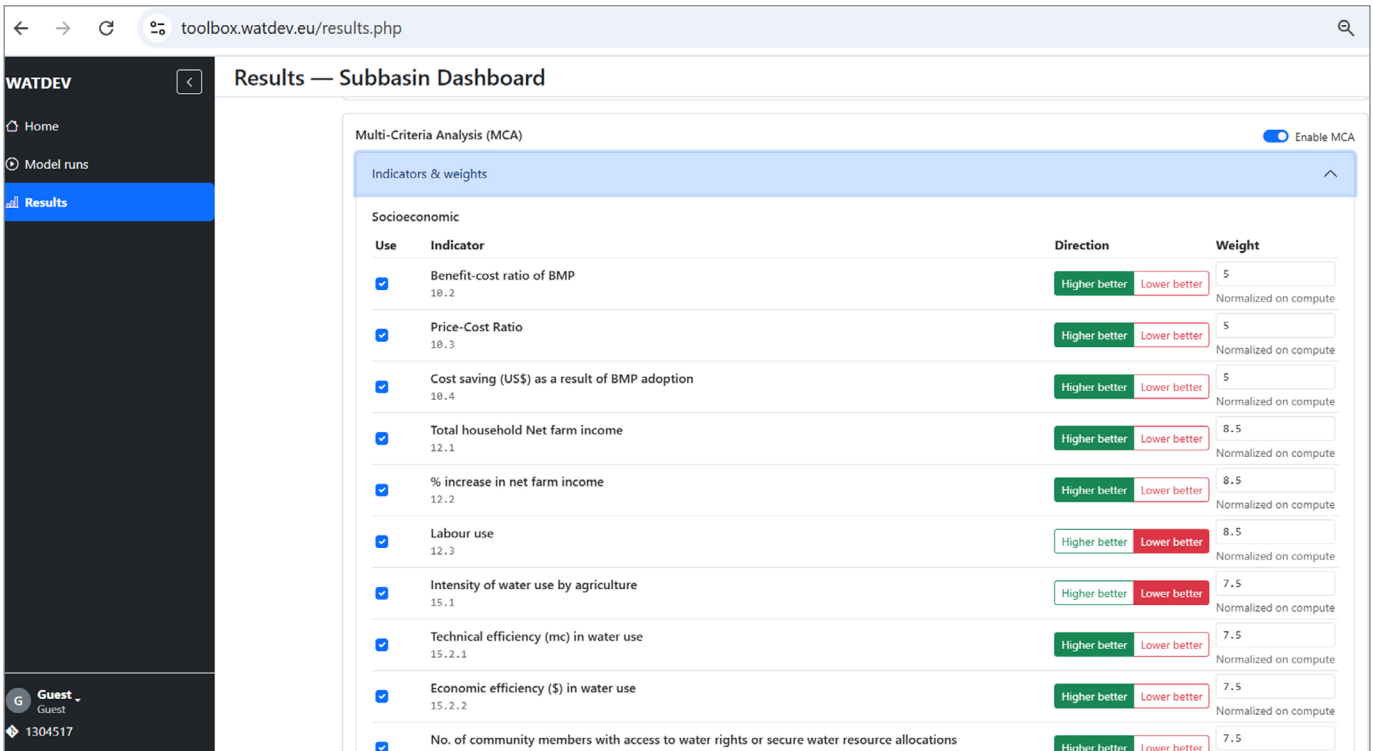


Figure 10: Crop variables

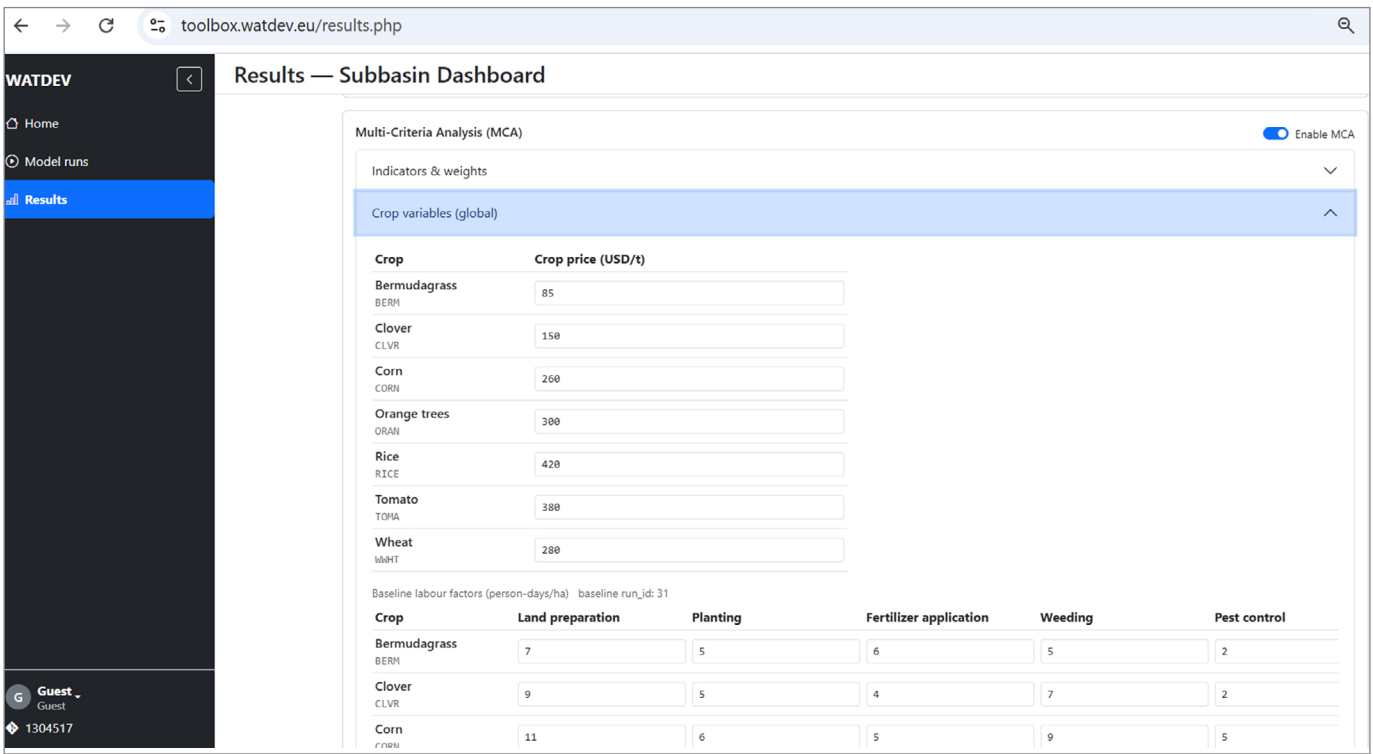


