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Uncertainty analysis in the modeling of wildlife corridors

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Uncertainty analysis in conservation planning

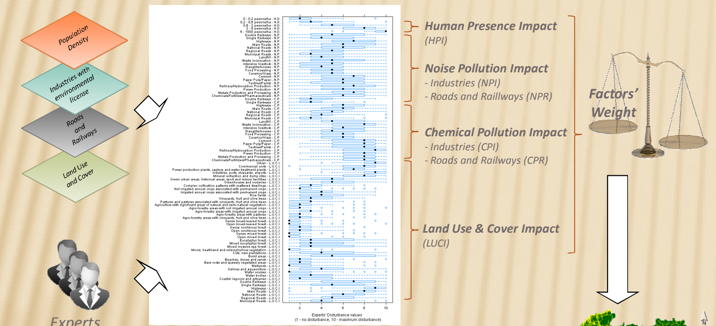
Uncertainty analysis tends to be ignored or disregarded in landscape management by the researchers or environmental decision makers *[1]*, namely in connectivity modeling maps *[2]*. Wu *[3]* revised uncertainty analysis as part of the top 10 list of key issues and research priorities in landscape ecology. Uncertainty is introduced in the model results by many ways including through observation error, inaccuracies of distribution modeling, ecological succession, land-use changes and climate change *[4]*, assumptions and algorithm selection *[5]*. On the other hand, stakeholder discomfort with a poorly defined or justified model can result in objections to the entire approach *[5]*.

Goal

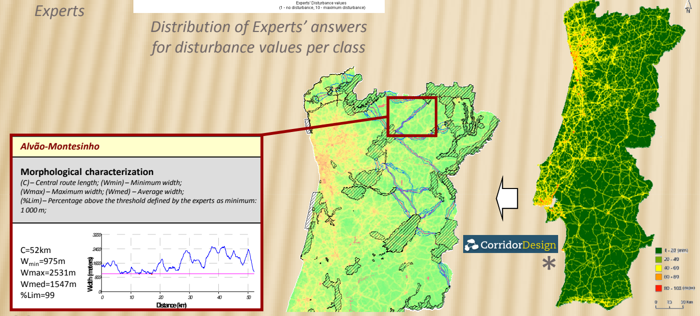
The work presented herein focuses on the uncertainty analysis performed to evaluate the robustness of a multicriteria expert system to support decisions on the identification of lower environmental disturbance corridors for wildlife in Portuguese mainland.

Model for less disturbance corridors

The improvement of connectivity between protected areas has been identified as a global priority for conservation *[6]*. The model aims to help in the generation of a human disturbance gradient for wildlife and in the delineation of less disturbed corridors between protected areas (Least-cost corridors). Least-cost corridor is a swath of contiguous cells expected to provide a low-cost route for movement as the path crosses from one protected area to the other. It assumes that less disturbed areas make less resistance to movement/progression of general wildlife and can be an additional perspective when delineating national scale corridor networks between protected areas. The disturbance factors for wildlife available with the same sampling effort for all the Portuguese mainland were combined in the model using different weights *[7]*. The resistance value for each class within each factor was obtained from the consultation of about 50 experts in conservation and land management *[8]*.



Distribution of Experts' answers for disturbance values per class



[8] *Example of a corridor's morphological characterization* *Less Disturbance Corridors between Protected Areas* *Disturbance Gradient for Wildlife*

(*) Software used to calculate corridors between pairs of protected areas. In this case each corridor has 1 km wide on at least 90% of the corridor length.

Uncertainty analysis of the model

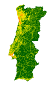
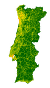
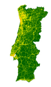
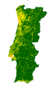
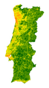
The extent to which the uncertainty in the weights of the factors and values of classes of each factor affected corridor identification was examined.

METHODS

Different scenarios

Five scenarios were generated, where the class's resistance of each factor and the factors' weights were varied. Four alternative scenarios were compared with a proposed scenario.

