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RESEARCH PAPER

Evaluating the Economic Prerequisites of Environmental Risk in the International Hamoun Wetland: A Fuzzy SAW and GRA Approach

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Abstract

A primary component of nature is wetlands, which are of special ecological and environmental importance and are valuable for people in different aspects. On the other hand, environmental risk assessment is an important instrument to identify and manage the environment and alleviate environmental damage in order to reduce the adverse results for achieving sustainable development. The present research aimed to evaluate and rank the environmental risks of the International Hamoun Wetland in the Sistan region using fuzzy simple additive weighting (fuzzy SAW) and grey relational analysis (GRA). The research was conducted by the survey method using a questionnaire by which 50 experts from the Regional Agriculture and Natural Resources Organization were interviewed. Based on the ranking by the fuzzy SAW method, the economic factor received the highest score of 4.91, followed by the cultural, biological, and social factors. The GRA results also ranked the economic factor at the top with a final weight of 0.62, followed by the cultural, biological, and social factors in the next ranks. The local communities and the Department of Environment are recommended to cooperate for the protection and restoration of the Hamoun Wetland in order to restore balance to this wetland using the Comprehensive Hamoun Management Program.

Keywords: environmental risk, fuzzy saw technique, grey relational analysis (GRA), Hamoun wetland, ranking.
JEL Classification: N5, O13.

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Introduction

Wetlands are important natural habitats in the world with numerous values and benefits that influence energy circulation in the environment (Taheri Azad and Shahsavaripour, 2006; Makvandi et al., 2013; Shahraki et al., 2023). They are, indeed, one of the three ecosystem types on Earth and provide undeniable ecological benefits for human communities and ecosystems. Currently, most wetlands have been ruined due to the lack of dredging, wastewater drainage, and the filling of their surface area (Zedler and Kercher, 2005; Shariat et al., 2013). Wetlands are valuable and complicated ecosystems that provide a habitat for many unicellular and higher organisms. The socioeconomic benefits of wetlands include flood control, shelter for wildlife, conservation of groundwater quality, and protection of genetic resources (Behrouzrad, 2008; Jafariazar et al., 2017; Shahraki et al., 2023). However, urbanization and industrialization have caused the degradation of wetlands in many developing and developed countries (Zedler and Kercher, 2005; Shariat et al., 2013).

The excessive exploitation of wetlands and their degradation are caused by the lack of scientific knowledge about their resources and ignorance of ecological equilibrium (Abdollahrash et al., 2013). A method to quantify environmental damage and risks of human activities and natural disasters is environmental risk assessment, which allows for adopting proper management policies and practices for coping with risks and alleviating their consequences in order to achieve an acceptable level of risk. Therefore, this method can be employed as a major instrument to manage the environment and identify, study, and mitigate the environmental risk factors to accomplish sustainable development (Janqorban, 2008; Sardar Shahraki and MohammadGhasemi, 2023).

Risk estimation is a process of assessing the likelihood of the occurrence of a desirable or undesirable event and its consequences. The results of risk estimation are, in fact, the inputs for the next steps of risk management (Jabal-Ameli et al., 2007). Environmental risk estimation is a step beyond risk estimation as it considers environmental sensitivity and specific local environmental values in addition to analyzing and investigating different dimensions of risk and understanding the whole environment of the target region (Haller, 2006; Shahbakhsh et al., 2020).

There are various methods for environmental risk assessment, such as FMEA, HAZAN, and William Fine, each with its own pros and cons based on the studied environment (Saffarian and Jozi, 2011). Based on the literature review, these methods alone or in combination with other methods have been important for risk assessment in ports and other sectors (Neil and Pritchard, 2004; Moghaddami et al., 2015). The environmental risk assessment of wetlands is a process of qualitative and quantitative estimation of the likely risks that can be threatening to the individual biotic and abiotic components of wetlands, which are expressed at different risk levels, including low, moderate, and high levels (Lemy, 1998; 2013; Sardar Shahraki, 2019).

Despite advances in the quantification of some main goods and services of ecosystems, there are still fundamental issues and problems, including the lack of adequate knowledge of the relationship between changes in the structure of an ecosystem and its performance in providing services (Barbier, 2013; Sardar Shahraki et al., 2018). Responses to environmental crises are growing in various forms. Environmental crises, which are the gradual or sudden consequences of human activities and natural disasters, threaten the security and health of local people (Kaviani Rad, 2010; Ramezani et al., 2019; Sardar Shahraki and Karim, 2018).

