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RESEARCH ARTICLE / ARAŞTIRMA MAKALESI

Assessment of an Underground Dams Site Selection in İZMİR Province by Using MAIRCA and EDAS Methods

İZMİR İlinde Kurulacak Olan Bir Yeraltı Barajı için Uygun Lokasyonun MAIRCA ve EDAS Yöntemleri Kullanılarak Belirlenmesi

Muhammet Enes Akpınar [1*], Mümin Emre Şenol [2]

[1] İzmir Bakırçay Üniversitesi İktisadi ve İdari Bilimler Fakültesi İşletme Bölümü, İzmir, TÜRKİYE
[2] Manisa Celal Bayar Üniversitesi Mühendislik ve Doğa Bilimleri Fakültesi Endüstri Mühendisliği Bölümü, Manisa, TÜRKİYE

Corresponding Author / Sorumlu Yazar *: enes.akpinar@bakircay.edu.tr

Abstract

Underground dam site selection is the process of selecting locations for dams constructed for the storage and management of groundwater to ensure the sustainable use of water resources. Underground dams store groundwater by utilizing underground aquifers, enabling more efficient and effective utilization of water resources. Particularly, the importance of underground dams has been observed to increase with global warming. They play a crucial role in various aspects, especially during periods of drought, in meeting agricultural irrigation and drinking water needs, among others. The construction of underground dams requires the simultaneous consideration of numerous criteria, thus turning the construction process into a decision-making problem. This decision problem is referred to in the literature as a multi-criteria decision-making (MCDM) problem. In this study, the site selection problem for a underground dam to be established in the province of Izmir has been addressed. In the problem at hand, there are five different alternatives consisting of districts within the province of Izmir and ten different criteria. These criteria and alternatives were determined by experts. In the study, the weights of the criteria were determined using the MAIRCA method, and the EDAS method was used for the selection of alternative locations. As a result of the study, Kınık district was identified as the most suitable alternative among the selected districts.

Keywords: *Underground dam, site selection, multi-criteria decision making, MAIRCA method, EDAS method*

Öz

Yer altı barajı yer seçimi, su kaynaklarının sürdürülebilir şekilde kullanılmasını sağlamak amacıyla yeraltı suyunun depolanması ve yönetimi için yapılan barajların yer seçim sürecidir. Yer altı barajları, yeraltı suyunun doğal rezervuarları olan yeraltı su tabakalarını depolayarak, su kaynaklarının daha verimli ve etkin bir şekilde kullanılmasını sağlar. Özellikle küresel ısınma ile yer altı barajlarının öneminin arttığı gözlemlenmiştir. Özellikle kuraklığın olduğu dönemlerde, başta tarımsal sulama ve içme suyu ihtiyaçlarını karşılamak gibi birçok konuda hayati bir rol oynadığı bilinmektedir. Yer altı barajlarının inşası için çok fazla kriterin eş zamanlı olarak dikkate alınması gerekmektedir. Bu nedenle, inşa süreci bir seçim problemine dönüştürmektedir. Söz konusu seçim problemi ise, literatürde çok kriterli karar verme (ÇKKV) problemi olarak geçmektedir. Bu çalışmada, İzmir ilinde kurulacak bir yer altı barajı için yer seçim problemi ele alınmıştır. Ele alınan problemde, İzmir ilindeki ilçelerden oluşan beş farklı alternatif ve on farklı kriter yer almaktadır. Bu kriterler ve alternatifler karar vericiler tarafından belirlenmiştir. Çalışmada, kriterlerin ağırlıkları MAIRCA yöntemi ile belirlenmiş, alternatif konumların seçiminde ise EDAS yöntemi kullanılmıştır. Çalışma sonucunda belirlenen alternatif ilçeler arasından Kınık ilçesi en uygun alternatif olarak belirlenmiştir.

