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Multi-criteria decision analysis for suitability mapping with the INOWAS platform

Tutorial 4: MAR suitability analysis with three criteria



MAR Junior Research Group

The INOWAS Platform

The INOWAS platform is a free web-based platform to provide a collection of simple, practical and reliable tools to solve groundwater related issues.

This tutorial uses the Tool 5 - “**GIS Multi criteria decision analysis**” to create suitability maps for MAR location analysis.

The benefits of creating suitability maps on the platform:

- ✓ **1. User-friendly** (easy to access, free)
- ✓ **2. Shareable maps** (shared via platform or download)
- ✓ **3. Intuitive results visualization**

Introduction

This tutorial provides an overview of the “**GIS Multi criteria decision analysis**” tool on the INOWAS platform and guides users to create a simple **suitability map** with three criteria through the platform.

More information about the tool can be found on the respective documentation page:

<https://inowas.com/tools/t05-gis-mcda/>

The tutorial takes about 30 min for completion.

Before you start, please register your user account here:

<https://inowas.com/>

Example background

The tutorial uses multi-criteria decision analysis (MCDA) to create a suitability map from three criteria (=GIS maps). The following maps will be used and are provided through a download [here](#):

1. Slope
2. Geology
3. Land cover

All maps are provided as simplified 10x10 raster files (tiff-file). The user is guided through MCDA steps, namely:

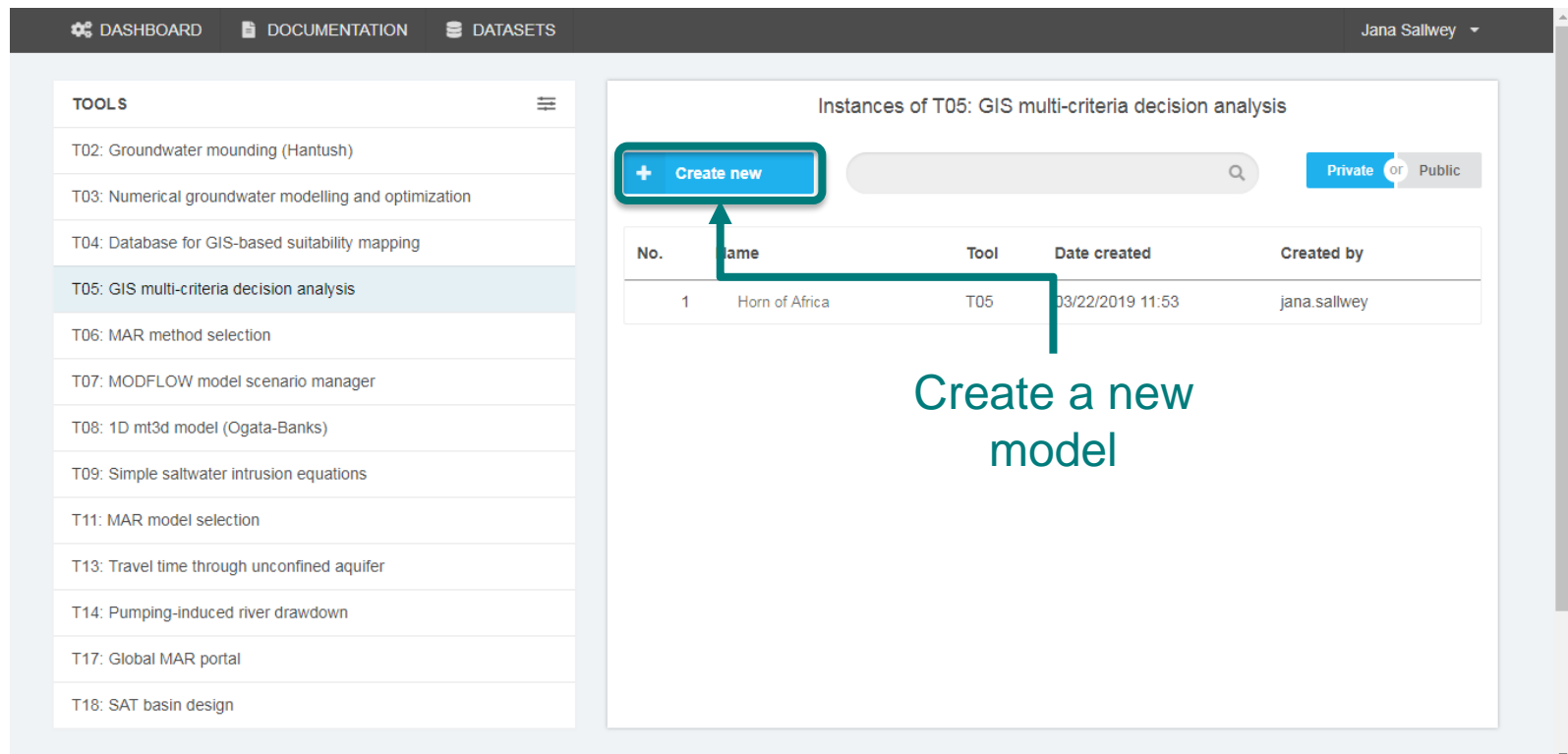
- Criteria definition
- Weight assignment
- Criteria standardization and reclassification
- Constraint mapping
- Decision Rules

