Deliverable 3.05: Decision support system developed in a GIS Environment (Template - PU)

v. 19.05.2023

Decision support system developed in a GIS Environment

A land-suitability assessment model aimed to support decision making for the implementation of SIMTAP systems in the Mediterranean area

Content and scope

The SIMTAP project is aimed at developing and testing an innovative integrated multi-trophic aquaponic system for environmentally friendly marine fish and halophytic plants production adapted to the typical socio-economic and climatic condition of Mediterranean areas.

A task of the SIMTAP project has focused on the definition and development of a multi-criteria spatial analysis model powered by geospatial technologies, aimed to assess the various levels of land suitability of regions of interest to host a SIMTAP.

The model considers environmental conditions, availability of resources and infrastructure, potential access to market and labour, and potential interferences with other land-uses and activities, with the aim to facilitate the diffusion of SIMTAP systems, while enhancing their environmental and landscape integration.

This document presents a template showing the structure and functioning of the model, together with examples of the implementation of the DSS on case studies in countries involved in the SIMTAP project, where the model has been tested to allow the applicability of the model in various regions in the Mediterranean area, where the most suitable areas to host a SIMTAP have to be identified.

Approach

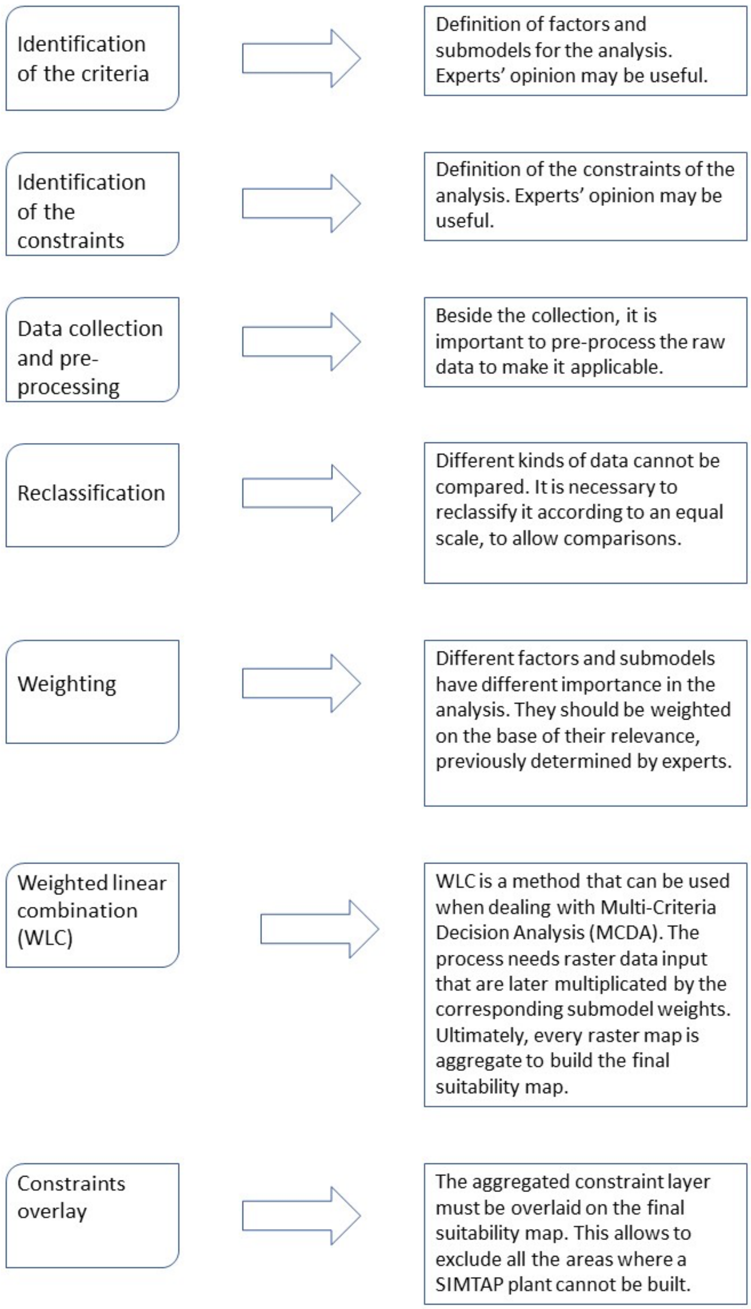
The model is implemented using a MCDA (Multi-Criteria Decision Analysis) approach. MCDA is a decision-making analysis that can be used to solve problems that are characterised by a consistent number of choices among alternatives. MCDA helps the decision makers to choose the best solution. Integrated GIS (Geographic Information System) and MCDA, or GIS-MCDA, is a prolific approach to solve many types of spatial problems because it converts and merges geographic data and the decision maker's preferences into a decision map that can later be used by planners (Tassinari, P., & Torreggiani, D., 2006).

The MCDA technique used in this model is the Weighted Linear Combination (WLC). In this method, every criterion of the analysis is called factor, and its subdivisions are called submodels. Each factor and submodel are assigned a weight on the basis of their importance. The results of the WLC are then overlayed with constraint maps to exclude unavailable sites.

Identification of criteria and constraints, reclassification and weighting of criteria have been estimated based on the inputs of a panel of experts, through focus groups, panel discussions, and questionnaires (Malczewski and Rinner, 2015).