Anahtar Kelimeler: *Yer altı barajı, yer seçimi, çok kriterli karar verme, MAIRCA yöntemi, EDAS yöntemi*

1. Introduction

Global warming and drought have become increasingly pressing issues worldwide in recent years. Among the possible effects of this problem are the reduction of water resources, decreased agricultural production, ecosystem degradation, increased waterborne diseases, and harm to wildlife. These effects pose serious threats to both humans and natural life [1].

Increased greenhouse gas emissions, deforestation, industrialization, and the usage of fossil fuels are some of the factors contributing to global warming. These elements raise the amount of greenhouse gases in the atmosphere, which raises the earth's temperature. Temperature increases, in turn, increase natural disasters such as droughts and increase the demand for water resources.

Drought, which is a natural consequence of global warming, is a condition that arises from prolonged hot and dry weather conditions. The problem of drought is increasing worldwide, and among its most prominent effects are decreased agricultural production, decreased water resources, and ecological degradation. Drought, especially in regions such as Africa, the Middle East, and Southeast Asia, lower people's quality of life and leads to food security issues [2].

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International cooperation and efforts are crucial to solving the problems of global warming and drought. Reducing greenhouse gas emissions, putting money into renewable energy sources, using water resources sustainably, and taking water conservation measures are a few of these initiatives. These efforts will contribute to both improving people's quality of life and preserving natural life.

Underground dams can be defined as structures built to collect and store groundwater. These dams provide water by using groundwater during periods of low precipitation, thereby reducing the demand for surface water sources during drought periods. Additionally, underground dams contribute to the sustainable use of water since they cause less evaporation and loss than surface water sources [3].

Because underground dams have less of an influence on the environment than surface dams, they are also favored for building. During the construction of surface dams, forests, and habitats are destroyed, agricultural land is damaged, and the lives of indigenous people are negatively affected. However, underground dams minimize these negative effects and contribute to the preservation of natural life. In summary, underground dams offer a solution to the effects of natural disasters such as global warming and drought, promote the sustainable use of water resources, and contribute to the preservation of natural life. Therefore, the construction and use of underground dams are of great importance in terms of the sustainability of water resources [4].

This study addresses an underground dam selection problem. In the problem addressed, a real-life application is made using Multi-Criteria Decision Making (MCDM) techniques. Ten different criteria and five alternative locations were identified by decision-makers in the study. MAIRCA (Multi Atributive Ideal-Real Comparative Analysis) method was used to define the weights of ten criteria. Finally, the results were evaluated using EDAS (Evaluation Based on Distance from Average Solution) method, and the most appropriate alternative was identified. These methods are used to optimize problems. Many different methods are used in the field of optimization [5-8]. In this study, the EDAS method is preferred due to its advantages such as transparency, robustness, flexibility, and not requiring internal inference and reference points when compared to other methods. Besides, MAIRCA method is selected because of its assessing alternative options by comparing their theoretical and empirical ratings. It determines the difference or distance between the actual empirical ratings and the ideal alternatives, utilizing both theoretical and empirical evaluations.

1.1. Literature Review

Numerous studies have been conducted to address the complexity of selecting suitable sites for constructing subsurface dams worldwide. The decision-making process in this domain is intricate due to the involvement of various qualitative and quantitative factors. Consequently, MCDM methods can be employed to tackle this challenge.

Geographic Information Systems (GIS) and MCDM serve as effective tools for spatial analysis and decision-making [9]. MCDM encompasses both conventional and specialized techniques that aid decision-makers in handling the complexities associated with large volumes of intricate information [10].

Finding suitable construction sites for subterranean dams is the main problem because many criteria and aspects need to be considered. Therefore, decision models that account for the significance of various criteria in selecting appropriate dam construction sites are crucial [11,12].

