Short Communication

A new fuzzy algorithm for ecological ranking

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Abstract
Ecological ranking is a prerequisite to many kinds of environmental decisions. It requires a set of "objects" (e.g., competing sites for species reintroduction, or competing alternatives of environmental management) to be evaluated on the basis of multiple weighted criteria, and then ranked from the best to the worst, or vice versa. The resulting ranking is then used to choose the course of an action (e.g., the optimal sites where a species can be reintroduced, or the optimal management scenario for a protected area).

In this work, a new tool called FuzRnk is proposed as a modification of classic fuzzy algorithm. FuzRnk, which is freely available upon request from the author, allows for a fuzzy ranking of GIS objects (e.g., landscape patches or zones within protected areas). With respect to classic fuzzy algorithm, FuzRnk introduces two modifications: a) criteria can be weighted on the basis of their importance, b) not only the best performances, but also the worst ones are considered in the ranking procedure.

Keywords fuzzy ranking; criteria weights; good performances; bad performances; fuzzy decision space.

1 Introduction

The theory of fuzzy sets (Zadeh, 1965) allows to deal with the imprecision of data, or the ambiguities implicit in decision rules (Zimmermann et al., 1984). These problems are very frequent in environmental contexts, where decisions based on imprecise measures are often required.

A fuzzy set is a class to which objects belong to different degrees, called "grades of membership". In general any element x_i that is part of a larger set X belongs to the subset K according to its membership function:

$$\mu_K : X \rightarrow [0,\ 1] \qquad (1)$$

where $\mu_K(x_i)$ is the degree of membership in fuzzy set K for $x_i \in X$. The membership function associates each generic element x_i to a value between 0 and 1: the latter means complete membership for x_i to the fuzzy set K, while the former assigns no membership. To establish this grade, rules of membership must be defined.

Environmental decision methods can be distinguished between compensatory and non-compensatory. Under the non-compensatory approach a poor criterion's outcome of an alternative can not be counterbalanced by another criterion's good outcome, and vice versa. In the non-compensatory approach the alternatives are compared without making intra-criteria tradeoffs. On the contrary, the compensatory approach is based on the assumption that the high performance of an alternative achieved on one or more criteria can compensate for the weak performance of the same alternative on another criteria, and vice versa.

The algorithm FuzRnk is a compensatory fuzzy approach to ecological ranking. FuzRnk proposes two modifications to the classic fuzzy approach in that it allows the use of weights, and also produces two fuzzy sets for each alternative, called “good” and “bad” performances.

I suggest that its utilization could be useful within GIS environment to apply a compensatory approach in environmental decision making

2 The Algorithm

FuzRnk requires 3 input parameters:

a) number of observations (alternatives);

b) number of properties (criteria);

c) the quantile rule.

The *q*-th quantile of a data set is defined as that value so that the *q*-fraction of the data is below it, and (1-*q*)-fraction of the data is above it. Within FuzRnk, the quantile method decides the number of observations assigned to the “good" and "bad" performance set. For instance, the first 20% of the observations (i.e., 20th percentile or quintile) for a given criterion could be assigned to the “good” performance set, whereas the last 20% of the scores to the “bad” performance set. The threshold value *q* is up to the user, since the choice of which quantile should be used is also dependent to the attention we want to give to the analysis of situations far from the mean or modal value (e.g. deciles will select situations more distant from the mean than quintiles). The input file for FuzRnk (Tab. 1) consists of a worksheet like a GIS GRASS table (Neteler and Mitasova, 2008), or can be assembled by any spreadsheet program. Columns and rows are referred to criteria and observations respectively. Weights can assume any numeric value greater or equal to 0: if 0 is given, then the criterion is not considered for the ranking. The last row indicates whether a criterion is a cost (the higher the worse) or a benefit (the higher the better).