Template

This scheme presents the steps and workflow to be followed to implement the decision support system for the land suitability assessment aimed to assess the various levels of land suitability to host a SIMTAP in regions of interest located in Mediterranean areas.



Implementation of the DSS on case studies

In this section, examples of the implementation of the decision support system model in study areas of countries involved in the SIMTAP project are presented.

Case study "Emilia-Romagna region", Italy

1) Identification of the criteria

Proximity to different types of water sources has been analysed, as well as topography and temperature, to allow good crop and fish growth, and reduce energy inputs for climate control. Proximity to infrastructure and facilities for the system functioning has been analysed, also in a circular economy perspective, considering water, nutrients and thermal cascades from greenhouses and industrial activities. Potential access to large distribution and consumers has been considered, as well as potential contribution to occupation. Finally, current land-use has been analysed to reduce conversion issues and minimize interferences.

In particular, the factors and the submodels used in this analysis are as follows:

Water availability	**Atmospheric conditions**	**Topography**	**Infrastructure and facilities**	**Access to market**	**Land use**
Distance from the nearest water source (sea, freshwater, brackish water)	Average annual temperature	Elevation	Distance from the Electricity network	Distance from settlements and urban areas	Current land use type
		Slope	Distance from the Gas network	Potential Consumers (proxy: density of inhabitants)	
			Distance from the Sewage network	Income	
			Distance from Fish hatcheries / fishfarms	Unemployment rate	
			Distance from the Road network	Distance from Logistic platforms (harbour, etc.)	
			Distance from Plant nurseries	Potential Organic products consumers (Proxy: age and education level)	
			Distance from Industrial activities		

Table 1 – List of criteria and their relative submodels

All data must be in raster format: if not, they must be previously pre-processed.

2) Identification of the constraints

Characteristics that may prevent the implementation of a SIMTAP, defined as constraints in the model, have been identified as follows:

- Archaeological areas
- Protected areas

- Natura 2000 sites
- Water availability (maximum distance from water sources): these thresholds have been considered based on experts' opinions: 1750 meters for freshwater, 3750 meters for the sea, 3500 meters for brackish underground water.
- Military zones
- Active mining areas

3) Data collection and pre-processing

Geodata have been collected from various websites and processed through ArcMap 10.8.2 and ArcGIS Pro. Most data had to be pre-processed before being used in the analysis.

The following table summarises the data sources and the main pre-processing operations used for the test on the Emilia-Romagna case study:

Submodels	**Source**	**Pre-processing operations**
Freshwater sources	Kindly provided by ARPA Emilia-Romagna	Reprojection, format conversion
Sea	Coastline shapefile	Reprojection, clipping
Brackish underground water sources	Water quality census of the Emilia-Romagna region	Format conversion, selection by attribute
Average annual temperature	Dext3r Emilia-Romagna	Reprojection, interpolation
Elevation	https://tinitaly.pi.ingv.it/	Reprojection
Slope	Own elaboration starting form DEM data	Computation starting from DEM
Electricity network	https://overpass-turbo.eu/	Reprojection, format conversion, clipping
Road network	Extraction from Emilia-Romagna land use map	Selection by attributes and format conversion
Sewage network	https://geoportale.regione.emilia-romagna.it/	Reprojection, format conversion
Fish hatcheries / fishfarms	https://overpass-turbo.eu/	Reprojection, format conversion, clipping
Gas network	https://overpass-turbo.eu/	Reprojection, format conversion, clipping
Plant nurseries	https://overpass-turbo.eu/	Reprojection, format conversion, clipping
Industrial activities	https://overpass-turbo.eu/	Reprojection, format conversion, clipping
Income	2011 Italian census (last available)	Format conversion

Proximity to settlements and urban areas	https://geoportale.regione.emilia-romagna.it/	Format conversion
Unemployment rate	2011 Italian census (last available)	Format conversion
Consumers (proxy: density of inhabitants)	2011 Italian census (last available)	Format conversion
Logistic platforms (harbour, etc.)	https://overpass-turbo.eu/	Reprojection, format conversion, clipping
Organic products consumers (percentage of people aged 25-40 and percentage of graduates)	2011 Italian census (last available)	Format conversion
Land use	CORINE landcover 2018 (last available)	Format conversion

Table 2 - Data sources and the main pre-processing operations

4) Reclassification

All factors and submodels have been reclassified, passing from the original variable values to comparable suitability scores, ranging from 1 (least suitable) to 8 (most suitable). Values corresponding to maximum and minimum suitability have been evaluated averaging experts' inputs and dividing the min-max interval into 8 parts.

In the following images some examples of reclassification are presented.