Various methods have been used in the literature to choose ideal sites for dam construction [13]. One of these studies, Rahman et al. [14] focuses on the application of weighted overlay analysis in ArcGIS for selecting an optimal site for a water reservoir. The researchers proposed to select the most suitable sites for the reservoir by integrating multiple criteria using GIS techniques. The study used a weighted overlay methodology, in which weights are given to several variables according to their relative importance. Various criteria, such as land use, slope, soil type, and proximity to water sources, were considered during the analysis. Using ArcGIS software, the researchers combined and analyzed the weighted criteria to generate a suitability map for potential reservoir sites. The integration of multiple criteria and the spatial analysis capabilities of GIS provided a systematic approach to decision-making in identifying suitable locations for water infrastructure projects.

Ajibade et al. [15] utilized integrated techniques of remote sensing (RS) and GIS to analyze and assess potential dam sites. Remote sensing data, such as satellite imagery, was used to extract relevant information about the landscape, including land cover, topography, and hydrological features. GIS tools and spatial analysis techniques were employed to process and integrate the data layers. The findings of the study demonstrated the effectiveness of integrating RS and GIS techniques for dam site selection. The integration of spatial data and analysis capabilities of GIS, along with the information obtained from RS, proved valuable in identifying areas that would be appropriate for building dams.

In another study, Dos Anjos and Cabral [16] aimed to decide appropriate locations for the construction of small dams/reservoirs to enhance water availability and promote agricultural development in the region. The study employed site location analysis techniques to determine optimal sites for small dams/reservoirs. Various factors such as topography, soil characteristics, land use, and hydrological data were considered as criteria for the analysis. The researchers integrated these criteria using GIS and MCDM methods.

In the literature, researchers also utilized MCDM techniques to select suitable places for underground dam construction. For example, in one of the studies, Jozaghi et al. [17] aims to compare the Analytic Hierarchy Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) techniques for dam site selection. The researchers focused on evaluating and comparing the suitability of different potential dam sites by considering multiple criteria. In that study geological factors, hydrological factors, socio-economic factors, and environmental factors are considered. These criteria were integrated into a GIS framework to facilitate the analysis and decision-making process. Findings of the study contribute to understanding the comparative performance of the AHP and TOPSIS techniques in dam site selection. The research demonstrates the potential of GIS-based MCDM methods for supporting decision-making processes in selecting optimal dam sites. In another study, Tsiko and Haile [18] focuses on the integration of fuzzy logic, AHP and GIS model to identify optimal sites for water reservoirs. The study utilized GIS to manage and analyze spatial data related to land cover, slope, drainage patterns, and proximity to water sources. Fuzzy logic was integrated into the analysis to handle the vagueness and ambiguity associated with the criteria. Through pairwise comparisons, the weights of the criteria and their relative relevance were established using the AHP approach. To evaluate the criteria and determine their importance in the selection process, expert opinions were requested. The study's conclusions demonstrated how well GIS, fuzzy logic, and AHP work together to pinpoint the best locations for water reservoirs. The integrated approach facilitated a comprehensive evaluation of multiple criteria, considering both spatial and non-spatial factors, and provided decision-makers with valuable information for informed decision-making in water resource management and infrastructure development. In order to make the process of choosing potential locations for dam construction easier, Minatour et al. [19] sought to offer a thorough framework that integrates several criteria and methods. The goal of this project is to create an integrated MCDM method for choosing a dam location that includes both fuzzy logic and group decision-making. The fuzzy AHP approach was expanded by the researchers to account for group decision-making, and it was then integrated with the VIKOR method. By combining these approaches, it was possible to consider decision-makers subjective opinions and include uncertainty by utilizing fuzzy notions while choosing a site. The group fuzzy AHP technique was used to calculate the weights of various criteria, and VIKOR was utilized to rank the possibilities.

