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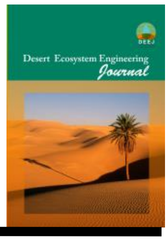

Applying Fuzzy Logic in Quantitative Analysis of Strategies Adopted for Combating Desertification Using Critical Analysis Approach

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Extended Abstract

Introduction

As desertification is growing rapidly, adopting appropriate managerial strategies could help reduce its extension and prevent its development and spread. Otherwise, the loss of resources such as time, energy, etc., would bring about destructive consequences for the efforts made to combat desertification. On the other hand, the process of land desertification results from the interactions between various factors that always operate under uncertain conditions, being strongly influenced by vague and implicit judgments. However, no comprehensive method has been introduced yet to offer operational and reliable solutions for evaluating the strategies used for combating desertification based on a systematic collective fuzzy approach. Therefore, this study sought to combine the fuzzy theory with multi-criteria decision-making methods to evaluate the strategies used in combating desertification, using the Fuzzy DEMATEL method.

Materials and methods: The fuzzy DEMATEL technique is a comprehensive method for creating and analyzing a structural model made out of causal relationships between a variety of complex factors under uncertain conditions. Accordingly, after determining the prioritized criteria and strategies via the fuzzy Delphi method and creating a fuzzy mean pair-wise comparison matrix, the matrix was changed to the normalized initial direct-relation matrix according to equation 1:

$$\tilde{x}_{ij} = \frac{\tilde{z}_{ij}}{r} = \left(\frac{l_{ij}}{r}, \frac{m_{ij}}{r}, \frac{u_{ij}}{r}\right) \quad (1)$$

Then the mass communication matrix was formed by Eq. 2 (Table 1), showing the relative effect of direct and indirect relationships in a system.

$$\tilde{T} = \lim_{k\to\infty}\left(\tilde{X} + \tilde{X}^2 + \cdots + \tilde{X}^K\right) \quad (2)$$

Table (1): Fuzzy Mass Communication Matrix

					$\tilde{D}_i$
$\tilde{T}_{ij}$=	$\tilde{t}^K{}_{11}$	$\tilde{t}^k{}_{12}$	…	$\tilde{t}^k{}_{1nk-1}$	$\tilde{D}_1$
	$\tilde{t}^k{}_{21}$	$\tilde{t}^k{}_{22}$	…	$\tilde{t}^k{}_{2nk-1}$	$\tilde{D}_2$
	:	:	:	:	:
	$\tilde{t}^k{}_{nk1}$	$\tilde{t}^k{}_{nk2}$	…	$\tilde{t}^k{}_{nknk-1}$	$\tilde{D}_n$
$\tilde{R}_i$	$\tilde{R}_1$	$\tilde{R}_2$	…	$\tilde{R}_n$	

$\tilde{t}_{ij} = (l''_{ij}, m''_{ij}, u''_{ij})$

In the fuzzy mass communication matrix, the sum line ($\tilde{D}_i$) indicates the extent of that factor's influence on other system's factors and its corresponding sum column ($\tilde{R}_i$) suggests the intensity of the influence of other system's factors on that factor. Therefore, $\tilde{D}_i + \tilde{R}_i$ determines the total mutual impact of the desired factor and other system's factors on each other, and $\tilde{D}_i - \tilde{R}_i$ shows the extent of each factor's final effect (only the effect) on all other system's factors.

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Then, the $\widetilde{D}_i + \widetilde{R}_i$ and $\widetilde{D}_i - \widetilde{R}_i$ were de-fuzzed according to Eq.3 to facilitate the analysis of the findings.

$$BNP=l_{ij}+\frac{(u_{ij}-l_{ij})+(m_{ij}-l_{ij})}{3} \quad (3)$$

Finally, a causal diagram (cause and effect) including a Cartesian coordinate system was drawn, with its horizontal and vertical axes being graded based on $(\widetilde{D}_i + \widetilde{R}_i)^{def}$ and $(\widetilde{D}_i - \widetilde{R}_i)^{def}$ values, respectively. $(\widetilde{D}_i + \widetilde{R}_i)^{def}$ is the total de-fuzzed cause and effect, and $(\widetilde{D}_i - \widetilde{R}_i)^{def}$ is the extent of the de-fuzzed effect. Moreover, the position of each existing strategy was determined within the system according to a point whose coordinates were (A: $(\widetilde{D}_i + \widetilde{R}_i)^{def}$, $(\widetilde{D}_i - \widetilde{R}_i)^{def}$). In this system, the points above the horizontal line indicate the effect strategies and vice versa, and the points to the right of the vertical line suggest the cause strategies and vice versa (Fig. 1).

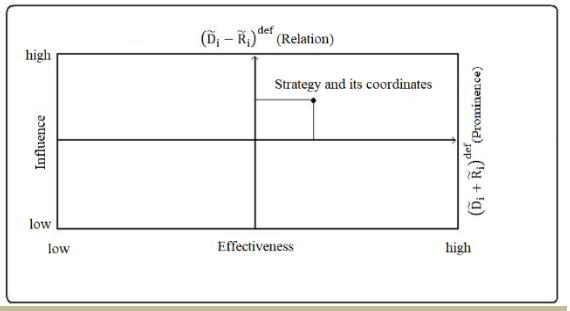

Figure (1): The causal diagram and the display of strategies

Results: According to the related literature, first, the matrix of the order of criteria's influence on each other, and the matrices of the order of strategies' influence on each other were created in terms of the goal and each criterion, respectively, finding that that the effective strategies differed based on each criterion. Therefore, to select final strategies and grade their impact, the matrix of the order of strategies' influence on each other was formed in terms of total criteria within the group.