Figure 11: Global variables

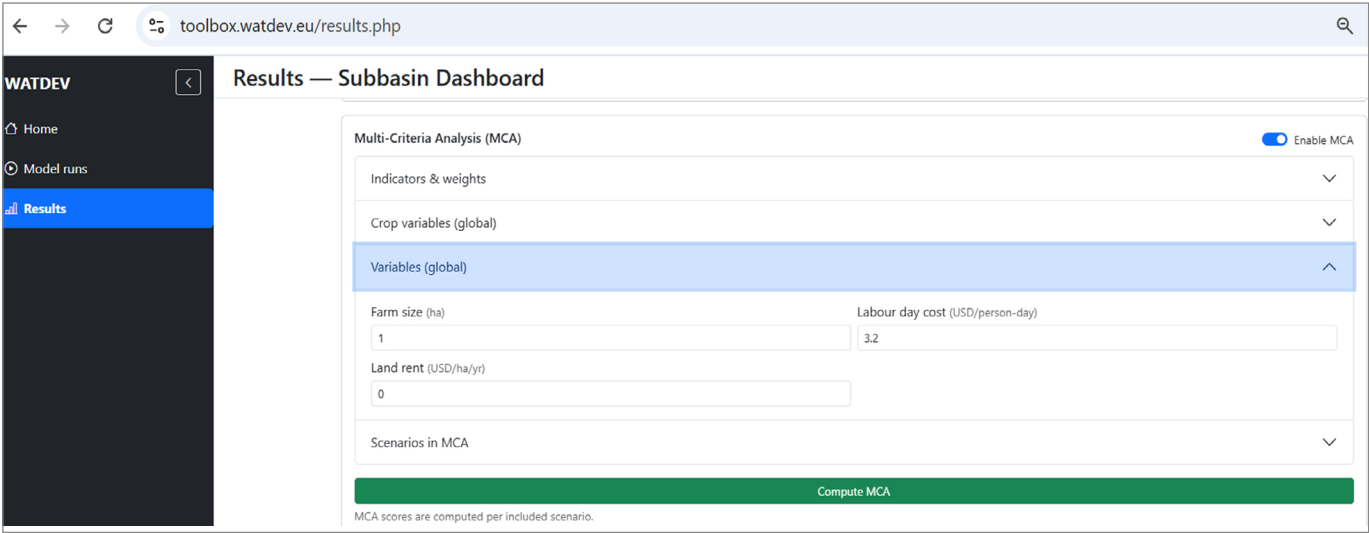