Create a new model on the platform

Step 1. Log in to the web-based INOWAS platform

Step 2. Navigate to the dashboard and select “T05. GIS multi-criteria decision analysis”

Step 3. Create a new model by clicking on the “Create new” button



The screenshot shows the INOWAS platform dashboard. The top navigation bar includes 'DASHBOARD', 'DOCUMENTATION', and 'DATASETS'. The user 'Jana Sallwey' is logged in. The left sidebar lists various tools, with 'T05: GIS multi-criteria decision analysis' selected. The main content area displays 'Instances of T05: GIS multi-criteria decision analysis'. A blue '+ Create new' button is highlighted with a red box and a red arrow pointing to it. Below the button is a table with the following data:

No.	Name	Tool	Date created	Created by
1	Horn of Africa	T05	03/22/2019 11:53	jana.sallwey

A red text annotation 'Create a new model' is positioned below the table, with a red line pointing to the 'Create new' button.

Define criteria

1. Change name and status

6. Save all changes

Name Public

Saron|

Description

Example for testing

Save

Save

Saron

Choose your criteria

For managed aquifer recharge (MAR) MCDA you can find information of former scientific works and recommendations for criteria in our database: T04 Do not forget to specify, if a criteria is described by continuous or discrete values.

Analytical Hierarchy Process (Saaty, 1980): Choose this method, to separate your criteria in main and sub criteria. It is recommended, to use it for large numbers of criteria. You should decide to use this method before adding criteria.

Analytical Hierarchy Process

5. Define units

	Name	Type	Unit	
1	Slope	Continuous	%	
2	Geology	Discrete		
3	Land Cover	Discrete		

Add new criterion

3. Name criteria

4. Define type

2. Click to add criterion

Tools > T05. GIS multi-criteria decision analysis

Criteria



Weight Assignment

Criteria Data

Global Constraints



Suitability



Assign weights to criteria

1. Click weight assignment to proceed to next step

The screenshot shows a software interface for assigning weights to criteria. On the left, a sidebar menu contains the following items: 'Criteria' (with a green checkmark), 'Weight Assignment' (highlighted with a red box and an arrow pointing to it), 'Criteria Data', 'Global Constraints' (with a yellow warning icon), and 'Suitability' (with a yellow warning icon). The main content area on the right has a 'Save' button in the top right corner. Below the 'Save' button, there is a grey box with a left-pointing arrow and the text: 'Adding new weight assignment methods. You can do more than one weight assignment and compare your results and choose which you want to use for the mcda in the end. Click on the appropriate icon on the left, to add a new weight assignment.' Below this text, there are four weight assignment methods listed vertically: 'Free Input' (with a pencil icon and a red box around it), 'Ranking' (with a list icon), 'Multi-Influence' (with a network icon), and 'Pairwise Comparison' (with a double-headed arrow icon).

Four different weight assignment methods are available, the user can choose one or various methods for comparison. For this tutorial we will test all methods.

