

Multi-Criteria Decision Analysis and GIS

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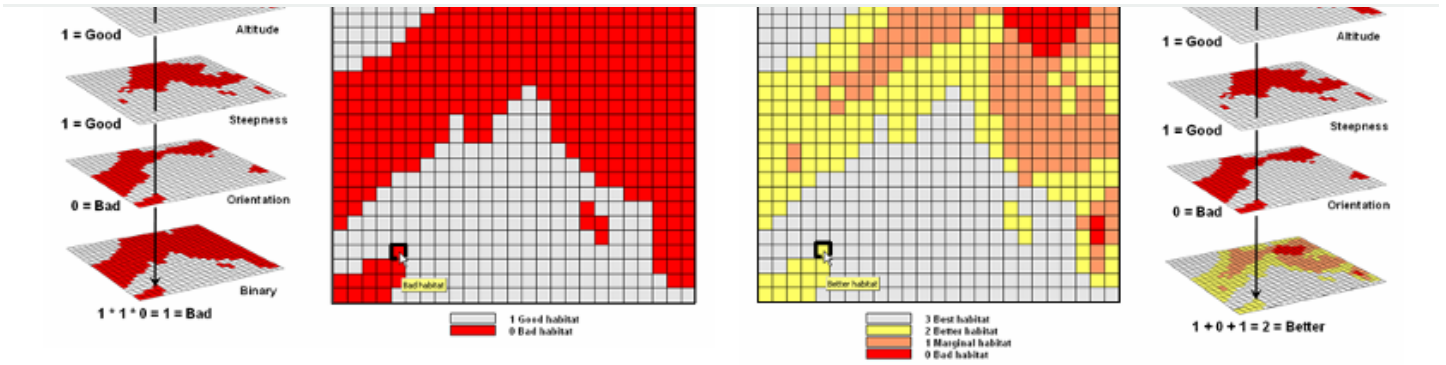
12 Αυγούστου 2019

Suitability Mapping

Many of the problems we are facing today are complicated, with a lot of conflicting interests and solutions. However, groups need to be able to work together and compromise to find a solution that is the most feasible. There is often a spatial or geographic nature to these problems, and thus, by using GIS with different frameworks or analyses, can aid the decision making process.

Binary

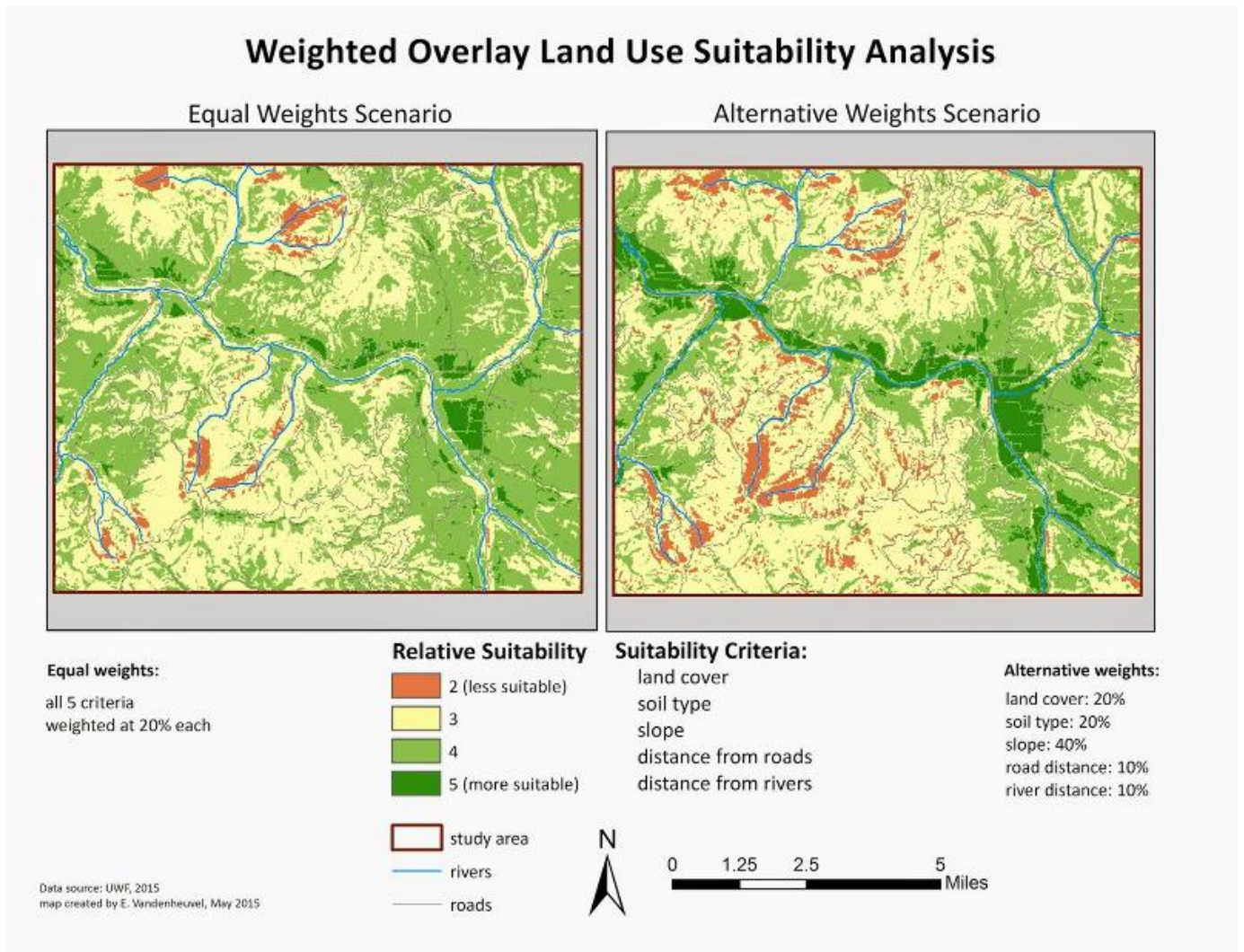
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Determined by multiplying the three individual binary preference map, so values 0 x 0 x 0 the same as 0 x 1 x 1 (AND)