Table 1 Example of input data matrix for FuzRnk

	criterion 1	criterion 2	...	criterion *m*
observation 1	6.50	9.90	4.00	10.00
observation 2	5.00	5.00	9.00	7.30
observation 3	7.00	6.00	1.00	6.00
observation 4	7.20	0.00	0.15	1.25
observation 5	5.00	5.40	9.00	0.00
...	7.00	4.00	6.00	7.00
observation *n*	10.00	2.00	10.00	4.00
weight	5	1.18	4.5	10
c/b	b	c	b	b

As stated before, FuzRnk produces two fuzzy sets, called good and bad performances. Given *n* observations x_i (i=1...*n*), *m* weighted criteria c_j (j=1…*m*), *m* weights w_j (j=1…*m*) and a quantile threshold, the rule of membership of a generic i-th observation $x_i \varepsilon X_k$ with regard to the j-th criterion is calculated as:

$$\lambda_j(x_i)= w_j \qquad (2)$$

if x_i is in the best quantile (e.g. first 20%) for that criterion;

$$\lambda_j(x_i)= 0 \qquad (3)$$

if x_i does not belong to that quantile.

The overall fuzzy "good score" for x_i is given by

$$\varphi_{xi} = \Sigma_m \lambda_j(x_i) \quad (4)$$

A similar algorithm is applied to find the grade of membership of any element $x_i \varepsilon X_k$ to the worst performances. The rule of membership of any element x_i with regard to the j-th criterion is:

$$\mu_j(x_i) = w_j \quad (5)$$

if x_i is in the worst quantile (e.g. last 20%);

$$\mu_j(x_i) = 0 \quad (6)$$

if x_i does not belong to that quantile.

The overall fuzzy "bad score" for x_i is given by

$$\Phi_{xi} = \Sigma_m \mu_j(x_i) \quad (7)$$

As a result, the generic i-th observation x_i gets a binary vector $<\varphi_{xi}, \Phi_{xi}>$, i.e. weighted grades of membership to the best and worst performances respectively.

Last, FuzRnk draws a biplot (Fig. 1) where each observation is placed using φ_{xi} as x-coordinate and Φ_{xi} as y-coordinate. Observations located in the A-subspace have optimal overall performances since φ is high and Φ is low. As opposite, observations in the D-subspace are the worst ones. Intermediate situations are for observations in subspaces B and C. I call this biplot “fuzzy decision space”. The results are fully compatible with most softwares, since they can be exported by FuzRnk as images or column-formatted data.

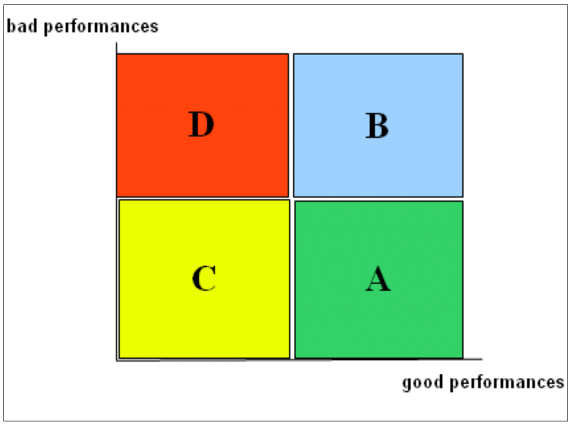

Fig. 1 Fuzzy decision space, where each observation is placed using φ_{xi} as x-coordinate and Φ_{xi} as y-coordinate.

3 Conclusions

Fuzzy ranking is one of the most common ways for ranking ecological “objects”. With respect to classic fuzzy approach, FuzRnk algorithm may be more informative, in that it gives the chance to assign different importance to criteria, and to keep into account both good and bad performances.

I wrote FuzRnk as a free add-on for GIS GRASS (Neteler and Mitasova, 2008). It's freely available upon request from the author. GRASS is very familiar to the most of scientists and students, hence using FuzRnk should be easy for anyone.

References

Neteler M, Mitasova H. 2008. Open Source GIS: A GRASS GIS Approach. Springer, New York, USA

Zadeh LA. 1965. Fuzzy sets. Information and control, 8: 338-353

Zimmermann HJL, Zadeh LA, Gaines BR. 1984. Fuzzy sets and decision analysis. North Holland, Amsterdam, Netherlands