2. Start Free input by clicking it.

Weight assignment – Free input

4. Go back to menu

3. Save changes

2. Name weight assignment scenario

1. Assign weights to criteria by giving the highest number to the most important criterion (range of weights is defined by user)

Standardized weights are calculated automatically

Criteria

Weight Assignment

Criteria Data

Global Constraints

Suitability

Editor

Slope 3

Geology 5

Land Cover 2

Settings

Name

Scenario 1

Resulting Weights

Criteria	Sum Weight [%]
Slope	30.00
Geology	50.00
Land Cover	20.00

Back

Save

Assign weights to criteria

The screenshot shows a software interface for assigning weights to criteria. On the left, a sidebar contains a list of options: 'Criteria' (with a lock icon), 'Weight Assignment' (with a checkmark icon), 'Criteria Data', 'Global Constraints' (with a warning icon), and 'Suitability' (with a warning icon). The 'Weight Assignment' option is selected. The main area displays four methods: 'Free Input' (with a pencil icon), 'Ranking' (with a list icon and highlighted by a red box and an arrow), 'Multi-Influence' (with a network icon), and 'Pairwise Comparison' (with a double-headed arrow icon). On the right, there is a 'Name' field containing 'Scenario 1' and a trash icon.

Choose ranking method by clicking it.

Weight assignment – Ranking

3. Save changes

4. Go back to menu

2. Choose name and ranking method

The screenshot displays the 'Weight Assignment' interface. On the left is a sidebar menu with 'Criteria' (locked), 'Weight Assignment' (checked), 'Criteria Data', 'Global Constraints' (warning), and 'Suitability' (warning). The main area is split into two panels: 'Most Important' and 'Least Important'. The 'Most Important' panel lists three criteria: 1. Geology, 2. Slope, and 3. Land Cover. Each criterion has up and down arrows for reordering. The 'Least Important' panel is currently empty. To the right is the 'Settings' panel, which includes a 'Name' field set to 'Ranking' and a 'Method' dropdown set to 'Rank sum weight'. Below the settings is a 'Resulting Weights' table. A 'Back' button is located at the top left of the main area, and a 'Save' button is at the top right. Red boxes and arrows highlight the 'Back' button, the ranking arrows, the 'Name' and 'Method' fields, and the 'Save' button.

Criteria	Sum Weight [%]
Geology	50.00
Slope	33.33
Land Cover	16.67

1. Rank criteria by clicking the up and down arrows

Standardized weights are calculated automatically

Assign weights to criteria

The screenshot shows a software interface for assigning weights to criteria. On the left, a sidebar contains a list of options: 'Criteria' (with a lock icon), 'Weight Assignment' (with a checkmark icon), 'Criteria Data', 'Global Constraints' (with an information icon), and 'Suitability' (with an information icon). The main area displays four methods: 'Free Input' (with a pencil icon), 'Ranking' (with a list icon), 'Multi-Influence' (with a network icon, highlighted by a red rounded rectangle and a red arrow pointing from the sidebar), and 'Pairwise Comparison' (with a comparison icon). On the right, there is a table with a 'Name' header and two rows: 'Scenario 1' and 'Ranking', each with a delete icon.

Name	
Scenario 1	
Ranking	

Choose multi-influence method by clicking it.

Weight assignment – Multi influence

3. Save changes

4. Go back to menu

The screenshot shows a software interface for weight assignment. On the left is a sidebar menu with items: Criteria (locked), Weight Assignment (checked), Criteria Data, Global Constraints (warning), and Suitability (warning). The main area is divided into 'Influence Chart' and 'Settings'. The 'Influence Chart' contains a diagram with nodes: Geology, Slope, Saron, and Land cover. Arrows indicate relationships: Geology to Slope, Geology to Saron, Slope to Saron, and Saron to Land cover. A dashed arrow points from Geology to Land cover. The 'Settings' panel has a 'Name' field containing 'Multi-Influence Factor'. Below it is a 'Resulting Weights' table:

Criteria	Sum Weight [%]
Slope	36.36
Geology	45.45
Land cover	18.18

Annotations with arrows point to: 'Back' button, 'Save' button, the 'Name' field, the 'Influence Chart' diagram, and the 'Sum Weight [%]' table. A text box at the bottom right states: 'Standardized weights are calculated automatically'.