Figure 12: Scenarios in MCA

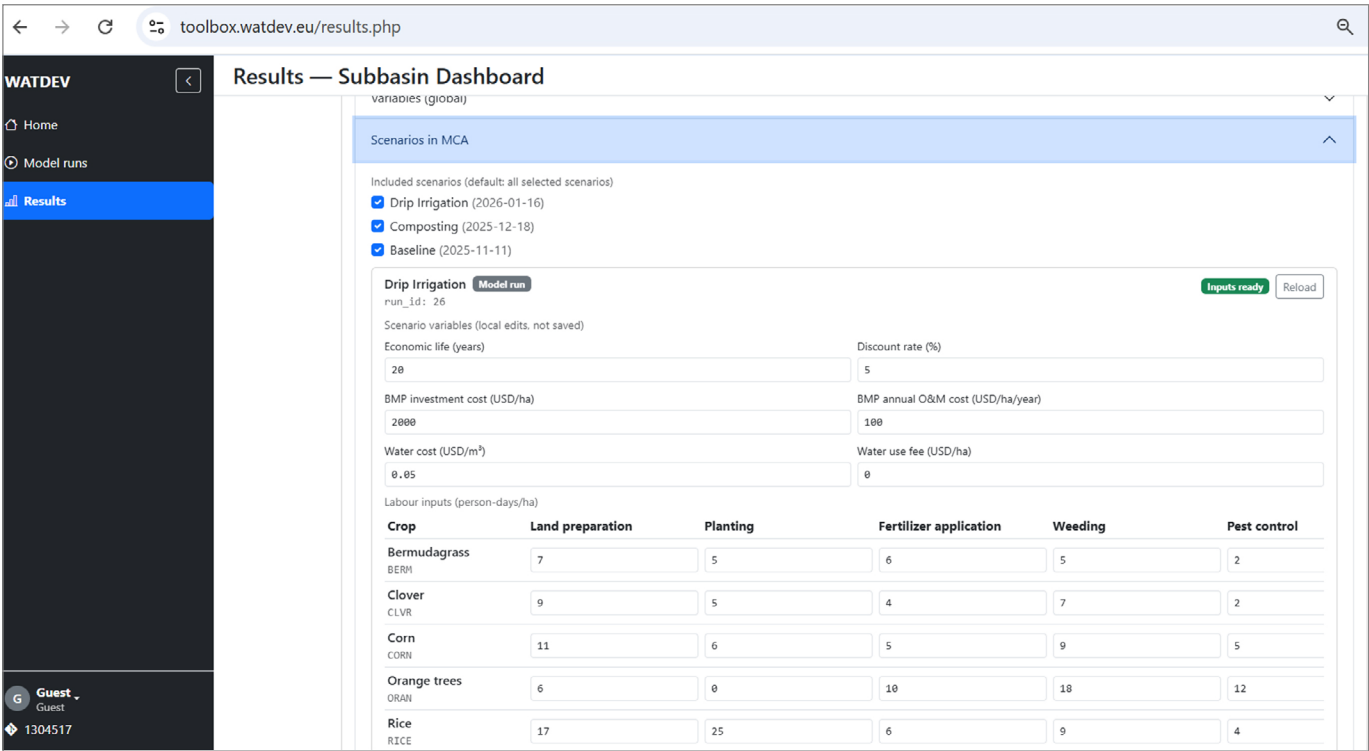
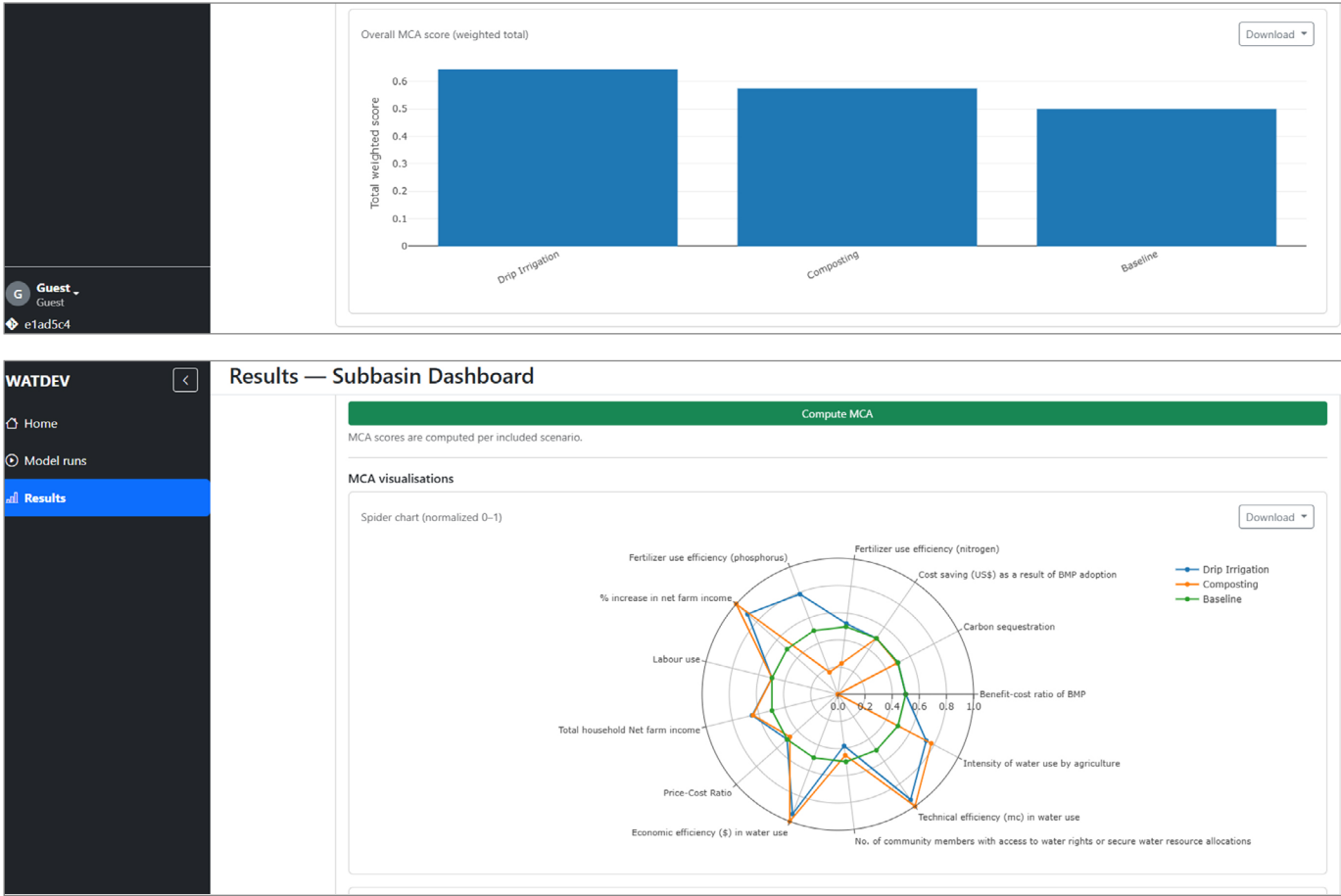