Adding can show areas on a scale that fit some of the criteria (OR)

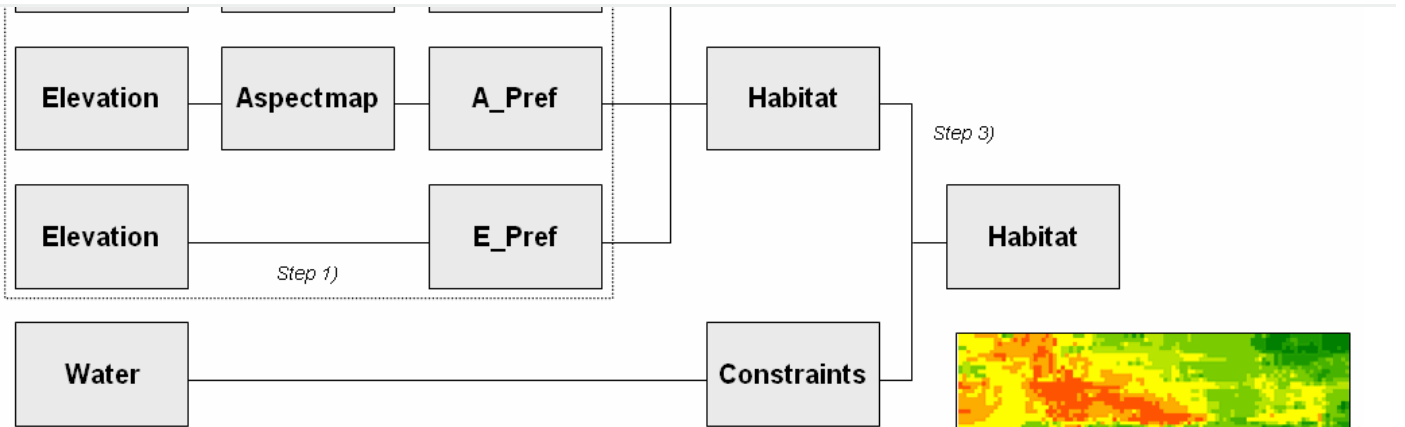
Weighted Overlays



100%.

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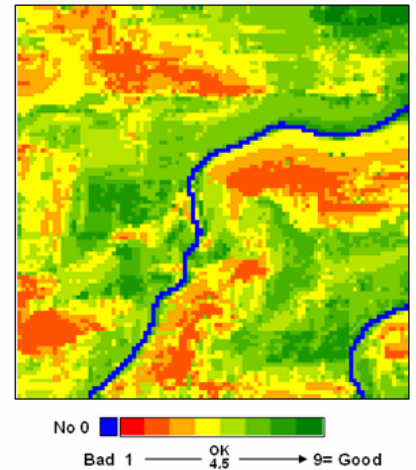
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Step 1) **Calibrate Criteria Maps.** Each of the criteria map categories are assigned a rating from 1= Very Bad to 9= Very Good.