Literature Review

Extensive research has already been conducted in this respect, which is reviewed below. For example, Makvandi et al. (2016) assessed the environmental risk of the international Gavkhoni wetland using the TOPSIS and EFMEA methods. Based on the results, the risk of drought and water loss of the wetland and the risk of the construction of the Zayanderoud Dam were ranked first and second, respectively. After the risks were ranked, risk degrees were determined, which showed the management priorities for risk control. Jafariazar et al. (2018) used multi-criteria decision-making (MCDM) methods to assess and analyze the environmental risks of the international wetland of Khur-e Khuran. According to the results, petroleum pollution (0.88), excessive and unauthorized fishing (0.87), and fuel smuggling were ranked higher among environmental criteria, and drought and climate change (0.72) were ranked first among natural criteria. Jafariazar et al. (2017) assessed and ranked the environmental risks of the international wetland of the estuary of the Gaz and Hara Rivers using the AHP and TOPSIS techniques. The results of TOPSIS based on closeness revealed that petroleum pollution and fuel smuggling (0.91) were in the first and second ranks, respectively. In terms of the risk level, 8.6% of the risks were intolerable, 8.6% were considerable, 26.08% were moderate, 30.43% were tolerable, and 26.08% were trivial. Jafariazar et al. (2018) assessed the environmental risks of the international wetlands of Shadegan, Khur-e Omayyeh, and Khur-e Mousa using MCDM techniques. Based on the results of the three indices of impact level, probability of occurrence, and sensitivity of the affected environment in terms of closeness, the four factors of drought and climate change, upstream water exploitation and water development projects (0.91), upstream dam construction (0.91), and petroleum pollution (0.79) were ranked first to fourth, respectively. Ramezani et al. (2019) explored the effect of environmental risks on national security on the southern coasts of the Caspian Sea. The results revealed that the Caspian realm was exposed to potential and de facto threats due to its bioclimatic, geomorphological, and geological situation. Mcinnes (2016) studied the management of wetlands and floods by natural hazard regulation. Accordingly, the use of land management choices, especially wetland management, is increasingly becoming a part of flood risk management practices. Makwana and Tiwari (2016) prioritized agricultural sub-watersheds in the Gujarat region using remote sensing and GIS. In general, the researchers concluded that the prioritization of these sub-watersheds would be important and very useful in the semi-arid region of Gujarat because there was a high diversity in agricultural practices and landholding sizes. Harik et al. (2017) investigated the consequences of adopting a biodiversity-based vulnerability index versus an environmental sensitivity index for coastal management and policymaking. According to the results, the two methods differed significantly, which can lead to deviations in decision-making and policy-making based on the stakeholder's interests. Fournier et al. (2018) assessed the agricultural risk for a river's watershed in Costa Rica. The most important region was the Mónico River, which had the highest pollution (75%) and highest risk quotient (RG > 1 in 75% of the samples). Velasco et al. (2018) studied the ecosystem services and primary environmental risks in a coastal lagoon in Spain. The services, perceived risks, and primary environmental effects were explored for all user groups. The value of the indirect use and non-use of the conservation of the wetland ecosystem was estimated at 43,326,181 Euros/year.

According to the studies conducted in Iran and other parts of the world, various factors are involved in the drying and degradation of wetlands, e.g., the loss of vegetation cover, overgrazing, plant and animal pests and diseases, petroleum pollution, soil and sediment pollution, the increasing rate of urban and rural development, fuel smuggling, soil erosion, drought, and climate change. Given the biological, physicochemical, cultural, social, and economic dimensions of the Hamoun Wetland and the diverse human activities in the region, which have caused extensive damage to the wetland's survival, it is necessary to monitor and manage the wetland and identify the factors influencing it. Therefore, the present research studied and assessed the factors that influence environmental risks and prioritized them using MCDM techniques. In this article, for the first time, two decision support system approaches have been used to analyze the economic evaluation in an international wetland. In this respect, this innovation is novel. This wetland, located in the eastern part of the country, has international significance, and the results of these two models can significantly assist in planning and policymaking. The review of previous studies showed that this issue has received limited attention in previous studies but is thoroughly examined in the present study.

Lake Hamoun covers an area of 5,660 km², half in Kerman Province and half in Sistan and Baluchestan Province. The plains of Jiroft, Faryab, and Rudbar-e Jonubi in Kerman Province and the plains of Iranshahr, Bampur, Sardegan, Delgan, Sar Takhte, and Espakeh in Sistan and Baluchestan Province are close to the Hamoun region. The mountainous area accounts for 34,000 km² of the Hamoun region, the plains and foothills account for 32,000 km², and the swamps account for 3,000 km². Precipitation may reach 600 mm in the elevated area of Hamoun, but it is as low as 100 mm in the southern lowlands.

Although the inland Hamoun region in Iran is far from the Sea of Oman, it receives high humidity from this sea, making it different from other deserts of Iran. This region is characterized by low precipitation and high temperatures and evaporation. Despite the high humidity in the region, the lake's renewable water resources can be exploited. There is an ellipsoid cavity in the central part of Hamoun which receives all regional surface waters and forms Lake Hamoun. The area of the lake is highly variable across different seasons. In its best condition, its area amounts to 5,660 km², of which 3,820 km² lies in Iran and the rest in Afghanistan.

Figure 1. The Location of the Hamoun Wetland
Source: Sardar Shahraki et al. (2021).

Methods and Materials

Fuzzy Simple Additive Weighting (SAW) Technique

This is one of the oldest methods used in MADM, in which the most appropriate alternative is calculated as follows, assuming a weight vector W (the importance weights of the indicators):

$$A^* = \{A_i \left| \max_i \frac{\sum_j w_j . r_{ij}}{\sum_j w_j} \right.\} \quad (1)$$

and if $\sum_j w_j = 1$, we have:

$$A^* = \{A_i \left| \max_i \sum_j w_j . r_{ij} \right.\} \quad (2)$$

This method needs similar scales and/or dimensionless measurements to allow their comparisons (Malekian and Mohammadi, 2017).

The steps of the fuzzy SAW method are as follows (Mohtashami and Miri Asl, 2017).