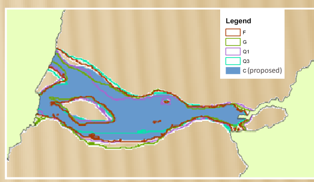
$$\text{Scenario} = R_{HPI} \times W_{HPI} + R_{NPR} \times W_{NPR} + R_{CPR} \times W_{CPR} + R_{NPI} \times W_{NPI} + R_{CPI} \times W_{CPI} + R_{LUCI} \times W_{LUCI}$$

Scenario	C (proposed) 	F 	G 	Q1 	Q3 
Resistance Values (R) from experts' answers	Median	Median	Median	1st quartile	3rd quartile
Factors' Weight (W)	4 1 1 1 1 2 HPI is bigger than LUCI	2 1 1 1 1 4 LUCI is bigger than HPI	6 x 1.67 Equal weight for all factors	4 1 1 1 1 2 Less conservative	4 1 1 1 1 2 More conservative

Indicators of robustness

Six corridors were randomly selected from the set of corridors obtained through the model application (C - proposed scenario). Each of these corridors was then compared with its equivalent in each of the four alternative scenarios in relation to:

i) location of the corridor;
ii) resistance to the movement/progression;
i) cost-distance.

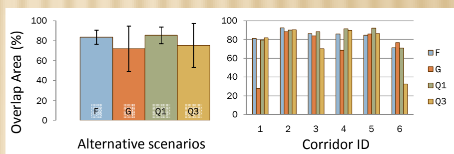


1 of the 6 corridors sampled

RESULTS

Corridors' location

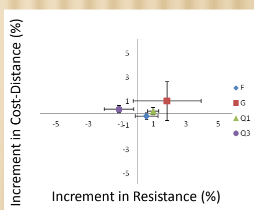
Location's overlap of corridors in proposed scenario was compared with their equivalent in each alternative scenario.



Overlap:
- Max: 92%
- Min: 28%
- Average: 79%
- G has less overlap with proposed scenario
- Q1 has the highest overlap with proposed scenario

In general, there is a high overlap percentage between alternative and proposed scenarios.

Variation in resistance and cost-distance



Mean resistance to movement (disturbance value) within the corridors of the proposed scenario was compared with the resistance obtained for the corridors of each alternative scenario.

Increase in resistance very close to zero (average of 0.5%).

Increase in cost-distance very close to zero (average of 0.3%).

DISCUSSION

In this analysis, several potential scenarios were developed, less (Q1) and more conservative (Q3) in relation to disturbance impacts in wildlife and with different combinations of factors' weights in disturbance gradient. **The proposed model for less disturbance corridors has shown to be robust for the evaluated indicators**, with few spatial changes in corridors between different scenarios (overlap of 79% in average) and with almost no difference in averages of resistance or cost-distance in each compared corridor, 0.5% and 0.3% in average, respectively.
Nevertheless, data carry its' own observation errors and model application to the data does not forecast ecological succession, climate change and land-use changes, so for the last case, attention is needed especially in more dynamic areas. Also, it was considered human disturbance to general wildlife, but it is known that different species and even individuals of the same species can have different sensitivities and avoidance behaviors to human presence and activities.
The use of multicriteria expert systems is common, but the selection of experts and the ambiguity of their interpretation can bring uncertainty to the model. To tackle this, we used a pool of about 50 experts with different backgrounds in areas related to nature conservation, environmental impact assessment and landscape planning, as well as the use of quartiles to capture a representative value from the asymmetrics distributions of answers.
Lastly, it is assumed that higher disturbed areas are more costly to general wildlife movement/progression, where "cost" may reflect the actual energy expended to move over the area or mortality risk, but that is not always true.
We consider the uncertainty analysis of these models as well as the discussion of model assumptions essential to promote decision-makers awareness on the potential impact of model uncertainty when applying these models in strategic decisions on conservation planning.

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