Step 2) **Combine Calibrated Maps.** The calibrated maps are averaged to derive an overall suitability map of habitat.

Step 3) **Apply Constraints.** Excluded areas are eliminated by assigning them a rating of 0 and masking.



Multi-Criteria Decision Analysis (MCDA)

Multi-criteria decision making is one approach used to facilitate the consideration of multiple criteria by decision makers. MCDA is used to logically evaluate and compare multiple criteria that are often conflicting to make the best possible decision. Particularly useful when you have a wide range of stakeholders with conflicting interests, values and goals.

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solve spatial problems. To do this it considers geographical data models, the spatial dimension of the evaluation criteria and decision alternatives in evaluating the criteria.

Some examples of GIS-MCDA applications include vehicle routing, site selection, scenario evaluation, land suitability, transportation scheduling, impact assessment, location-allocation to a variety of sectors.

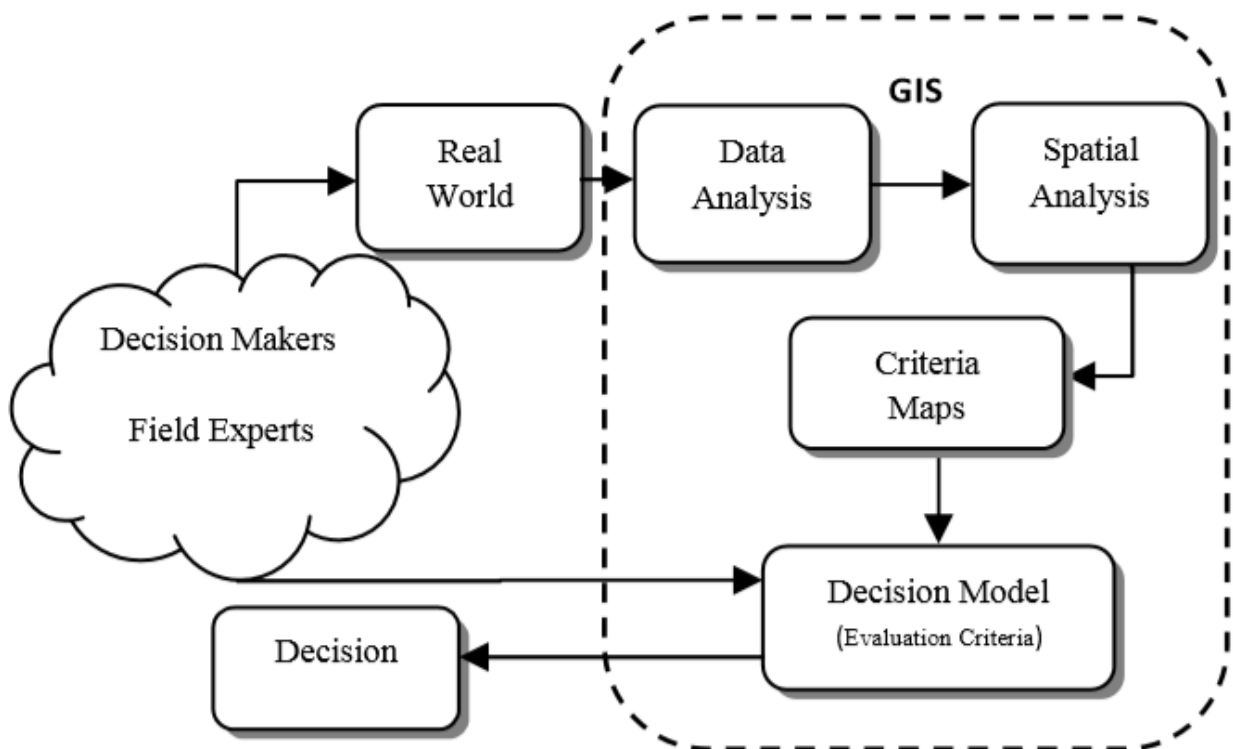


Figure 1. Integrated GIS/ MCDA approach comprehensively as possible.