• Step 1. Selecting criteria as a reference for decision-making and forming a panel of experts for decision-making

• Step 2. Assigning weights to criteria by experts using linguistic variables

• Step 3. Determining a fuzzy decision matrix for all criteria considering triangular fuzzy values

$$\tilde{D}_{jk} = \begin{bmatrix} \tilde{X}_{11} & \tilde{X}_{12} & \cdots & \tilde{X}_{1n} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ \tilde{X}_{m1} & \tilde{X}_{m2} & \cdots & \tilde{X}_{mn} \end{bmatrix} \tag{3}$$

- Step 4. Specifying average fuzzy score, defuzzified score, and normalized weights for the criteria

The average fuzzy score is calculated by Equation (4) as follows:

$$(A_{jk}) = \left(f_{j1}^{k} + f_{j2}^{k} + \ldots + f_{jn}^{k}\right) / n \; ; \tag{4}$$

$j=1,2,\ldots,m; k=1,2,\ldots,n$

The defuzzified score is calculated by Equation (5) in which the fuzzy number is considered $\tilde{n} = (a, b, c)$ and then, we have (Sagara et al., 2013).

$$crisp(\tilde{n}) = (a,b,c) / n \tag{5}$$

Grey Relational Analysis (GRA) Technique

A grey system is described by grey numbers, grey equations, and grey matrices. Grey numbers are like the atoms and cells of the system. A grey number can define a number that is subject to uncertainty. For example, criteria in decision-making can be expressed by linguistic variables that can be put in numerical intervals. These intervals will contain uncertain information. In 1982, Deng Julong published his first paper "Control Problem of Grey Systems" on grey concepts and theory in Control & Systems (Deng, 1989; Liu and Lin, 2006). Deng performed extensive research on the prediction and control of economic systems and fuzzy systems. He faced highly uncertain systems. The indicators of these systems could hardly be described by fuzzy mathematics or statistics and probabilities. In general, fuzzy mathematics deals with problems in which uncertainty can be expressed by experts with discrete/continuous membership functions. Statistics and probabilities need distribution functions and large sample sizes to achieve the required validity. Grey systems are named after the color of the studied topics. One of the best examples is *Black Box*, which refers to a system in which all internal structures and relationships are fully encoded and unknown. Here, the term Black refers to fully unknown information, White refers to fully known information, and Grey refers to information that is partially known and partially unknown. Accordingly, systems with fully known information are called "white systems", systems with fully unknown or missing information are called "black systems", and systems with partially known and partially unknown information are called "grey systems". Figure 2 depicts a schematic view of the grey theory (Taghavifard and Malek, 2011).

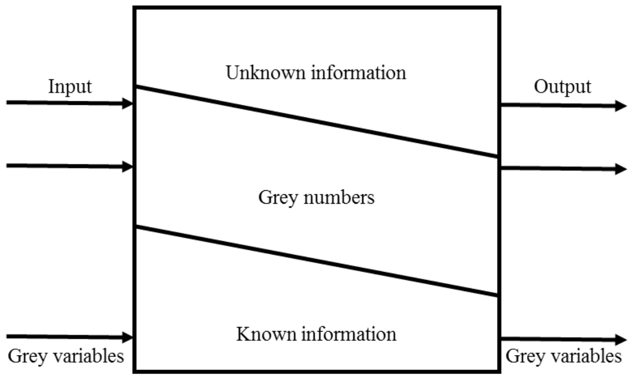

Figure 2. A Schematic View of a Grey System
Source: Taghavifard and Malek (2011).

Steps of GRA

- Step 1. Assigning weights to effective components

It is assumed that there are k decision-makers, so the component weights Q_j can be calculated by

$$\otimes w_j = \frac{1}{k}\left[\otimes w_j^1 + \otimes w_j^2 + ... + \otimes w_j^k\right] \tag{6}$$

in which $\otimes w_j^k (j = 1, 2, ..., n)$ represents the weight of component j for the kth decision-maker and can be expressed by the grey number $\otimes w_j^k = \left[\underline{\alpha}_j^k \bar{\alpha}_j^k\right]$.

- Step 2. The use of lingual variables (e.g., very low, low, moderate, and very high) to specify the component values

According to these variables, the component values can be estimated by

$$\otimes G_{ij} = \frac{1}{k}\left[\otimes G_{ij}^1 + \otimes G_{ij}^2 + ... + \otimes G_{ij}^k\right] \tag{7}$$

in which $\otimes G_{ij}^{k}(i=1,2,...,n;j=1,2,...,n)$ is the value of component *ij* for the *k*th decision-maker and can be represented by the grey number $\otimes G_{ij}^{k}=\left[\underline{\alpha}_{ij}^{k}\bar{\alpha}_{ij}^{k}\right]$ (Li et al., 2007).

- Step 3. Building a grey decision matrix

$$D=\begin{bmatrix}\otimes G_{11} & \otimes G_{12} & \cdots & \otimes G_{1n}\\ \otimes G_{21} & \otimes G_{22} & \cdots & \otimes G_{2n}\\ . & . & \cdots & .\\ . & . & \cdots & .\\ . & . & \cdots & .\\ \otimes G_{m1} & \otimes G_{m2} & \cdots & \otimes G_{mn}\end{bmatrix} \tag{8}$$

in which ⊗G’s are the lingual variables converted into grey numbers.