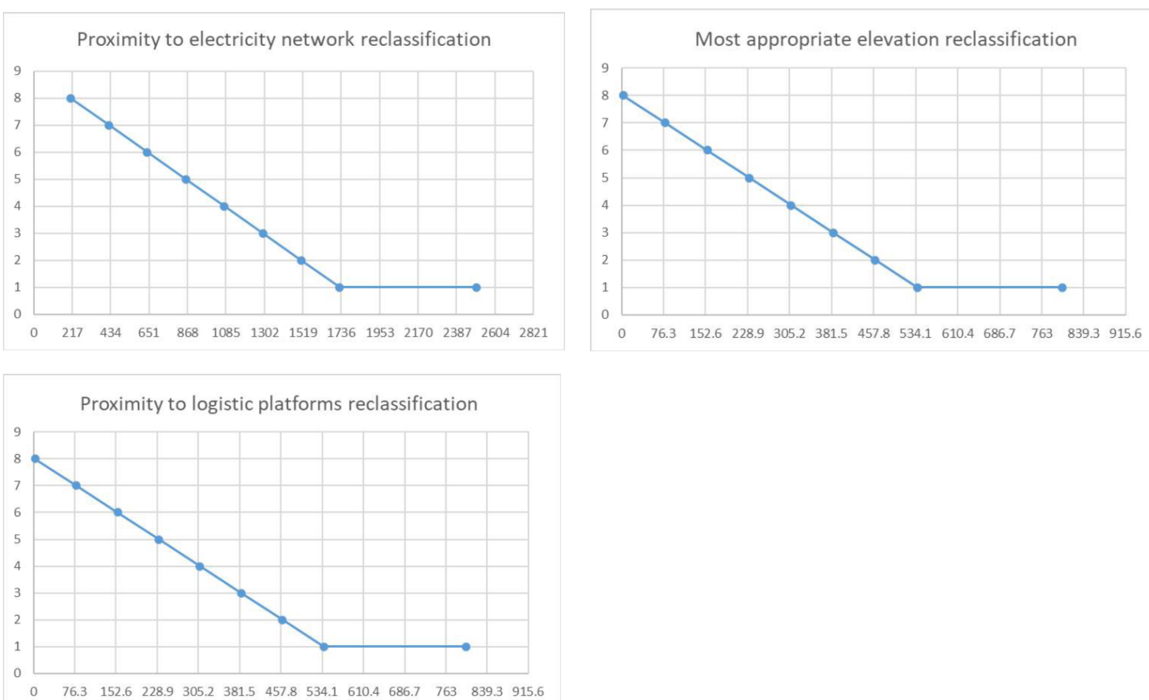


Figure 1 – Reclassification of some submodels (Proximity form electricity network, elevation, and proximity to logistic platforms)

The distance from water sources (sea, freshwater, brackish water) was reclassified and the suitability values were normalised using the best water sources type as the maximum and proportionally reducing the other ones. Lastly, every pixel was assigned the highest result of the three related to the different water sources.

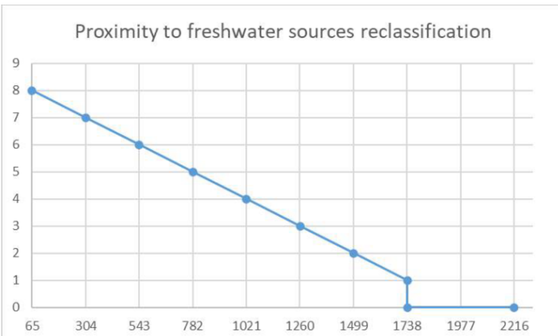


Figure 2 - Reclassification of proximity to freshwater sources

Land use types were reclassified according to experts' opinions, as it is shown in the following table:

Land use types	**Classes**
Road and rail networks and associated land	8
Salines	7
Industrial or commercial units	7
Non-irrigated arable land	7
Salt marshes	7
Port areas	7
Continuous urban fabric	7
Discontinuous urban fabric	6
Land principally occupied by agriculture with significant areas of natural vegetation	6
Dump sites	6
Annual crops associated with permanent crops	6
Rice fields	6
Construction sites	5
Complex cultivation patterns	5
Permanently irrigated land	5
Pastures	5

Table 3 – Reclassification of land uses

Reclassified maps of some of the most relevant submodels are shown in the next images.