Figure 13: Results of the MCA analysis



6. Advanced options

For advanced users, there is an option for downloading own management scenarios for command area. These own management scenarios must be modelled separately in the integrated model outside the Toolbox. The modelling can be done via the SWAT editor application which is available at SWAT pages (<https://swat.tamu.edu/software/swat/>). That editor allows to change crops, management practices etc.

For advanced users there is a button 'Import' on the left panel (Figure 14: First step to import own management scenarios), that opens the page Import model run. In the first step the user can choose between import sources. Original SWAT output files is the recommended option. Uploading may take some time.

In the second step the user can define the command area, give name and description for the scenario, In the third step the user can select sub-catchments (Figure 15: Second and third steps to import own management scenarios).

Finally, the uploaded management scenario is visible on page 'Results' under 'Datasets/scenarios' as 'User uploaded model runs.' It can further be studied like the other scenarios Figure 16: Own management scenarios (In this figure Example) can be found in 'Datasets/scenarios'.

Figure 14: First step to import own management scenarios

WATDEV

Home

Model runs

Results

Import

Katri Rankinen

Advanced user

e1ad5c4

Import model outputs

Import model run

Import a SWAT run from original output files, CSV exports, or later from GitHub. The system will inspect the files, detect crops and subbasins, and then import the normalized results.

Step 1 — Choose source and inspect files

Import source

Original SWAT output files CSV files GitHub

file.cio

Choose File No file chosen

Required for original output import. Used to derive simulation timing metadata.

output.hru

Choose File output.hru

Required for original output import.

output.rch

Choose File output.rch

Optional for study areas without reach results.

output.snu

Choose File output.snu

Required for original output import.

Inspect files

Step 2 — Metadata

Study area

Choose...