Table (2): The matrix of the order of influence of strategies on each other in terms of total criteria

Alternatives	$\widetilde{R}_i$	$\widetilde{D}_i$	$(\widetilde{D}_i + \widetilde{R}_i)$	$(\widetilde{D}_i - \widetilde{R}_i)$	$(\widetilde{D}_i + \widetilde{R}_i)^{def}$	$(\widetilde{D}_i - \widetilde{R}_i)^{def}$
A_{23}	0.145, 0.323, 1.262	-0.625, -0.633, -0.767	-0.480, -0.31, 0.496	-1.887, -0.956, -0.912	-0.098	-1.252
A_{18}	-0.371, -0.410, -0.335	0.776, 1.105, 1.942	0.406, 0.695, 1.607	1.110, 1.515, 2.313	0.903	1.646
A_{33}	0.346, 0.376, 0.127	-0.421, -0.681, -1.081	-0.075, -0.305, -0.954	-0.548, 1.058, -1.427	-0.444	-1.011
A_{20}	0.155, 0.070, 0.064	-0.121, -0.194, -0.209	0.034, -0.123, -0.145	-0.186, -0.264, -0.364	-0.078	-0.271
A_{31}	-0.343, -0.283, -0.156	0.324, 0.480, 1.078	-0.019, 0.197, 0.922	0.480, 0.763, 1.421	0.367	0.889

Finally, the causal diagram (cause and effect) was drawn based on Table 2 (Fig. 2) to better interpret the results.

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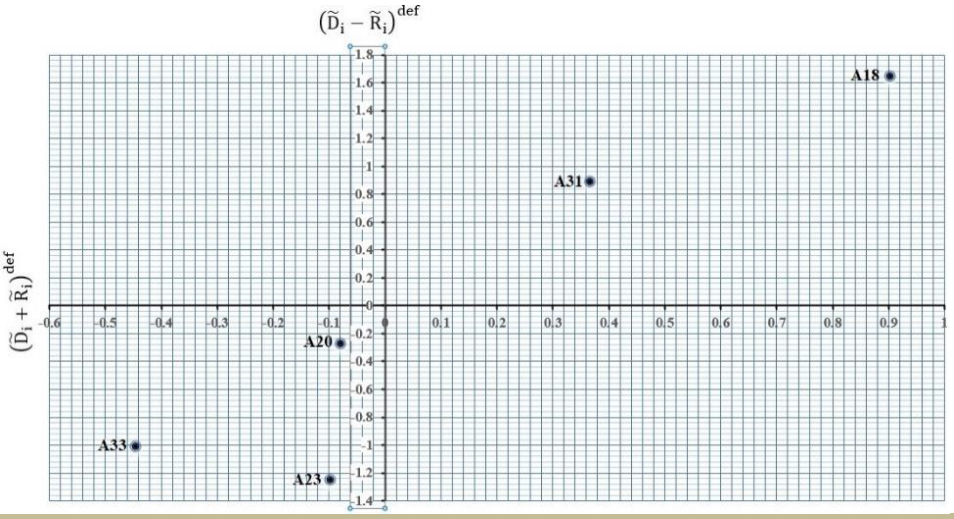

Figure (2): The diagram of cause and effect (causal) strategies to combat desertification based on total criteria

Discussion and Conclusion: According to the study's results, "appropriateness and compatibility with the environment" (C_7) with the intensity effect of $(\widetilde{D}_i - \widetilde{R}_i)^{def} = 0.874$ were the most important criteria based on the Fuzzy DEMATEL perspective, followed by "Destruction of resources, and environmental and human damages" (C_{16}), "Specialized human resources" (C_6), "Scientific and technological tools" (C_5), and "time", with their effect intensity $(\widetilde{D}_i - \widetilde{R}_i)^{def}$ being 0.802, −132, -630, and -0.914, respectively, indicating the experts' concerns for the environmental issues and the existing challenges in terms of the destruction of the environment.

Based on the above-mentioned criteria, "preventing inappropriate land-use change" (A_{18}) with the intensity effect of $(\widetilde{D}_i + \widetilde{R}_i)^{def} = 0.903$ is definitely the most effective strategy to achieve the goal. Moreover, in terms of increasing cause and decreasing effect, other strategies were found to be "Reduction in extracting water from groundwater resources"(A_{31}), " Controlling livestock grazing "(A_{20}), "Developing and restoring the vegetation" (A_{23}), "Changing the irrigation pattern and implementing less water-consuming methods "(A_{33}), whose intensity effect $(\widetilde{D}_i + \widetilde{R}_i)^{def}$ was 0.903, −0.078, −0.098 , and − 0.444, respectively. Therefore, it is suggested that the results of this study be considered in the plans devised to control and reduce the consequences of desertification and land restoration in the study area. In fact, the current study's findings enable the managers working in desert areas to use limited facilities and assets available to them to effectively control the desertification process, prevent the loss of national assets, and achieve better results.

Keywords: Causal Diagram, Fuzzy DEMETAL Method, Hierarchical Structure, Multi-Criteria Decision Making, Pair-wise Comparison.