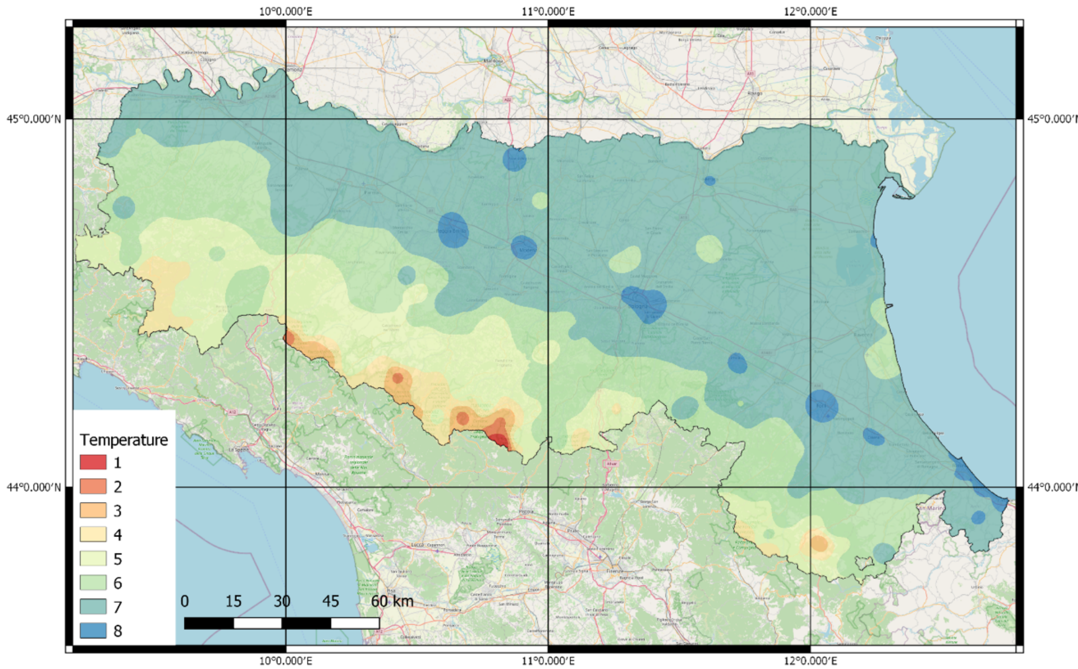


Figure 3 - Temperature reclassification

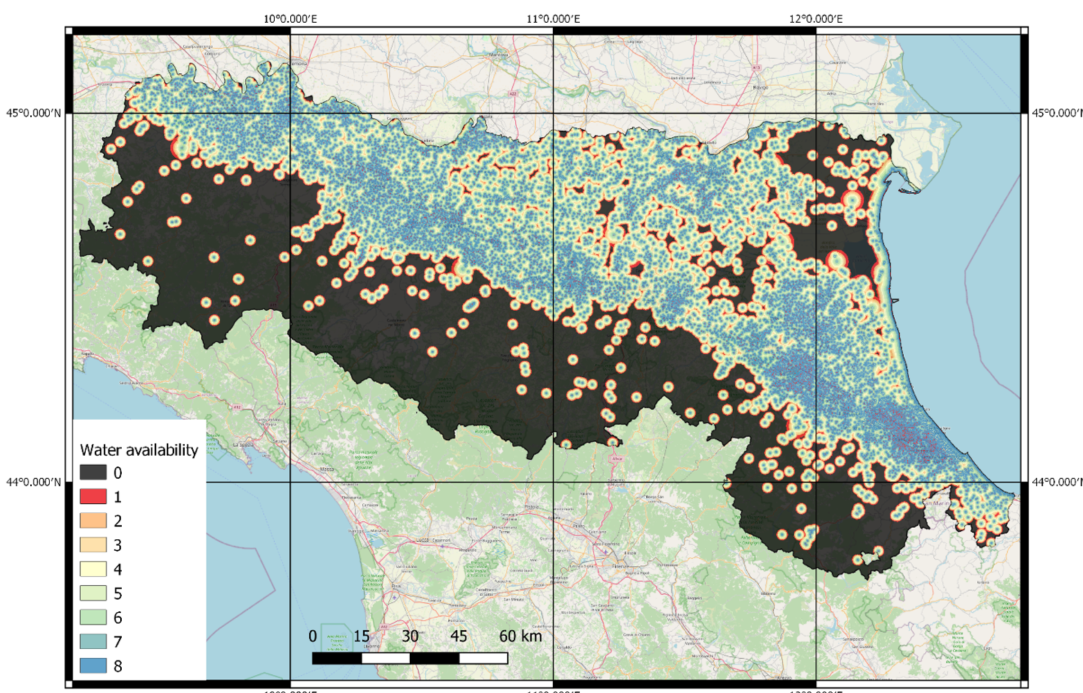


Figure 4 - Water availability reclassification

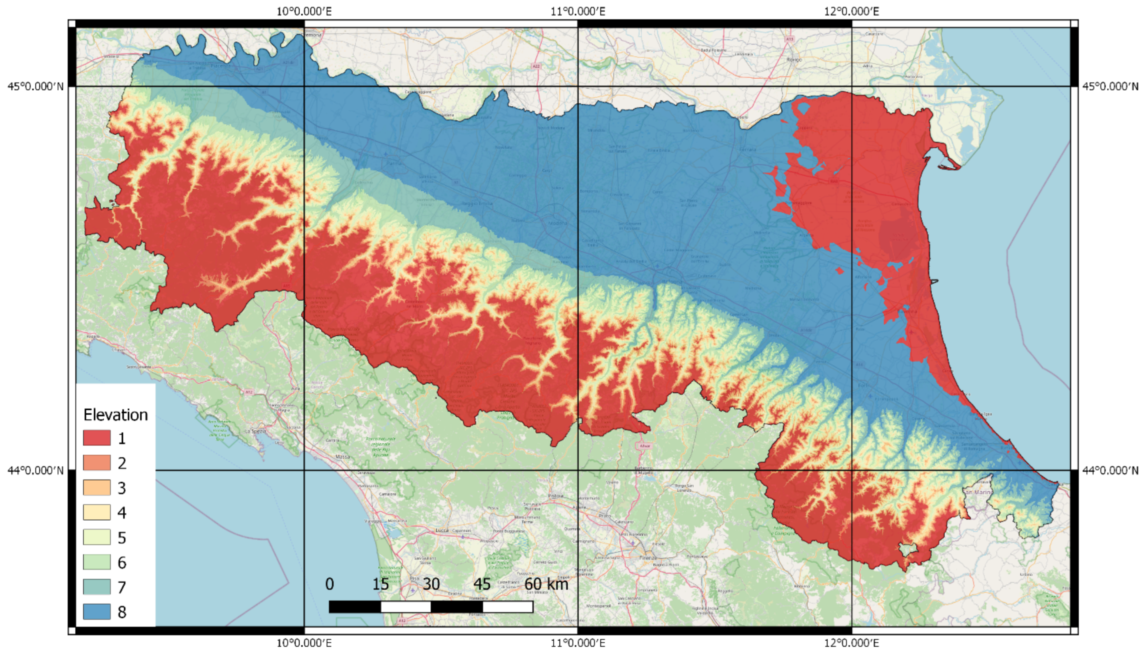


Figure 5 - Elevation reclassification

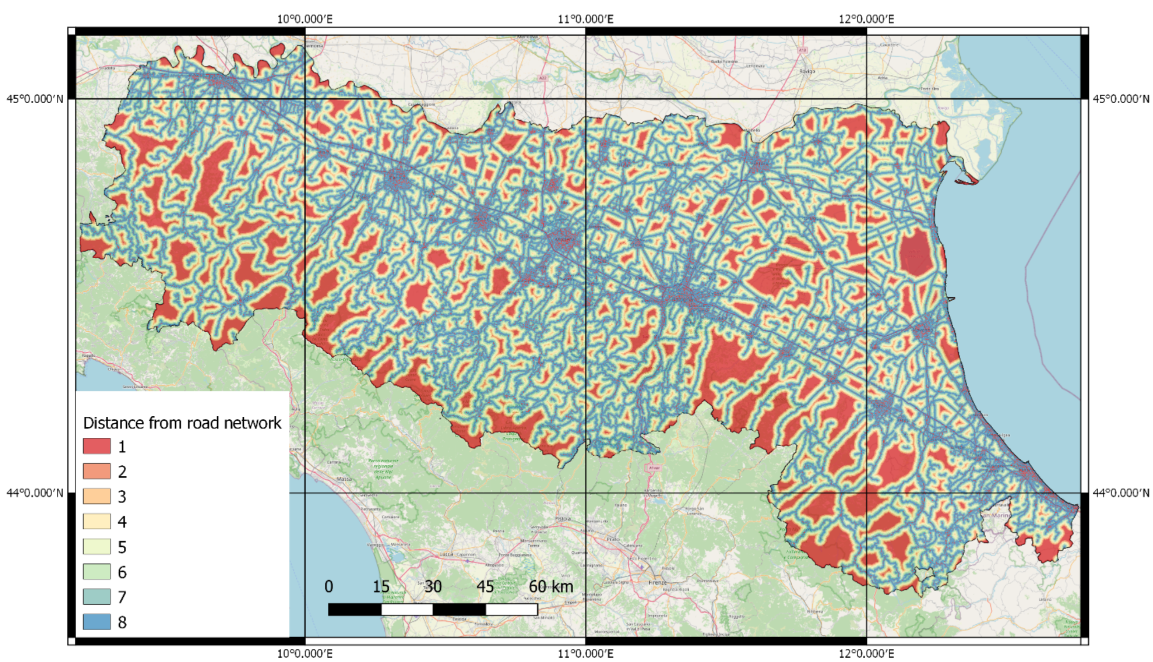


Figure 6 - Distance to road network reclassification

5) Weighting