- Step 4. Normalizing the grey decision matrix

$$D^{*}=\begin{bmatrix}\otimes G_{11}^{*} & \otimes G_{12}^{*} & \cdots & \otimes G_{1n}^{*}\\ \otimes G_{21}^{*} & \otimes G_{22}^{*} & \cdots & \otimes G_{2n}^{*}\\ . & . & \cdots & .\\ . & . & \cdots & .\\ . & . & \cdots & .\\ \otimes G_{m1}^{*} & \otimes G_{m2}^{*} & \cdots & \otimes G_{mn}^{*}\end{bmatrix} \tag{9}$$

in which $\otimes G_{ij}^{*}$ is represented as follows for the incremental components:

$$\otimes G_{ij}^{*}=\left[\frac{\underline{\alpha}_{ij}}{G_{j}^{\max}}\frac{\bar{\alpha}_{ij}}{G_{j}^{\max}}\right] \tag{10}$$

$$\otimes G_{j}^{\max}=\max_{1\le i\le m}\left\{\bar{\alpha}_{ij}\right\}$$

and $\otimes G_{ij}^{*}$ is represented as follows for the decremental components.

$$\otimes G_{ij}^{*}=\left[\frac{G_{j}^{\min}}{\bar{\alpha}_{ij}}\frac{G_{j}^{\min}}{\underline{\alpha}_{ij}}\right] \tag{11}$$

$$\otimes G_{j}^{\min}=\max_{1\le i\le m}\left\{\underline{\alpha}_{ij}\right\}$$

- Step 5. Building a normalized weighted decision matrix

Assuming different significance of the components, the normalized weighted matrix is represented by:

$$D^* = \begin{bmatrix} \otimes N_{11} & \otimes N_{12} & \cdots & \otimes N_{1n} \\ \otimes N_{21} & \otimes N_{22} & \cdots & \otimes N_{2n} \\ . & . & \cdots & . \\ . & . & \cdots & . \\ . & . & \cdots & . \\ \otimes N_{m1} & \otimes N_{m2} & \cdots & \otimes N_{mn} \end{bmatrix} \quad (12)$$

in which $\otimes N_{ij} = \otimes G_{ij}^* \times \otimes w_j$ (Dong et al., 2006).

- Step 6. Selecting the best alternative

The best possible alternative $C = \{C_1, C_2, ..., C_m\}$ for m different criteria $M^{\max}\{\otimes G_1^{\max}, \otimes G_2^{\max}, ..., \otimes G_n^{\max}\}$ can be estimated by

$$M^{\max} = \{[\max_{1 \le i \le m} \underline{a}_{i1} \max_{1 \le i \le m} \bar{\alpha}_{i1}][\max_{1 \le i \le m} \underline{a}_{i2} \max_{1 \le i \le m} \bar{\alpha}_{i2}] \cdots [\max_{1 \le i \le m} \underline{a}_{in} \max_{1 \le i \le m} \bar{\alpha}_{in}]\} \quad (13)$$

- Step 7. Calculating the grey possibility degree

It is represented by Equation (14) for different alternatives:

$$P\{M_i \le M^{\max}\} = \frac{1}{n} \sum_{j=1}^{n} P\{\otimes N_{ij} \le \otimes G_j^{\max}\} \quad (14)$$

- Step 8. Ranking different alternatives

The lower the grey possibility degree of an alternative, the higher its rank (Li et al., 2007).

Data were collected for modeling with a questionnaire from 50 experts at the Agriculture Organization in 2018. The data were analyzed using the Fuzzy SAW and GRA Solver$_{2015}$ software packages. Table 1 presents the ranking of the environmental risks of the International Hamoun Wetland based on the experts' opinions.

Table 1. The Indicators for Environmental Risk Assessment of the International Hamoun Wetland

Risk types	Dimensions	Alternatives
Environmental risk	Biological	The loss of vegetation density
		Overgrazing
		Animal and plant pests and diseases
		Loss of aquatic reproduction
		Soil and sediment pollution
		Illegal fishing tools
	Cultural	Abandonment of worn-out boats and launches
		Unsustainable tourism
		Increasing rate of urban and rural development
		Garbage disposal
	Social	Easy access to the region
		Commute of vehicles
		Road construction
		Fuel smuggling
	Economic	Illegal and excessive fishing
		Commute of motor boats and launches
Natural risks		Drought and climate change
		Abnormal sedimentation
		Soil erosion

Source: Research finding.

Results and Discussion

Results of SAW

In the first step, the decision matrix is quantified. Then, the indices and alternatives are specified and estimated. Qualitative indices are scored based on their degrees of importance and are converted into quantitative indices. To discover the importance of the indices related to the environmental risk of the international wetland of Hamoun, 50 experts were selected. Table 2 summarizes the opinions of these experts. This approach would improve decision-making accuracy.

The criteria had different measurement scales and units. This would prevent their comparison. To solve this problem, the criteria influencing the sub-basins were measured independently of the measurement unit by using the linear dimensionless normalization technique, the results of which are presented in Table3.

After the criteria were made dimensionless, their importance should be determined for which the entropy index method was utilized. This method is based on the principle that the more dispersed the values of a criterion are, the more important the criterion will be. The weights of the criteria were calculated by Equations 2 to 4, the results of which are summarized in Table 4. Also, Table 5 shows the final estimated scores and ranking of the dimensions.

Table 2. The Sum of the Experts' Opinions

Average matrix	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	Criterion 7	Criterion 8	Criterion 9
Biological	(2.68,4.32,6.04)	(5.46,6.84,7.88)	(3.22,5,6.64)	(3.68,5.38,7.1)	(3.66,5.4,7.02)	(2.32,4.08,5.92)	(4.6,6.4,7.82)	(1.6,2.64,4.1)	(4.2,5.94,7.58)
Cultural	(2.36,4.2,6.12)	(4.56,6.24,7.76)	(2.66,4.24,5.9)	(2.48,3.78,5.34)	(4.08,5.7,7.18)	(2.96,4.6,6.32)	(3.1,4.64,6.26)	(2.72,4.34,6.06)	(3.56,5.12,6.64)
Social	(4.02,5.92,7.48)	(4.48,6.26,7.82)	(2.14,3.62,5.36)	(3.1,4.76,6.6)	(3.7,5.38,6.86)	(2.8,4.58,6.36)	(2.72,4.24,5.78)	(2.94,4.44,6.02)	(2.76,4.12,5.66)
Economic	(3.64,5.5,7.26)	(5.64,7.4,8.64)	(3.96,5.3,6.6)	(3.26,4.84,6.64)	(5,6.88,8.26)	(4.8,6.38,7.64)	(3.92,5.68,7.34)	(4.16,5.82,7.22)	(5.2,6.58,7.62)

Source: Research finding.