1. Use graphical display to assign weights (explained on next slide)

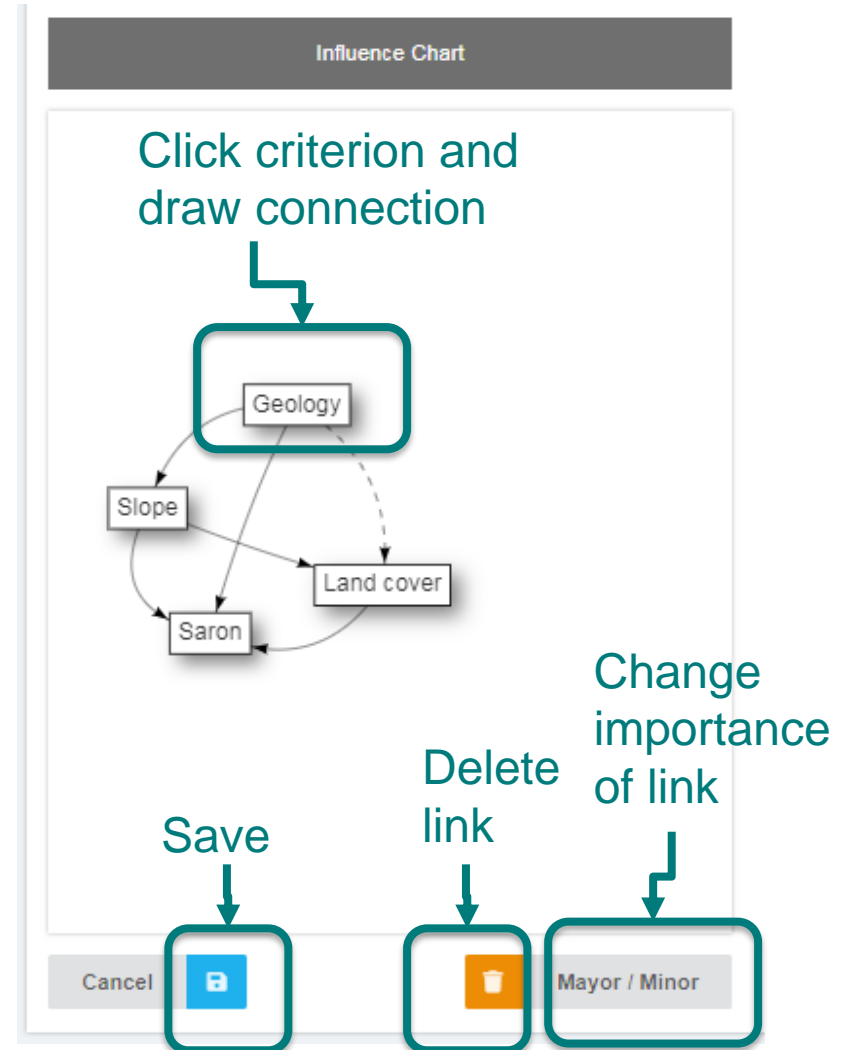
2. Choose name

Standardized weights are calculated automatically

Weight assignment – Multi influence

Steps for multi influence method:

1. Click: Start editing
2. Click on a criterion and then draw a connection to another criterion or the project itself to indicate that they influence each other (arrow appears)
3. Click on an arrow and then the major/minor button to change importance of link for geology/land cover link. Minor links are indicated by dashed lines.
4. Save changes



Assign weights to criteria

Criteria

Weight Assignment

Criteria Data

Global Constraints

Suitability

Free Input

Ranking

Multi-Influence

Pairwise Comparison

Name

Scenario 1	
Ranking	
Multi-Influence Factor	

Save

Choose pairwise comparison by clicking it.

Weight assignment – Pairwise comparison

4. Go back to menu

3. Save changes

2. Name scenario

Criteria

Weight Assignment

Criteria Data

Global Constraints

Suitability

Comparison

Slope

Slope

Geology

Geology

Land Cover

Land Cover

Settings

Name

Pairwise Comparison

Resulting Weights

Criteria	Sum Weight [%]
Slope	27.21
Geology	60.80
Land Cover	11.99

Consistency Ratio

CR = 0.064 < 0.100

Your comparisons are reasonably consistent.