Weights were defined by averaging the relative importance of the criteria as scored by experts through a Likert scale, used to rate every subcriterion on a scale from 1 (less important) to 7 (most important). Weights were then used during the final phase of the study (WLC phase) to give the correct importance to every submodel.

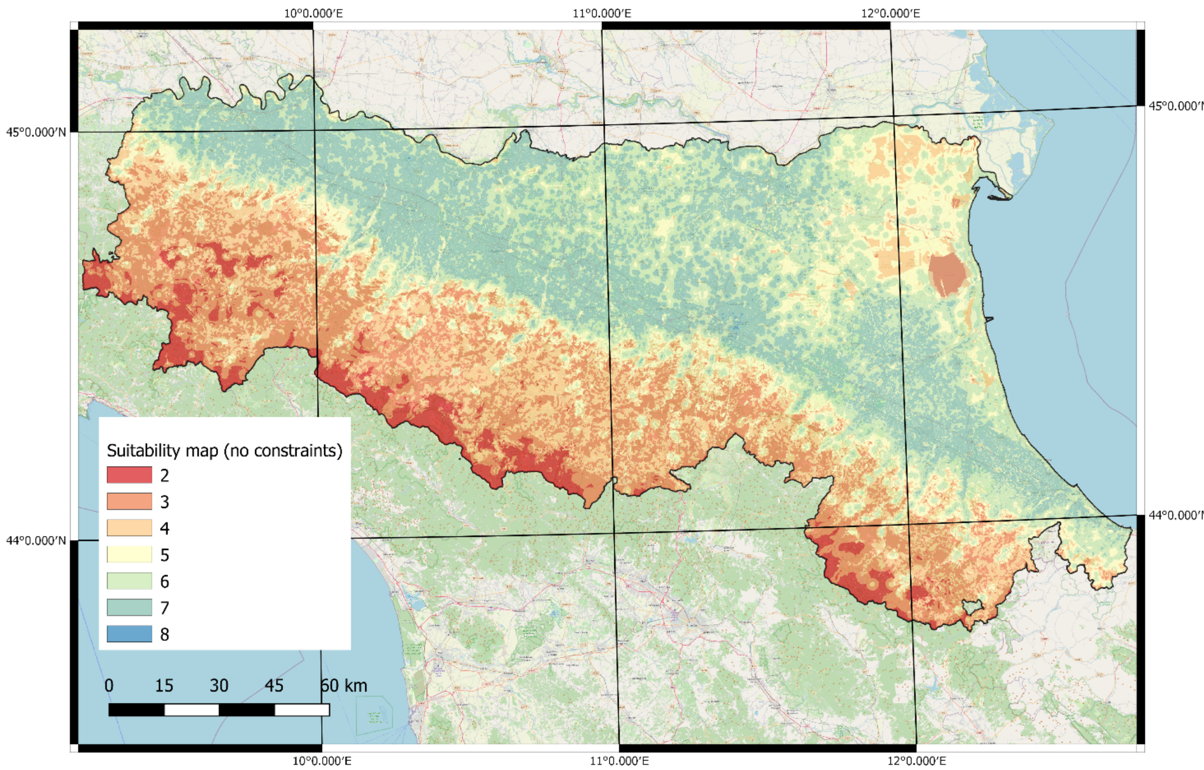
The following table shows the final weights for each criterion and submodel.