2. **Determine the criteria and the constraints.** Using a combination of experts' opinions and information from various sources. This could be acquired from discussions

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of the criteria, and for us to represent the judgments and expert knowledge with meaningful numbers.

4. **Weight the importance** of each criteria in regards to the objective, and in respect to each other.
5. Combine, synthesise and **aggregate** the layers/criteria together.
6. **Analyse** and then **validate** your results

Analytical Hierarchy Process (AHP)

Created by Thomas Saaty in 1980, AHP is a **pairwise** comparison method to be used on the criteria in regards to the objective. These pairwise comparisons are carried out for all relevant factors within an analysis- usually no more than 7.


Relative importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to objective
3	Weak importance	Experience and judgment slightly favour one activity over another
5	Strong importance	Experience and judgment strongly favour one activity over another
7	Demonstrated importance	One activity is strongly favoured and demonstrated in practice
9	Extreme importance	The evidence favouring one activity over another is of highest possible order of affirmation
2, 4, 6, 8	Intermediate values	When compromise is needed between two adjacent judgments


		Apple A	Apple B	Apple C		
Size Comparison						
	Apple A	1	2	6	6/10	A
	Apple B	1/2	1	3	3/10	B
	Apple C	1/6	1/3	1	1/10	C


understood when looking specifically at their lower and more specific forms or indicators.

- AHP allows for the participation of both experts and stakeholders in providing input. Such framework allows the incorporation and accommodation of both qualitative and quantitative criteria and the input of expert knowledge.

AHP: Choosing a Leader


Tom


Dick


Harry

Goal: Choose a Leader 1.000

Criteria: Experience .547, Education .127, Charisma .270, Age .056

Alternatives: Tom .358, Dick .493, Harry .149

Education	Tom	Dick	Harry	Priority
Tom	1	3	1/5	0.188
Dick	1/3	1	1/7	0.081
Harry	5	7	1	0.731

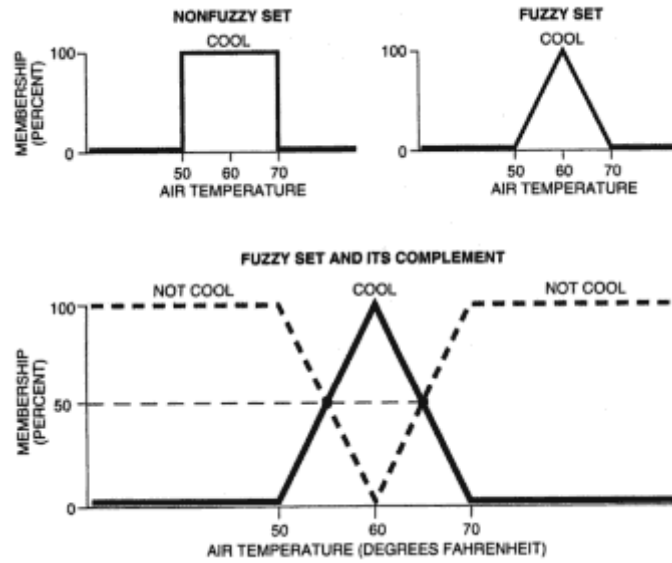
Sum of Priorities 1.000
Inconsistency 0.062

Fuzzy Logic

Decisions makers face numerous and increasingly complex situations, and are often uncertain when it comes to assigning evaluation scores as crisp value. Therefore,

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There are various types of fuzzy numbers and the nomenclature for each is associated with its format: sine numbers, bell shape, polygonal, triangular, trapezoids etc.

We are able to fuzzify two parts of the GIS-MCDA process:

1. We can transform the values of each criteria.
2. Make the weightings or relative importance of the criteria fuzzy.

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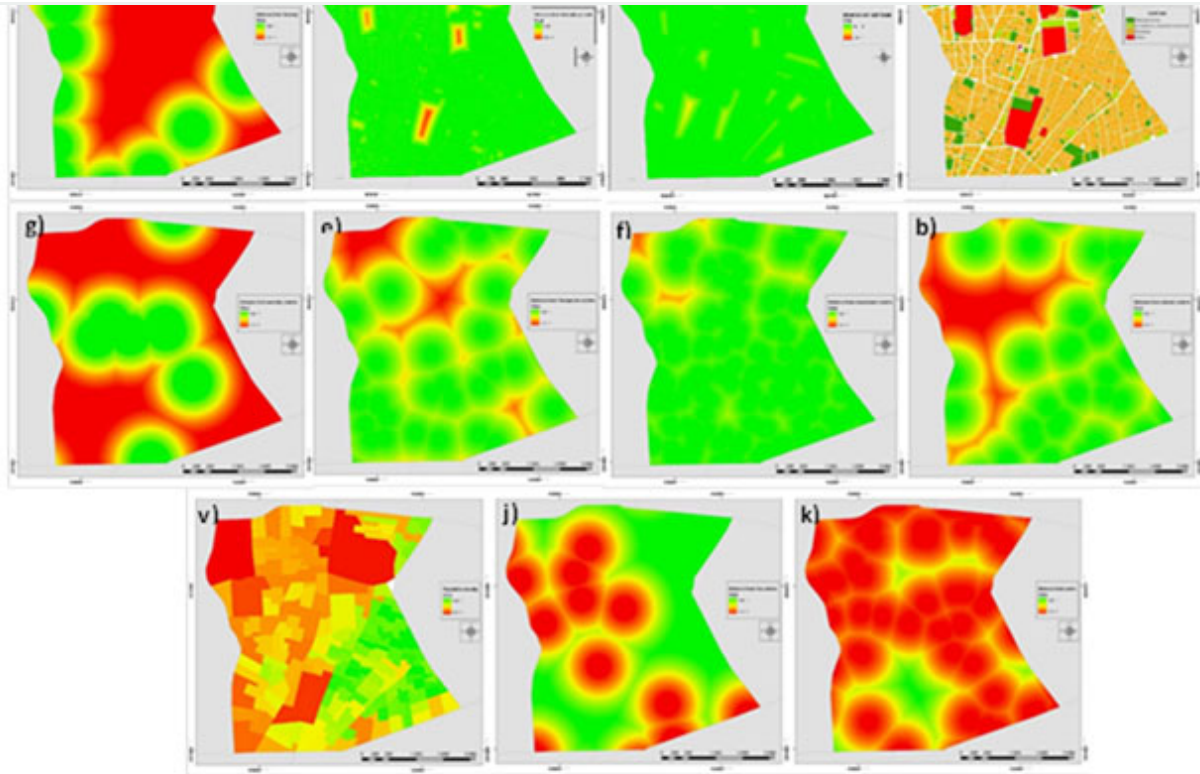


Figure 2. d) land use, c) main roads, h) subsidiary roads, a) subway network, b) distance from cultural centers, f) distance from educational centers, e) Distance from Therapeutic centers ,g) Distance from security centers ,k) Distance from park , j) distance from petrol station, v) population density map .

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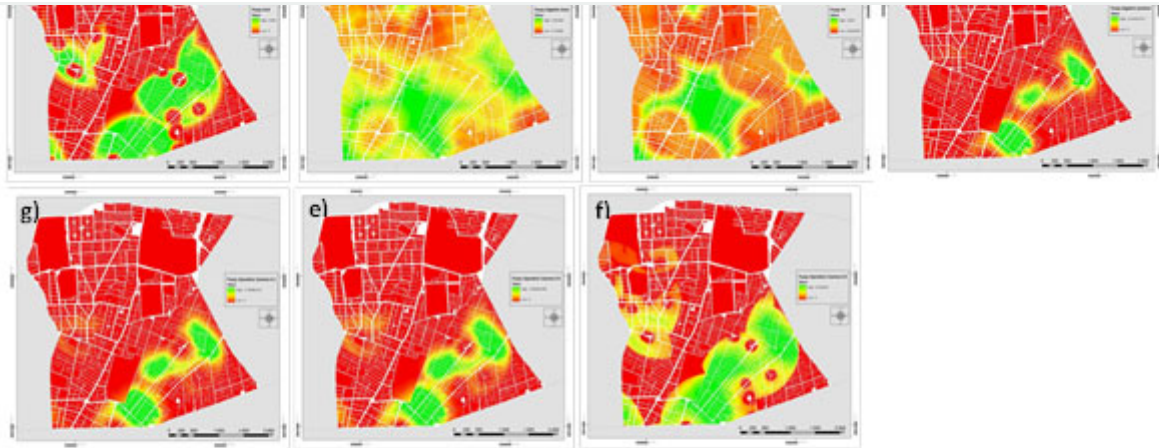


Figure 3. a) areas site selection map by using and method , b) areas site selection map by using sum method, c) areas site selection map by using or method, d,g,e) : areas site selection map by using gamma 0.9.0.5.0.3 method, f) areas site selection map using product method.