Table 2. Continued

Average matrix	Criterion 10	Criterion 11	Criterion 12	Criterion 13	Criterion 14	Criterion 15	Criterion 16	Criterion 17	Criterion 18	Criterion 19
Biological	(2.26,3.46,5.08)	(4.84,6.12,7.22)	(3.44,4.98,6.6)	(3.76,5.42,6.92)	(4.46,6.16,7.52)	(2.64,3.74,5.06)	(3.6,5.24,6.94)	(3.36,4.92,6.48)	(2.44,4.08,5.8)	(5.2,6.94,8.22)
Cultural	(3.12,4.7,6.36)	(2.66,3.88,5.3)	(4.22,5.84,7.24)	(3,4.46,6)	(2.3,3.78,5.48)	(3.2,4.82,6.44)	(2.82,4.02,5.44)	(3.7,5.44,7.06)	(2.3,3.8,5.54)	(2.82,4.22,5.72)
Social	(3.18,4.84,6.62)	(3.22,4.42,5.76)	(4.28,5.9,7.3)	(2.76,4.3,5.94)	(3.06,4.82,6.5)	(3,4.58,6.16)	(3.04,4.56,6.2)	(3.88,5.64,7.18)	(2.76,4.52,6.32)	(3.24,5,6.6)
Economic	(4.32,6.02,7.5)	(3.66,5.08,6.64)	(4.86,6.54,7.82)	(4.56,6.04,7.26)	(3.84,5.62,7.32)	(3.94,5.58,7.02)	(4.74,6.1,7.22)	(4.34,6.24,7.96)	(4.88,6.66,8)	(4.46,5.84,7.02)

Source: Research finding.

Table 3. Decision Matrix Normalization to Make it Dimensionless

Normal matrix	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	Criterion 7	Criterion 8	Criterion 9
Biological	(0.358,0.578,0.807)	(0.632,0.792,0.912)	(0.485,0.753,1)	(0.518,0.758,1)	(0.443,0.654,0.85)	(0.304,0.534,0.775)	(0.588,0.818,1)	(0.222,0.366,0.568)	(0.551,0.78,0.995)
Cultural	(0.316,0.561,0.818)	(0.528,0.722,0.898)	(0.401,0.639,0.889)	(0.349,0.532,0.752)	(0.494,0.69,0.869)	(0.387,0.602,0.827)	(0.396,0.593,0.801)	(0.377,0.601,0.839)	(0.467,0.672,0.871)
Social	(0.537,0.791,1)	(0.519,0.725,0.905)	(0.322,0.545,0.807)	(0.437,0.67,0.93)	(0.448,0.651,0.831)	(0.366,0.599,0.832)	(0.348,0.542,0.739)	(0.407,0.615,0.834)	(0.362,0.541,0.743)
Economic	(0.487,0.735,0.971)	(0.653,0.856,1)	(0.596,0.798,0.994)	(0.459,0.682,0.935)	(0.605,0.833,1)	(0.628,0.835,1)	(0.501,0.726,0.939)	(0.576,0.806,1)	(0.682,0.864,1)

Source: Research finding.

Table 3. Continued

Normal matrix	Criterion 10	Criterion 11	Criterion 12	Criterion 13	Criterion 14	Criterion 15	Criterion 16	Criterion 17	Criterion 18	Criterion 19
Biological	(0.301,0.461,0.677)	(0.67,0.848,1)	(0.44,0.637,0.844)	(0.518,0.747,0.953)	(0.593,0.819,1)	(0.376,0.533,0.721)	(0.499,0.726,0.961)	(0.422,0.618,0.814)	(0.305,0.51,0.725)	(0.633,0.844,1)
Cultural	(0.416,0.627,0.848)	(0.368,0.537,0.734)	(0.54,0.747,0.926)	(0.413,0.614,0.826)	(0.306,0.503,0.729)	(0.456,0.687,0.917)	(0.391,0.557,0.753)	(0.465,0.683,0.887)	(0.288,0.475,0.692)	(0.343,0.513,0.696)
Social	(0.424,0.645,0.883)	(0.446,0.612,0.798)	(0.547,0.754,0.934)	(0.38,0.592,0.818)	(0.407,0.641,0.864)	(0.427,0.652,0.877)	(0.421,0.632,0.859)	(0.487,0.709,0.902)	(0.345,0.565,0.79)	(0.394,0.608,0.803)
Economic	(0.576,0.803,1)	(0.507,0.704,0.92)	(0.621,0.836,1)	(0.628,0.832,1)	(0.511,0.747,0.973)	(0.561,0.795,1)	(0.657,0.845,1)	(0.545,0.784,1)	(0.61,0.832,1)	(0.543,0.71,0.854)

Source: Research finding.