Water availability 20.82%	**Atmospheric conditions 14.67%**	**Geomorphological conditions 12.31%**	**Infrastructure and facilities 18.16%**	**Access to market 16.46%**	**Land use 17.58%**
Distance from the nearest water source (sea, freshwater, brackish water) 20.82%	Average temperature 14.67%	Elevation 6.58%	Distance from the Electricity network 3.29%	Distance from settlements and urban areas 2.97%	Current land use type 17.58%
		Slope 5.73%	Distance from the Gas network 2.40%	Potential Consumers (proxy: density of inhabitants) 2.79%	
			Distance from the Sewage network 2.70%	Income 3.42%	
			Distance from Fish hatcheries / fishfarms 2.54%	Unemployment rate 2.33%	
			Distance from the Road network 3.29%	Distance from Logistic platforms (harbour, etc.) 2.77%	
			Distance from Plant nurseries 2.24%	Potential organic products consumers (proxy: age and education level) 2.18%	
			Distance from Industrial activities 1.70%		

Table 4 – Weights of each criterion and submodel

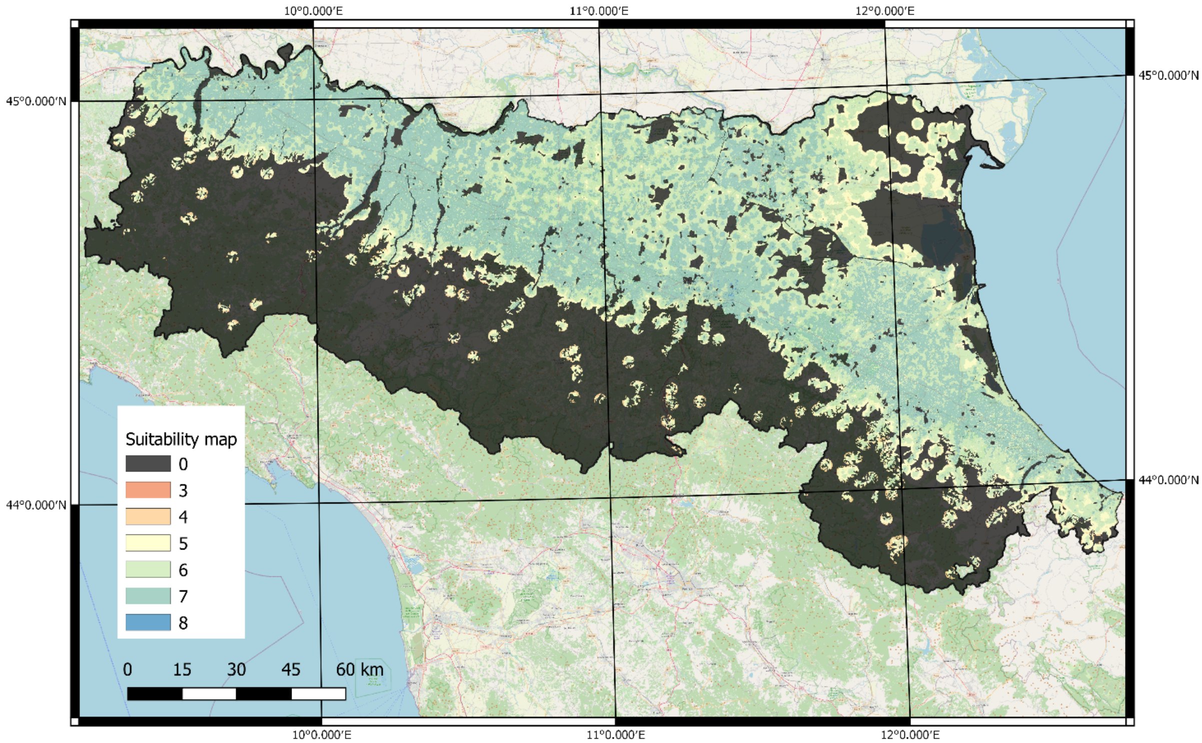
6) Weighted linear combination (WLC)