Run name

Model run date

19/05/2026

Model run author

Katri Rankinen

Publication / GitHub link

https://

License

Choose

Figure 15: Second and third steps to import own management scenarios

WATDEV

Home

Model runs

Results

Import

Katri Rankinen

Advanced user

e1ad5c4

Import model outputs

Step 2 — Metadata

Study area

Ethiopia

Run name

Example

Model run date

19/05/2026

Model run author

Katri Rankinen

Publication / GitHub link

https://...

License

Choose...

Visibility

Private

Baseline run

No

Optional.

Dataset is downloadable

Downloadable from date

dd/mm/yyyy

Description

Step 3 — Crops and subbasins

Subbasin map

Selected subbasins

Select the subbasins for which the uploaded run contains valid results. These subbasins determine where the run is available in the dashboard and where it can be used when creating custom scenarios.

Add detected subbasins Use only detected subbasins Clear selection

Add detected subbasins adds detected subbasins to your current selection. Use only detected subbasins replaces the current selection with only the detected subbasins.

Subbasin 1 detected

Subbasin 2 detected

Subbasin 3 detected

Figure 16: Own management scenarios (In this figure Example) can be found in 'Datasets/scenarios'

Results — Subbasin Dashboard

Study area: Egypt Ethiopia Kenya Sudan

Workspace

Default configuration

Load Save as new

Subbasins — Ethiopia

Nitrate in groundwater — Irrigated Wheat — Scenario: Example — Year 0

Nitrate in groundwater (kg/ha)

Controls — Ethiopia

Datasets / scenarios

Baseline Crop Rotation CA Agroforestry CA

User-uploaded model runs

Example (2026-05-19)

Custom scenarios

katri

Manage custom scenarios

Use the checkboxes to enable or disable scenarios.

None of the selected datasets are currently available for download.

Metric

Nitrate in groundwater

Average nitrate leaching to groundwater per hectare, aggregated to subbasin and crop.

Crop

Irrigated Wheat

Select crops for visualisation and analysis

7. Examples of MCA

These are two examples from the Regional Toolbox Training hold in Wageningen, Addis Abeba and Cairo in April-May 2026. First, the users need to know which factors they are interested in and how much emphasis they get. After this, users can select the desired KPIs and assign weights to them.

Egyptian example

In Egypt the main interests are environmental protection, water use, soil fertility and also higher profits for farmers. In [Table 1: Emphasis of different sectors in objectives](#) there are emphasis for three partly contrasting objective.

In addition to baseline(current situation)the studied scenarios are composting, in which organic fertilizers are used, and intercropping of citrus trees with soybean or eggplants. The selected KPIs and their weights are in [Figure 17: Weights for the first objective 'Food security'](#).

Only the results of the first objective are presented here. In the objective 'Food security' main emphasis is in water use, and lower emphasis in economy. Overall MCA scores are lower in baseline than in scenarios([Figure 18: Results of the objective 'Food security'](#)).

The KPI values related to water use are higher (good) both in the scenario 'Intercropping' and 'Composting'. On the other hand, KPI of 'Benefit-Cost ratio' is low (bad) in 'Composting', and KPI Erosion is low (bad) in 'Intercropping'.

Table 1: Emphasis of different sectors in objectives

Objectives	Crop	Soil	Water	Economy
Food security	25	25	40	10
Water management	15	15	50	20
Soil fertility improvement	20	50	20	10

Figure 17: Weights for the first objective 'Food security'.

Economy:

☒

Price-Cost Ratio
10.3

Higher betterLower better

2.5

Normalized on compute

☒

% increase in net farm income
12.2

Higher betterLower better

2.5

Normalized on compute

☒

Labour use
12.3

Higher betterLower better

2.5

Normalized on compute

☒

Economic efficiency (\$) in water use
15.2.2

Higher betterLower better

2.5

Normalized on compute

Water:

☒

Intensity of water use by agriculture
15.1

Higher betterLower better

20

Normalized on compute

☒

Irrigation water use
irr_mm

Higher betterLower better

25

Normalized on compute

Soil:

☒

Soil erosion
soil_erosion_t_ha

Higher betterLower better

15

Normalized on compute

☐

Soil organic carbon
soil_org_c_kg_ha

Higher betterLower better

5

Normalized on compute

☐

Soil fertility SOC
soil_fert_soc_kg_ha

Higher betterLower better

5

Normalized on compute

☒

Soil fertility N
soil_fert_n_kg_ha

Higher betterLower better

10

Normalized on compute

Crop

☒

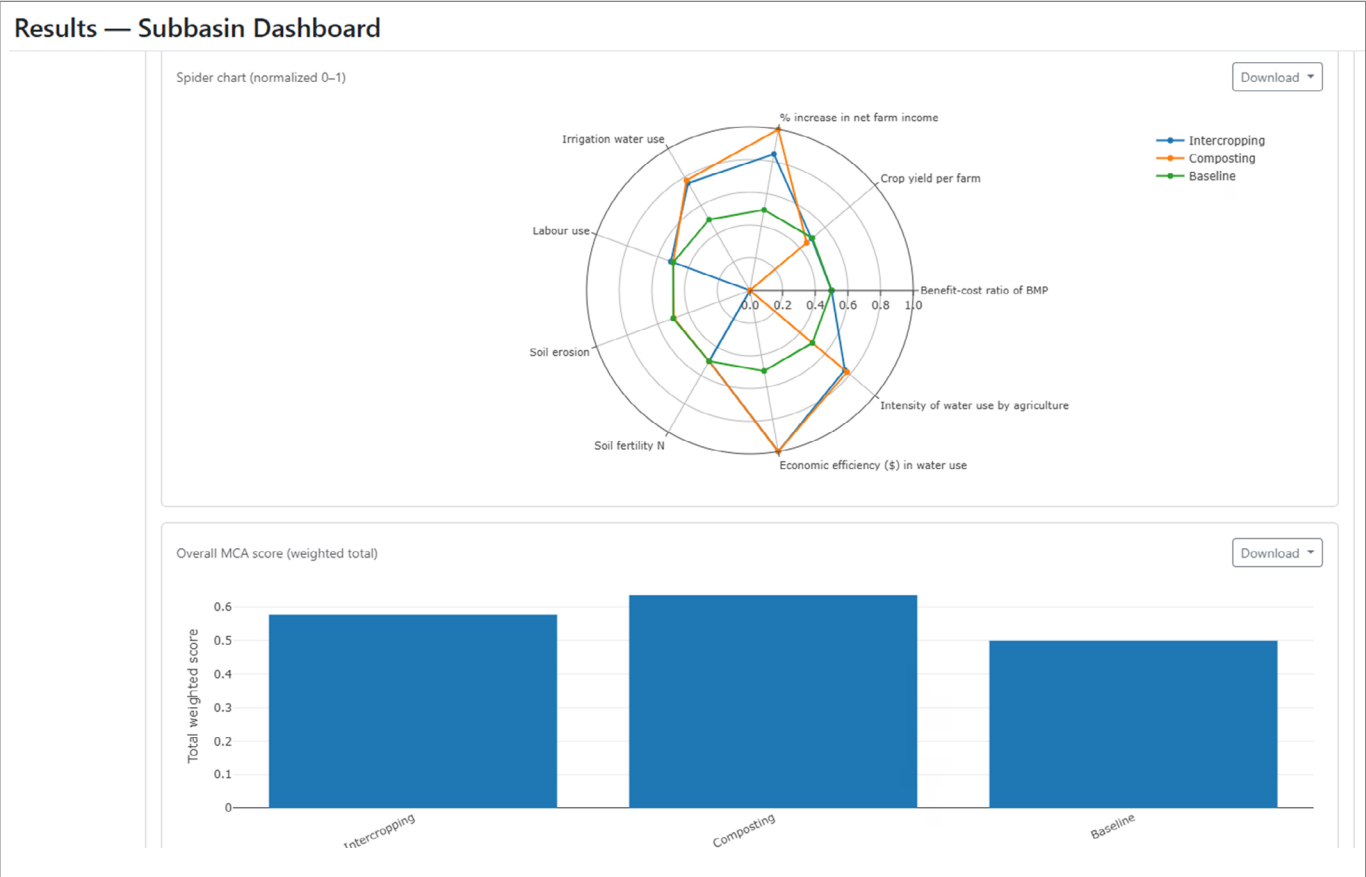
Crop yield per farm
crop_yield_t_ha

Higher betterLower better

25

Normalized on compute

Figure 18: Results of the objective 'Food security'



Sudanese example

Lack of water is not really the problem in the Gezira irrigation scheme in Sudan. There is enough annual streamflow reaching Sennar Dam to meet the needs of various crops, but the distribution of water from the dam to the fields has become increasingly delayed due to maintenance issues. As a result, yields have decreased, and farmers’ income levels have fallen.

The original scenarios include, in addition to the baseline, early planting and irrigation through diversion gate maintenance (Scenario A) and, in addition, increased irrigation due to canal maintenance (Scenario B). An additional scenario was made by adding compost to the soil, as organic matter improves the water retention capacity of the soil. A new fertilizer was added which is Food Waste Compost. Amount was 10,000kg/ha for all crops in scenario B.