Table 4. Weight Assignment to the Dimensionless Matrix

Weighted matrix	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	Criterion 7	Criterion 8	Criterion 9
Biological	(0.118,0.191,0.266)	(0.209,0.261,0.301)	(0.16,0.248,0.33)	(0.171,0.25,0.33)	(0.146,0.216,0.28)	(0.1,0.176,0.256)	(0.194,0.27,0.33)	(0.073,0.121,0.187)	(0.182,0.257,0.328)
Cultural	(0.104,0.185,0.27)	(0.174,0.238,0.296)	(0.132,0.211,0.293)	(0.115,0.176,0.248)	(0.163,0.228,0.287)	(0.128,0.199,0.273)	(0.131,0.196,0.264)	(0.124,0.198,0.277)	(0.154,0.222,0.288)
Social	(0.177,0.261,0.33)	(0.171,0.239,0.299)	(0.106,0.18,0.266)	(0.144,0.221,0.307)	(0.148,0.215,0.274)	(0.121,0.198,0.275)	(0.115,0.179,0.244)	(0.134,0.203,0.275)	(0.12,0.178,0.245)
Economic	(0.161,0.243,0.32)	(0.215,0.283,0.33)	(0.197,0.263,0.328)	(0.152,0.225,0.309)	(0.2,0.275,0.33)	(0.207,0.276,0.33)	(0.165,0.24,0.31)	(0.19,0.266,0.33)	(0.225,0.285,0.33)

Source: Research finding.

Table 4. Continued

Weighted matrix	Criterion 10	Criterion 11	Criterion 12	Criterion 13	Criterion 14	Criterion 15	Criterion 16	Criterion 17	Criterion 18	Criterion 19
Biological	(0.099,0.152,0.224)	(0.221,0.28,0.33)	(0.145,0.21,0.279)	(0.171,0.246,0.315)	(0.196,0.27,0.33)	(0.124,0.176,0.238)	(0.165,0.24,0.317)	(0.139,0.204,0.269)	(0.101,0.168,0.239)	(0.209,0.279,0.33)
Cultural	(0.137,0.207,0.28)	(0.122,0.177,0.242)	(0.178,0.246,0.306)	(0.136,0.203,0.273)	(0.101,0.166,0.24)	(0.15,0.227,0.303)	(0.129,0.184,0.249)	(0.153,0.226,0.293)	(0.095,0.157,0.229)	(0.113,0.169,0.23)
Social	(0.14,0.213,0.291)	(0.147,0.202,0.263)	(0.181,0.249,0.308)	(0.125,0.195,0.27)	(0.134,0.212,0.285)	(0.141,0.215,0.29)	(0.139,0.208,0.283)	(0.161,0.234,0.298)	(0.114,0.186,0.261)	(0.13,0.201,0.265)
Economic	(0.19,0.265,0.33)	(0.167,0.232,0.303)	(0.205,0.276,0.33)	(0.207,0.275,0.33)	(0.169,0.247,0.321)	(0.185,0.262,0.33)	(0.217,0.279,0.33)	(0.18,0.259,0.33)	(0.201,0.275,0.33)	(0.179,0.234,0.282)

Source: Research finding.

Finally, the criteria could be prioritized based on the degree of their importance and the weight of the prioritized alternatives within each criterion. The results of these calculations are depicted in Figure 3 in which the economic factor has the highest score of 4.91 followed by the cultural, biological, and social factors with scores of 4.20, 3.98, and 3.82, respectively.

Table 5. The Final Fuzzy Scores

Dimension	Final fuzzy score
Cultural	(2.923, 4.215, 5.479)
Social	(2.541, 3.814, 5.139)
Biological	(2.649, 3.99, 5.329)
Economic	(3.613, 4.958, 6.133)

Source: Research finding.

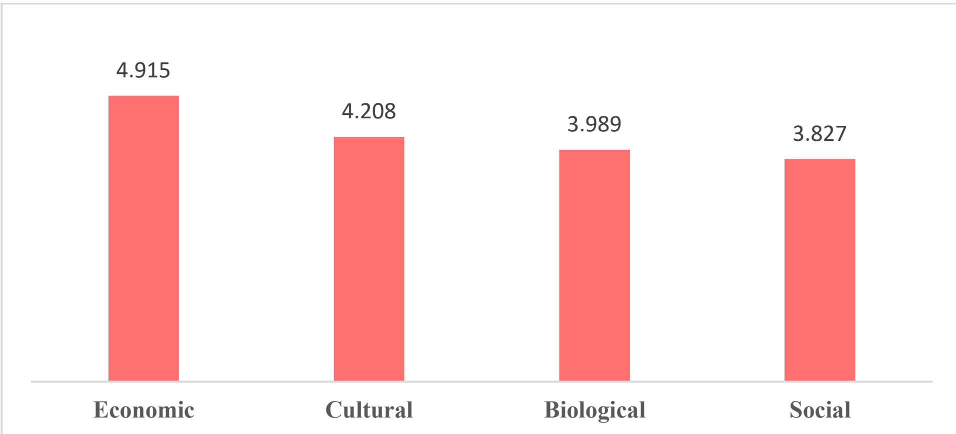

Figure 3. The Definite Score of the Prioritization of the Environmental Risks of the International Hamoun Wetland
Source: Research finding.

Results of GRA

In this section, GRA is used to check the environmental risks in the studied wetland. The data were collected with a questionnaire that was composed of four factors (economic, social, cultural, and biological) and 19 criteria prepared in accordance with regional conditions. The questionnaire was provided to 50 experts at the Agriculture and Natural Resources Organization in the Sistan region. Table 6 shows the final results of scoring the completed questionnaires. According to Table 6, the criteria of overgrazing, illegal fishing tools, and easy access to the region (2, 6, and 11, respectively) had higher weights than the other criteria. Table7 provides the results of normalization by Equation 9.