WLC is the process through which the final MCDA map is produced, aggregating all the information together and pairing with the correct weights. The result of this procedure is the final suitability map (without constraints, see next section) shown in the next image:



7) Constraints overlay

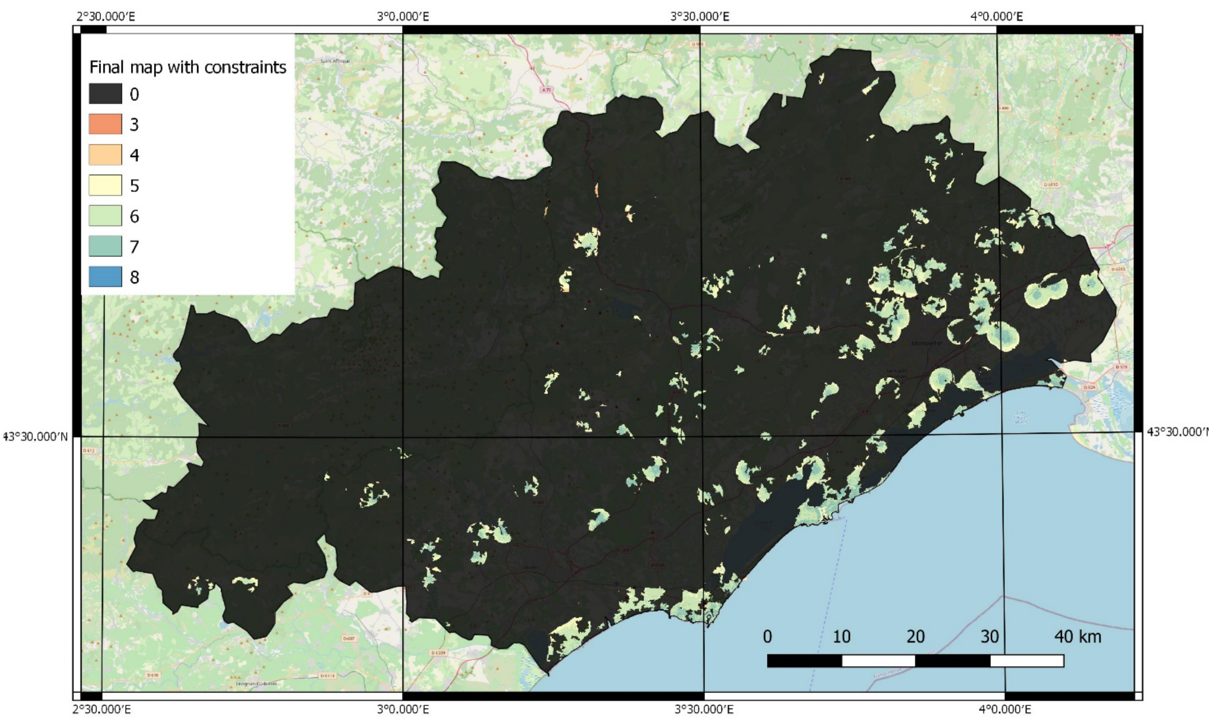
The aggregated constraint layer must be overlaid on the final suitability map. This allows to exclude all the areas where a SIMTAP cannot be built. The final result is displayed in the next image. The constraints are represented in black, while the other scaled colours depict different levels of suitability, from red (represent locations with the lowest suitability to host a SIMTAP) to blue (representing areas with the highest suitability).


10°0.000′E
11°0.000′E
12°0.000′E
45°0.000′N
44°0.000′N
Suitability map
0
3
4
5
6
7
8
0 15 30 45 60 km