In MCA higher investment and operational costs were added to scenarios A and (especially) B, accounting for repairs and increased maintenance requirements.

Scenario B gave higher total MCA scores than Baseline. The Best scores were in the scenario ‘Composting’.

Farmer net income increased (due to better yield) in both Scenario A and Scenario B compared to the baseline (Figure 19 MCA visualisation with default options visualisation with default options). The impacts on soil erosion and nitrogen use efficiency depend on the crop ([Table 2: Results of the original scenarios](#)). Higher labour costs (double to defaults cost) with higher weight did not change the situation that Scenario B gave the highest net income to the farmers [Figure 12: MCA visualisation with higher costs](#) ([Figure 20: MCA visualisation with higher labour costs](#)).

Table 2: Results of the original scenarios

Objectives	Baseline	BMP A	BMP B
Yield	3rd	2nd	1st
Irrigation water use	2nd	1st	1st
Soil erosion	Cotton: 1st Sorghum: 2nd	Cotton: 1st Sorghum: 2nd	Cotton: 2nd Sorghum: 1st
N use efficiency	Cotton: 2nd Sorghum: 2nd	Cotton: 2nd Sorghum: 1st	Cotton: 1st Sorghum: 3rd

Figure 19: MCA visualisation with default options

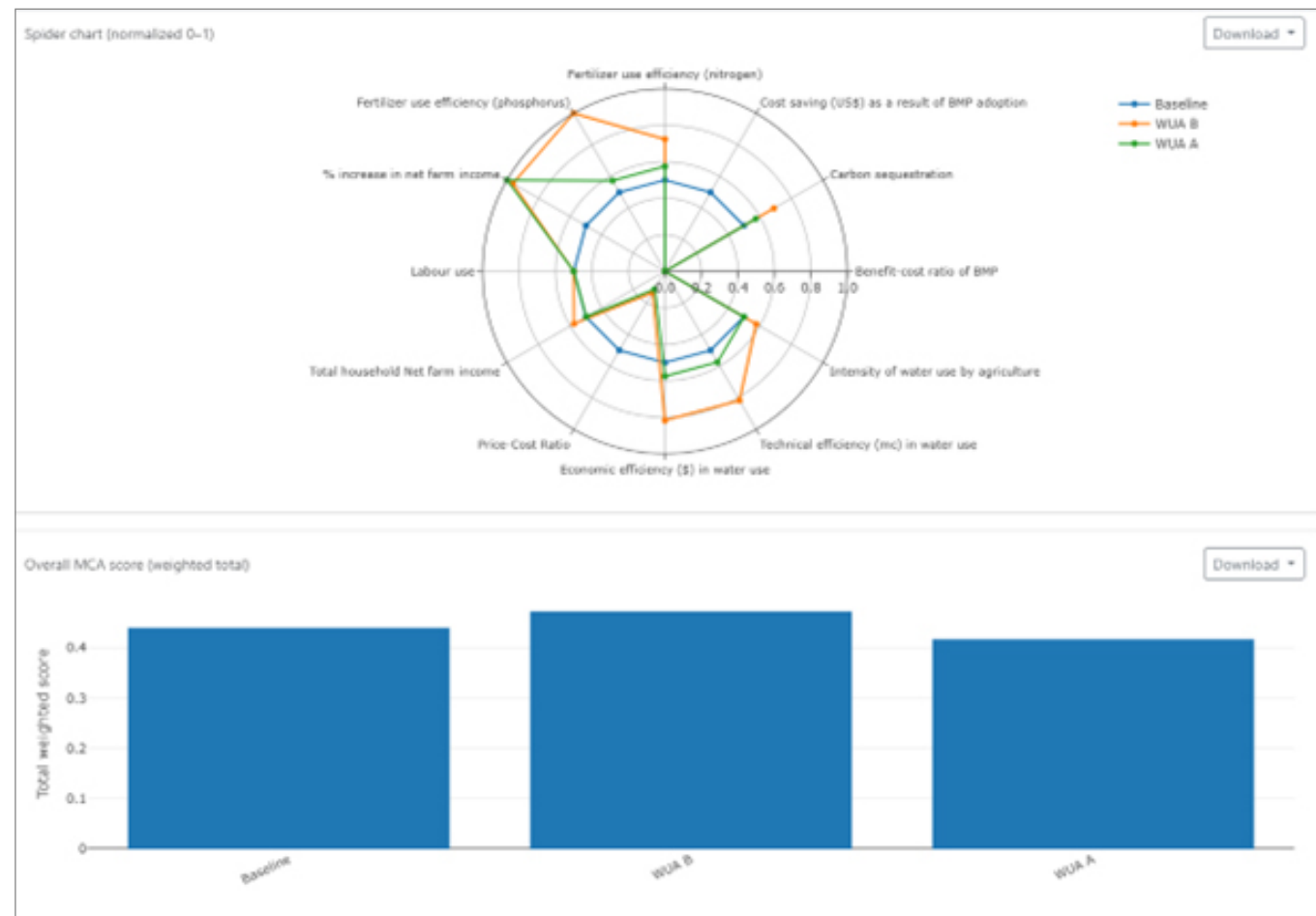
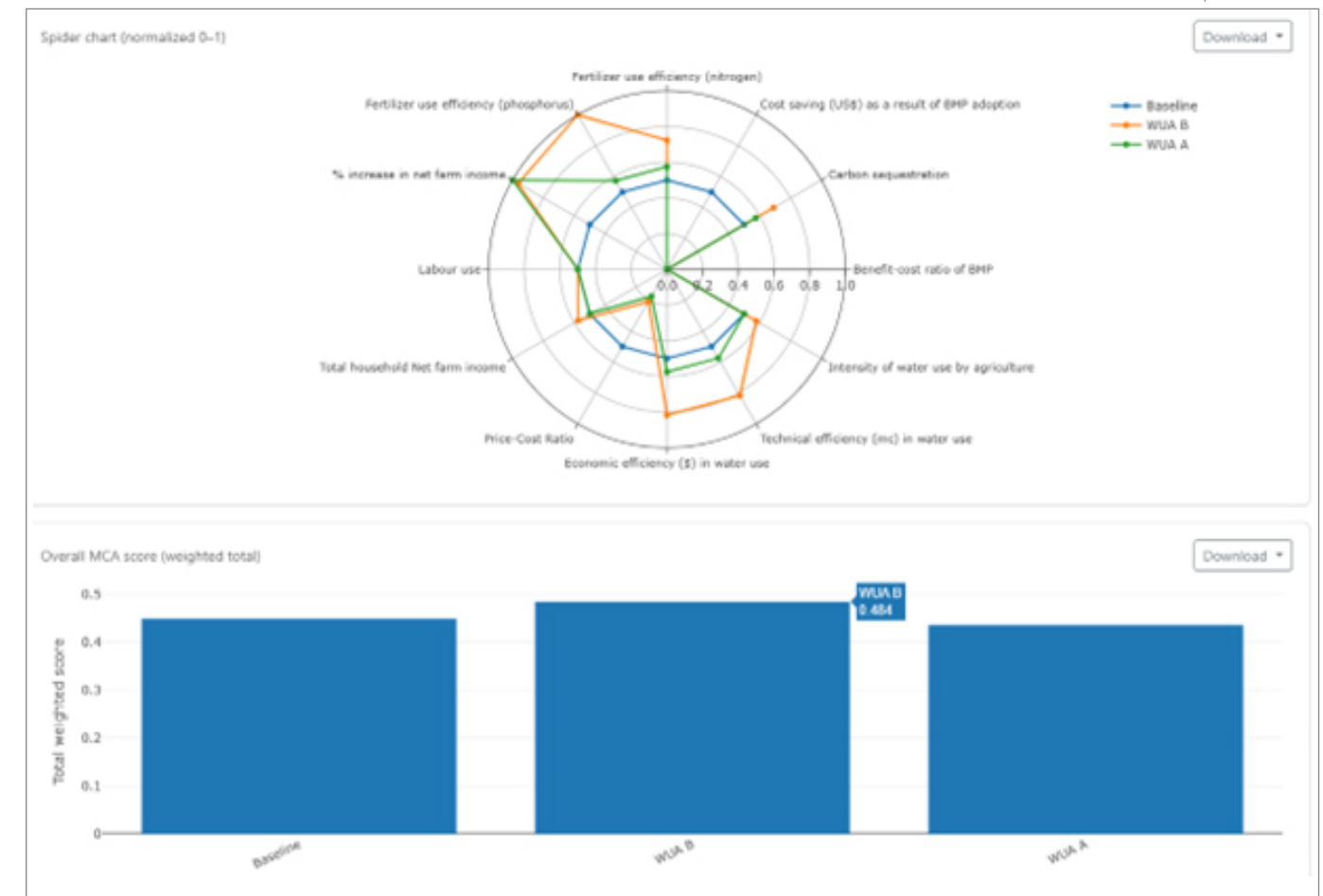


Figure 20: MCA visualisation with higher labour costs





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