- **Step 1.** Building the Decision Matrix

Table 6. Building the Decision Matrix for Assessing the Environmental Risks of the International Hamoun Wetland

Matrix	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	Criterion 7	Criterion 8	Criterion 9	Criterion 10	Criterion 11	Criterion 12	Criterion 13	Criterion 14	Criterion 15	Criterion 16	Criterion 17	Criterion 18	Criterion 19
Biological	4	4	4	5	4	2	6	2	3	4	1	2	5	5	4	4	2	1	4
Cultural	5	9	9	8	7	6	5	9	5	5	4	3	5	5	7	5	5	1	7
Social	3	3	6	5	5	6	2	3	3	6	4	3	3	6	7	3	3	6	4
Economic	6	2	3	7	5	8	3	6	4	6	5	3	7	2	2	7	4	6	2
Weight	0.021	0.114	0.059	0.015	0.014	0.064	0.057	0.106	0.037	0.009	0.080	0.038	0.029	0.045	0.070	0.033	0.071	0.011	0.062

Source: Research finding.

- **Step 2.** Normalizing to make the matrix dimensionless

Table 7. Normalization of the Environmental Risk Assessment of the International Hamoun Wetland

Dimensionless matrix	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	Criterion 7	Criterion 8	Criterion 9	Criterion 10	Criterion 11	Criterion 12	Criterion 13	Criterion 14	Criterion 15	Criterion 16	Criterion 17	Criterion 18	Criterion 19
Biological	0.5	0.25	0.28	0.25	0.5	0.14	1	1	0.33	0.6	0.33	0	0.66	0.75	0.6	0.5	1	1	0.5
Cultural	0	1	1	1	1	0.17	0.8	0.16	1	0.8	0.66	1	0.66	0.75	0	0.66	0.75	0	0.25
Social	1	0.5	0.57	0.25	0	0.17	0.2	0.38	0	1	0.66	0.33	0.33	1	0	0.33	0.85	0.66	0.5
Economic	0.5	0.75	0.14	0.75	0	1	0.4	0.33	0.66	1	1	0.33	1	0	1	1	0.71	0.66	1

Source: Research finding.

- **Step 3.** Defining reference target series

Table 8. Defining Reference Target Series for the Environmental Risk Assessment of the International Hamoun Wetland

Reference target series	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	Criterion 7	Criterion 8	Criterion 9	Criterion 10	Criterion 11	Criterion 12	Criterion 13	Criterion 14	Criterion 15	Criterion 16	Criterion 17	Criterion 18	Criterion 19
Biological	0.5	0.75	0.714	0.75	0.5	0.857	0	0	0.666	0.4	0.666	1	0.333	0.25	0.4	0.5	0	0	0.5
Cultural	1	0	0	0	0	0.285	0.2	0.833	0	0.2	0.333	0	0.333	0.25	1	0.333	0.428	1	0.75
Social	0	0.5	0.428	0.75	1	0.285	0.8	0.166	1	0	0.333	0.666	0.666	0	1	0.666	0.142	0.333	0.5
Economic	0.5	0.25	0.857	0.25	1	0	0.6	0.666	0.333	0	0	0.666	0	1	0	0	0.285	0.333	0

Source: Research finding.

- **Step 4.** The effect of grey relational coefficient

Table 9. The Effect of the Grey Relational Coefficient on the Environmental Risk Assessment of the International Hamoun Wetland

Coefficient effect	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	Criterion 7	Criterion 8	Criterion 9	Criterion 10	Criterion 11	Criterion 12	Criterion 13	Criterion 14	Criterion 15	Criterion 16	Criterion 17	Criterion 18	Criterion 19
Biological	0.444	0.285	0.324	0.285	0.444	0.285	1	1	0.375	0.285	0.285	0.285	0.444	0.615	0.5	0.347	1	1	0.375
Cultural	0.285	1	1	1	1	0.545	0.615	0.285	1	0.444	0.444	1	0.444	0.615	0.285	0.444	0.285	0.285	0.285
Social	1	0.375	0.444	0.285	0.285	0.545	0.285	0.666	0.285	1	0.444	0.375	0.285	1	0.285	0.285	0.545	0.545	0.375
Economic	0.444	0.545	0.285	0.545	0.285	1	0.347	0.333	0.545	1	1	0.375	1	0.285	1	1	0.375	0.545	1

Source: Research finding.

- **Step 5.** Grey relational rank

Table 10 presents the grey relational rank of the environmental risk assessment of the International Hamoun Wetland for each risk factor (alternatives). As with the previous section, this section shows the grey rank of the correlation between the reference target series and the comparative series. So, if the comparative series for each alternative has a higher grey relational rank with the reference target series, it means that the alternative is successful in realizing the environmental risk assessment. According to Table 10, a higher superiority was observed in the criteria of unsustainable tourism, abnormal sedimentation, drought and climate change, and illegal and excessive fishing in the biological dimension, overgrazing, plant and animal pests and diseases, and traffic of vehicles in the cultural dimension, unsustainable tourism, fuel smuggling, and overgrazing in the social dimension, and easy access to the region, overgrazing, and illegal fishing tools in the economic dimension.

Table 10. The Grey Relational Rank of the Environmental Risk Assessment of the International Hamoun Wetland

Rank	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	Criterion 7	Criterion 8	Criterion 9	Criterion 10	Criterion 11	Criterion 12	Criterion 13	Criterion 14	Criterion 15	Criterion 16	Criterion 17	Criterion 18	Criterion 19
Biological	0.009	0.032	0.019	0.004	0.006	0.018	0.057	0.106	0.013	0.002	0.023	0.010	0.012	0.027	0.035	0.011	0.037	0.101	0.023
Cultural	0.006	0.114	0.059	0.015	0.014	0.035	0.035	0.030	0.037	0.004	0.035	0.038	0.012	0.027	0.020	0.014	0.010	0.029	0.017
Social	0.022	0.043	0.026	0.004	0.004	0.035	0.016	0.071	0.010	0.009	0.035	0.014	0.008	0.045	0.020	0.009	0.020	0.055	0.023
Economic	0.009	0.062	0.017	0.008	0.004	0.064	0.019	0.035	0.020	0.009	0.080	0.014	0.029	0.012	0.070	0.033	0.013	0.055	0.062

Source: Research finding.