1. Mark importance by moving the slider towards the more important criterion of the pair.
Used comparison values
Slope – Geology 3
Slope – Land cover -3
Geology – Land cover -4

Consistency ratio: shows robustness of comparison, should be below 0.1

Standardized weights

Criteria upload

1. Click on criteria data to start uploading data

Criteria

Weight Assignment

Criteria Data

Global Constraints

Suitability

GRID SIZE

Columns	Rows
10	10

CRITERIA

Search criterion...

Slope

Geology

Land cover

Select a criterion from the navigation on the bottom left. Don't forget to set gridSize first.

Save

2. Define grid size for the project (10x10)

3. Choose criterion

Criteria upload

1. Click to start data upload

The screenshot shows the 'Criteria upload' interface. On the left, there is a sidebar with a 'Criteria' menu and a 'GRID SIZE' section with 'Columns' and 'Rows' both set to 10. Below that is a 'CRITERIA' section with a search bar and a list of criteria: Slope, Geology, and Land cover. The main area has a top navigation bar with 'Upload', 'Constraints', 'Reclassification', and 'Results' buttons. The 'Upload' button is highlighted with a red box and an arrow pointing to it. Below the navigation bar, there is an 'Upload raster' section with instructions and a 'File size: smaller than 100 MB | File type: geoTiff | Projection: EPSG:4326 - WGS 84' note. Below this is an 'Upload' button and an 'Upload Raster File' button, which is also highlighted with a red box and an arrow pointing to it. At the bottom, there is a 'Bounding Box' section with a table of coordinates.

Bounding Box		
0.000	0.000	0.000
0.000	0.000	0.000

2. Open upload window

Criteria upload

1. Choose file for data upload (slope.tif)

Upload Rasterfile

Important

- The rasterfile should have the same bounds as the model area.
- The grid size will be interpolated automatically, if an interpolation method is selected.

Interpolation method

Nearest-neighbor (default)

Keine ausgewählt

Metadata

7166dff2-e2a8-41ac-84b7-bc2a66d38cf8.tif

GTiff

X: 19.011, Y: -33.151

0.00970000000000013


-0.00979999999999997

GEOGCS["WGS 84",DATUM["WGS_1984",SPHEROID["WGS 84",6378137,298.257223563,AUTHORITY["EPSG","7030"]],AUTHORITY["EPSG",

X: 10, Y: 10, Z: 1

Data

Band 0



3.1e-1 - 1.6444999999999997e+1 - 3.258e+1 -

2. Upload

Criteria reclassification slope

1. Click to reclassify slope data

5. Save changes

2. Add three classes

4. Press to calculate reclassification

3. Edit class data (see next slide)

The screenshot shows a software interface for reclassifying slope data. The interface is divided into several sections:

- Criteria:** A sidebar on the left with a lock icon and a list of criteria: 'Criteria Data', 'Global Constraints', and 'Suitability'. Below this is the 'GRID SIZE' section with 'Columns' and 'Rows' both set to 10.
- Criteria List:** A list of criteria with status indicators: 'Slope' (checked), 'Geology' (checked), and 'Land Cover'.
- Toolbar:** A horizontal toolbar with icons for 'Upload', 'Constraints', 'Reclassification' (highlighted with a red box), and 'Results'. A 'Save' button is located in the top right corner.
- Commands:** A section with two buttons: 'Add Class' (highlighted with a red box) and 'Perform reclassification' (highlighted with a red box).
- Table:** A table with columns 'Name', 'From', 'To', and 'Class'. It contains three rows of data:

Name	From	To	Class
High slope	≥ 30	≤ 50	0
Medium slope	> 5	< 30	$1.2 - 0.04 \cdot x$
Low slope	≥ 0	≤ 5	1
- Graph:** A line graph showing the reclassification function. The x-axis represents slope values from 0 to 33, and the y-axis represents the class value from 0 to 1. The graph shows a piecewise linear function: it is 1 for $x \leq 5$, then decreases linearly from $(5, 1)$ to $(30, 0)$, and is 0 for $x \geq 30$.