GIS methods

To be able to carry out a GIS-MCDA in ArcGIS Pro there are a few steps to go through. Once you have defined your goal and determined your criteria and constraints you can then carry out an analysis.

Reclassify ✕

Parameters | Environments ?

Input raster

Reclass field

Reclassification

		Reverse New Values
Start	End	New
-1	0.911111	1
0.911111	2.822222	2
2.822222	4.733334	3
4.733334	6.644445	4
6.644445	8.555556	5
8.555556	10.466667	6
10.466667	12.377778	7

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Unique Classify

Output raster

Change missing values to NoData

Raster Calculator

Parameters | Environments

✗ Map Algebra expression

Rasters

- Reclass_MeAnu_Temp_02
- LENZ_MeAnu_Temp_Nlc5
- Reclass_DEM_80m_02
- NZTM_DEM_80m_Nlc3
- Habitat_Suitability_Product

Tools

Operators

- +
-
- *
- /

`('%Reclassified_1%' * weighting) + ('%Reclassified_2%' * weighting) ...`

Output raster

3) Using the raster method; a **raster calculator** is then used to apply your AHP matrix weightings and aggregate the layers.

4) **Sensitivity analysis:** alter some of the weightings or criteria to check how the results differ to judge how reliable your results are.

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selected criteria. Certain settings for Membership types use various parameter to determine how rapidly the fuzzy membership values decrease from 1 to 0. The default values change depending on the membership you select.

Fuzzy Membership

Parameters | Environments

Input raster
NZTM_DEM_80m_N1c3

Output raster
FuzzyDEM

Membership type
MS Small

Mean multiplier
1

Standard deviation multiplier
1

Hedge
None

OK

- Small—Used to indicate that small values of the input raster are more important.
- Large—Used to indicate that large values of the input raster have high membership in the fuzzy set.
- Near—Calculates memberships for values near some intermediate value. Same curve as a gaussian, just steeper
- MS Large and MS Small—Similar to Large and Small however the transformation is defined by a specified mean and standard deviation. Often used when number are particularly small or large.

After weightings have been applied a **Fuzzy Overlay** can be used to fuzzify the aggregation of the criteria. However, this process in ArcGIS does not allow for the

memberships in the overlay to produce its results.

Summary

- a GIS-MCDA is a alternative to a typical binary or 'coincidence' analysis, providing a more robust criteria based methodology. It can therefore support multiple values of multiple criteria at once. This allows for more in-depth decision making.
- Additional statistical models such as AHP and FAHP can be integrated into a GIS-MCDA, which typically increasing the reliability and overall significance of an analysis.
- Stakeholders/decision makers are a crucial component of making an analysis feasible and applicable. They are a valuable part of determining the weighting criteria, however have the potential to be biased.
- Expert opinion/applicable literature are necessary for producing an informed MCDA and can counter inconsistencies/bias from stakeholders
- A GIS-MCDA is a relatively recent methodology, and has been applied to an array of fields and spatial issues.

Discussion Questions

- For Green et al., What were some of the limitations addressed in using a MCDA approach to both spatial and non-spatial decision making? For example, are relative decision-maker derived values and weightings suitable? Or do they allow for human error?
- Where the criteria that each paper used appropriate?
- Critique the methodology used in the papers. Compare and contrast?
- What were some of approaches the studies have used? How and why they did this?
- For what other situations could we apply these methods? What other contexts would they be useful?
- Further, for conservation initiatives, should GIS-MCDA be used to aid just one species at a time (as seen in the literature), or perhaps groupings?

Lab tutorial

Now that we understand the methodology of a GIS-MCDA, it's real-world applications, and the concept of incorporating either an AHP or FAHP, we shall perform our own analysis within ArcGIS Pro.

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In this lab, we will apply GIS-MCDA to a significant conversation issue in New Zealand; the species translocation of the endemic manbearpig to a suitable habitat within its historic range. By using a GIS-MCDA, we will determine which areas of North Island New Zealand are suitable for recommending to the Department of Conservation. To do this, as a group we shall logically designate weightings to the criteria of several spatial factors. Each of these factors has been predetermined and sourced from Expert/Al Gore's - opinions. Our analysis shall include a AHP pairwise-matrix, which will improve our overall reliability and validity of our recommendations

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Maybe We Should Have Done Something About ManBearPig - South Park

Παρέχεται από το ArcGIS StoryMaps