- **Step 6.** Final score based on the grey relational rank

As is evident in Figure 4, the economic dimension was ranked first with a final weight of 0.62 followed by the cultural (0.56), biological (0.55), and social dimensions (0.47) in the second to fourth ranks, respectively.

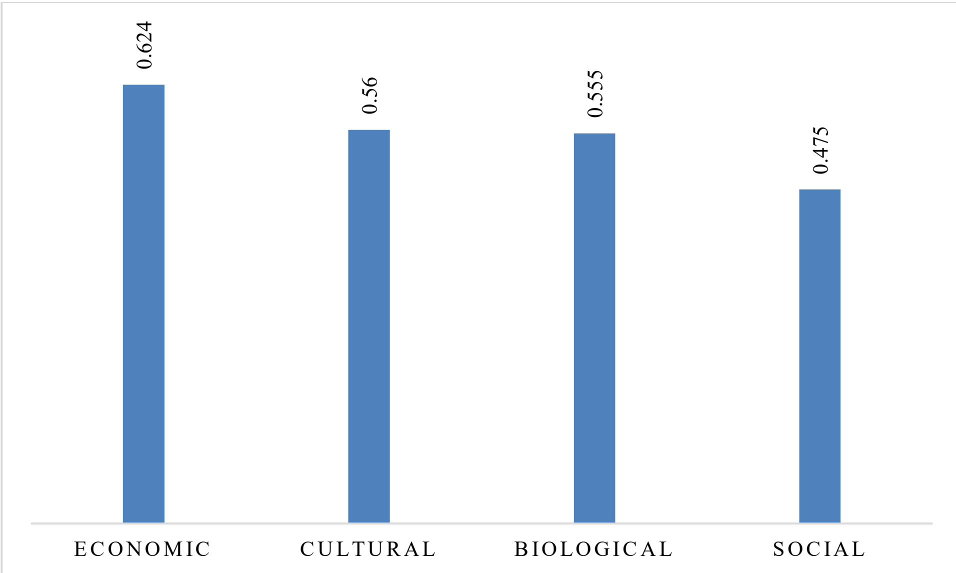

Figure 4. The Final Score Based on the Grey Relational Rank of the Environmental Risk Assessment of the International Hamoun Wetland
Source: Research finding.

Conclusion and Recommendations

Wetlands provide diverse services and functions, including the supply of livelihoods and assistance to the economy of local communities. The prevention of dust production is another important function of wetlands. Considering recent events in some provinces in Iran, it is necessary to put effort into protecting and maintaining wetlands in order to use these services. The identification of the factors that are responsible for the degradation of wetlands is important for developing efficient regulations and proper mechanisms for fighting those who destroy the environment. So, the present research aimed to identify and rank the environmental risks of the International Hamoun Wetland using the fuzzy SAW and GRA techniques. The research identified the indicators and criteria based on the previous studies and the local experts' opinions and categorized them into economic, social, cultural, and biological factors. These factors were divided into two categories of environmental risks (biological, social, and cultural) and natural risks (economic). The results of this study are in line with the results of Piri and Ansari (2014) and Ebrahimi Khosfi and Mirakbari (2020).

According to the fuzzy SAW results (see Figure 2), the economic factor has the highest score of 4.91, and the cultural (4.20), biological (3.98), and social factors (3.82) are in the next ranks, respectively. Also, the results of GRA show that the first rank is for the economic factor with a final score of 0.62 and the next ranks are for the cultural (0.56), biological (0.55), and social factors (0.47), respectively.

As is evident, the two techniques of fuzzy SAW and GRA provided similar results, and both put the economic factor in the first rank. This factor includes the criteria of illegal and excessive fishing, traffic of motor boats and launches, drought and climate change, abnormal sedimentation, and soil erosion. Given the droughts in the Sistan region over the past 20 years, climate change (very low precipitation, high evaporation, and very high temperatures) has caused the drying of the Hamoun. On the other hand, the 120-day winds have eroded the soil in the region, which has damaged soil fertility.

In general, mismanagement of water resources along with such issues as climate change and drought has caused problems in wetlands, including the International Hamoun Wetland. Indeed, in drought conditions, the more improper the water resources management is, the more fragile the resources will be and the more risks they will be faced with.

Based on the results, the following recommendations can be drawn:

1. It is suggested that the officials and planners pay attention to the various economic aspects of stabilization of micro-dusts in the Hamoun Wetland. This can help all areas in the region. It is very important to identify the centers of storm crisis in the region. These micro dusts have caused a lot of economic damage to the region, which should be considered in policies.
2. Local communities and the Department of Environment are recommended to cooperate on adopting measures for the protection and revival of the Hamoun Wetland in order to bring balance to the wetland through a comprehensive Hamoun management program.
3. All executive agencies (the Ministry of Energy, the Agricultural Organization, the Natural Resources Organization, universities, and the Department of Environment) are recommended to provide a program for the prevention of the degradation and the revival of this wetland.

4. It is recommended to plant trees that have low water requirements. These trees can protect the wetland from dust damage.
5. The governments of Iran and Afghanistan are recommended to develop an integrated management program.

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