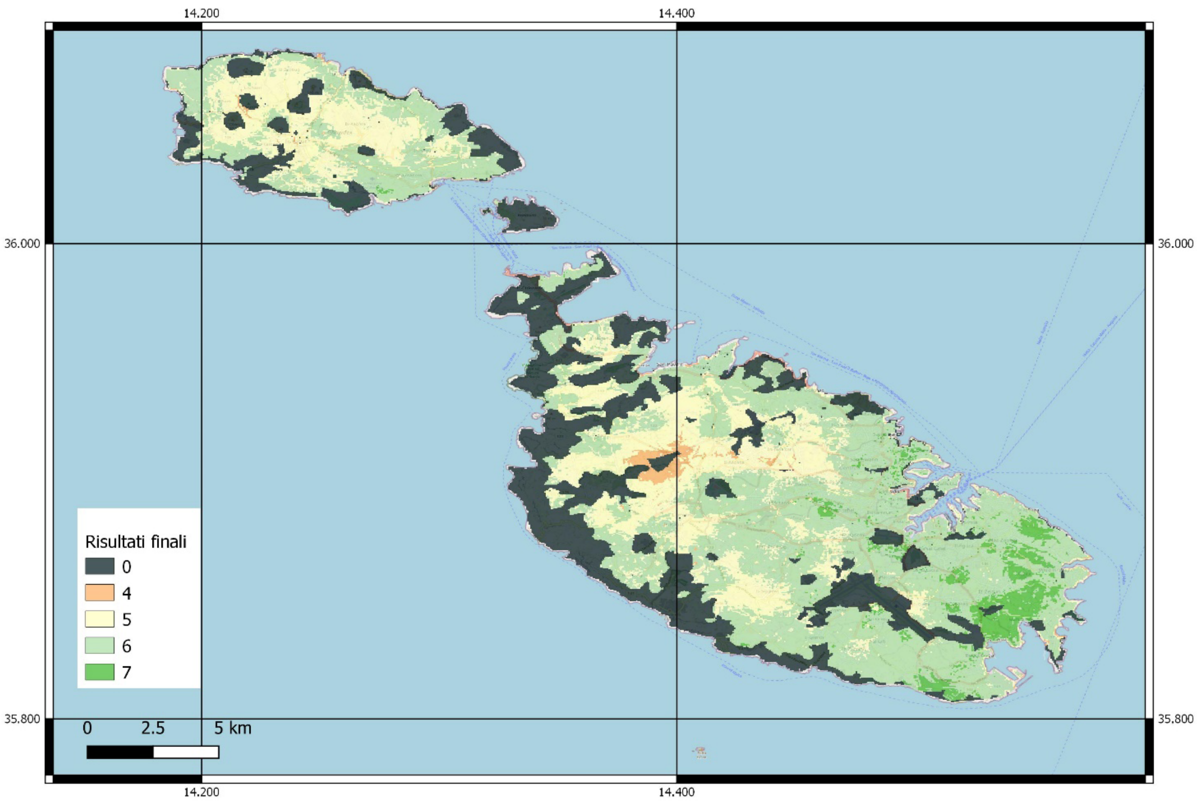
Other case studies

The DSS model has been implemented also in study areas of other countries involved in the SIMTAP project, following the above-described process. The final results in case studies in France, Turkey and Malta are reported in this section.

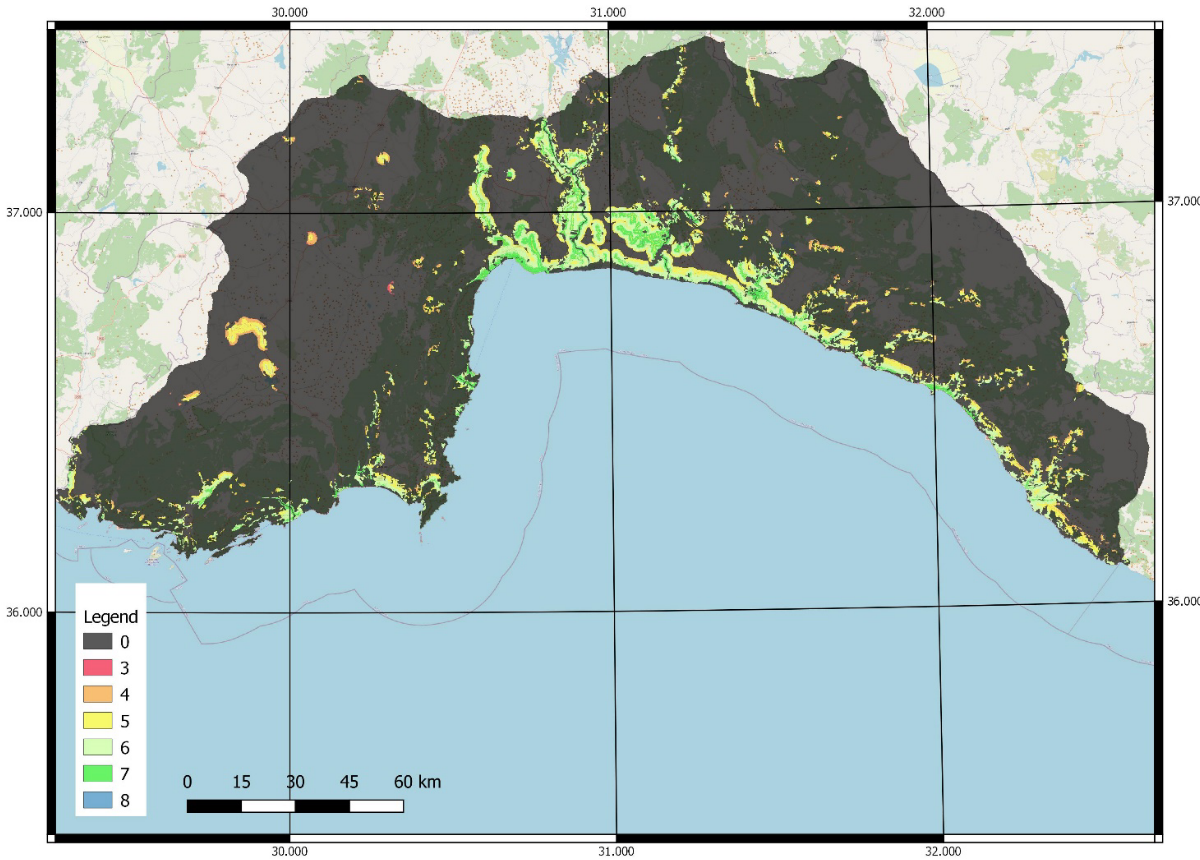
a) Case study "Hérault department, France"



b) Case study “Malta”



c) Case study “Antalya region, Turkey”



References

Malczewski, J., & C. Rinner, (2015) Multicriteria Decision Analysis in Geographic Information Science. Springer Berlin Heidelberg

Tassinari, P., & Torreggiani, D. (2006) Location planning: A methodological approach for agro-industrial buildings in rural territory