Criteria reclassification slope




1. Chose name and display color

2. Choose minimum and maximum values of class

3. Choose suitability index or calculation formula and add respective class value

4. Save

Values used for three classes:

Name	From	To	Class
 High slope	≥ 30	≤ 50	0
 Medium slope	> 5	< 30	$1.2-0.04*x$
 Low slope	≥ 0	≤ 5	1

For medium slope use Rule type “calculation formula” instead of “fixed suitability index” and type in $1.2-0.04*x$ which represents a linear connection between the highest and lowest suitability index

Criteria reclassification geology



Upload geology data (geology.tiff) and reclassify according to data below. Don't forget to save!

Reclassification for discrete values

A suitability value between 0 and 1 can be set for each unique value of the uploaded raster. It is also possible to choose a color and name for each value for a better visualization of the criteria data in the next step. It is necessary to click on the 'Perform Reclassification' button after making changes.

Commands

Perform Reclassification

Value	Color	Name	Class
5		Consolidated Sedimentary	0,8
6		Basement	0,2

2. Reclassify

1. Fill in information

3. Save

Criteria reclassification land cover

Upload land cover data (landcover.tiff) and reclassify according to data below. Don't forget to save!

Reclassification for discrete values

A suitability value between 0 and 1 can be set for each unique value of the uploaded raster. It is also possible to choose a color and name for each value for a better visualization of the criteria data in the next step. It is necessary to click on the 'Perform Reclassification' button after making changes.

Value	Color	Name	Class
1	Green	Tree covered	0,25
2	Brown	Shrubs covered	0,5
3	Orange	Grassland	0,75
4	Yellow	Cropland	0,75
7	Light Green	Bare areas	1
8	Red	Built up areas	0

2. Reclassify

1. Fill in information

Criteria reclassification results

Press to view reclassification results

Save

Upload Constraints Reclassification Results

Layer

Suitability
 Criteria Data
 Constraints

Color Scheme

Default
 Reclassified

Base map

Turn on base map

Commands

Download Suitability Raster

+
-

Reclassified slope map

Low slope
Medium slope
High slope
Not Classified

Leaflet

Global constraints

1. Click to add global constraint

2. Click to draw polygon on map

3. Draw polygon connecting first and last point. Area is located in the lower right corner of raster.

4. Click to cut area from final map

5. Save

Suitability calculation

1. Click to start suitability calculation

The screenshot shows a software interface for suitability calculation. On the left, a sidebar contains a list of menu items: Criteria (locked), Weight Assignment (checked), Criteria Data (checked), Global Constraints (checked), and Suitability (checked and highlighted with a red box). Below the sidebar is an 'Overview' section with a zoomable heatmap and a legend ranging from 0.00 (red) to 1.00 (green). The main panel has a 'Save' button in the top right and three tabs: 'Calculation' (active), 'Classes', and 'Results'. Under the 'Calculation' tab, there is a 'Method' selection area with four radio buttons: Ranking, Multi-Influence Factor, Pairwise Comparison, and Scenario 1 (selected). Below the methods is a 'Start Calculation' button. A table displays the results for three classes: Slope, Geology, and Land Cover. The table data is as follows:

Method	Slope	Geology	Land Cover
<input type="radio"/> Ranking	0.333	0.500	0.167
<input type="radio"/> Multi-Influence Factor	0.364	0.455	0.182
<input type="radio"/> Pairwise Comparison	0.272	0.608	0.120
<input checked="" type="radio"/> Scenario 1	0.300	0.500	0.200

Annotations include: a red box around the 'Suitability' menu item; a red box around the 'Method' selection area; a red box around the 'Start Calculation' button; and three numbered text boxes with arrows pointing to the 'Suitability' menu item, the 'Scenario 1' radio button, and the 'Start Calculation' button respectively.

Suitability results

2. Save

Criteria

Weight Assignment

Criteria Data

Global Constraints

Suitability

Back

Calculation

Classes

Results

Layer

Suitability

Color Scheme

Reclassified

Default heat map

Barrier-free colors

Base map

Turn off base map

Commands

Download Raster

Saron

R44

R44

1.00

0.75

0.50

0.25

0.00

Leaflet | © OpenStreetMap contributors

2. Save

1. Click to view results

Contact

Thank you for going through this tutorial. If you have any comments or questions, please contact us!



Further Tutorials about the INOWAS platform:

Tutorial 1 - Setup of steady-state groundwater flow model

Tutorial 2 - transient groundwater flow modeling and scenario analysis

Tutorial 3 - set up of solute transport model