There are numerous MCDM techniques in the related literature. MAIRCA and EDAS are in the group of these techniques. Despite the MAIRCA methos is relatively new, it has received significant attention in the literature. Gigović et al. [20] used the GIS along with the DEMATEL (Decision Making Trial and Evaluation Laboratory), Analytic Network Process (ANP), and MAIRCA methods to determine suitable locations for an ammunition depot. The study evaluated eight locations based on six criteria. In another study, Pamučar et al. [21] assessed bidders in a public procurement tender using interval rough set-based DEMATEL, ANP, and MAIRCA methods. Chatterjee et al. [22] evaluated supplier performance considering green supply chain criteria using rough set-based MAIRCA ANP and DEMATEL methods. Badi and Ballem [23] used rough set-based BWM (Best-Worst Method) and MAIRCA methods to identify the optimal supplier. Pamucar et al. [24] applied DEMATEL and MAIRCA methods to decide where to put a logistics center. Pamučar et al. [25] evaluated water barriers using the interval-valued fuzzy rough set-based MAIRCA method. Arsic et al. [26] used the BWM and rough set-based MAIRCA methodologies to evaluate a restaurant's menu. In Turkish studies related to MAIRCA, Ekinci and Can [27] assessed operators' ergonomic risks using the CRITIC (Criteria Importance Through Intercriteria Correlation) and MAIRCA methods. Haq et al. [28] used MAIRCA method to select sustainable material. Kıran [29] evaluated countries' occupational health and safety performances using the MAIRCA method. Moreover, MAIRCA functions as a valuable mathematical tool and solution approach, providing the flexibility to integrate with other methods. Besides, numerous studies conducted after the EDAS method's creation have attempted to increase its application and reliability by incorporating various uncertainty sets in order to successfully handle challenging real-world issues involving qualitative data.

For example, Yalcin and Uncu [30] investigate the suitability of the EDAS method for the selection of industrial robots. They aim to address the complex decision-making process involved in selecting the most suitable industrial robot among various alternatives. They propose the use of the EDAS method as a MCDM tool to evaluate and rank the alternatives based on multiple criteria. In another study, Veskovic et. al. [31] explores the application of a combined approach using the EDAS and AHP method for evaluating logistics processes. The study applies the combined AHP-EDAS method to evaluate logistics processes in a real-world context. While the EDAS technique is used to assess and rank the alternatives based on their distances from the average solution, the AHP approach is used to determine the weights of various criteria, representing their relative relevance.

To overcome the challenges associated with type-1 fuzzy sets, a novel version of the EDAS methodology was introduced by Kahraman et al. [32]. This modified approach incorporates intuitionistic fuzzy sets, which provide a more advanced framework for addressing the location selection of solid waste disposals. By utilizing the concepts of intuitionistic fuzzy sets, the enhanced EDAS method offers an improved methodology for dealing with the complexities and uncertainties associated with this decision-making problem. Darwis et al. [33] used EDAS method in the selection of the best student. He et. al. [34] propose an extended version of the EDAS method to handle MCDM problems in the context of green supplier selection. The researchers focus on the challenges of decision-making when dealing with probabilistic uncertain linguistic information, which often occurs in real-world situations. They develop an enhanced EDAS method that incorporates probabilistic uncertain linguistic information to enable more accurate and reliable decision-making.

MAIRCA Method

The MAIRCA method, which utilizes linear normalization and possesses a straightforward mathematical framework, is introduced by Pamucar and Lukovac [35]. The core focus of MAIRCA revolves around assessing the differences between theoretical and actual outcomes. Its prominent characteristic is the utilization of a unique linear normalization algorithm that generates reliable results. The main steps of the MAIRCA method include the following:

Step 1. Construct the decision matrix:

Identify the criteria and alternatives.

Create a decision matrix (X) with rows representing alternatives and columns representing criteria.

$$X = \begin{bmatrix} X_{11}\, X_{12} \dots X_{1n} \\ X_{21}\, X_{22} \dots X_{2n} \\ \dots \dots \dots \dots \dots \dots \\ X_{m1}\, X_{m2} \dots X_{mn} \end{bmatrix}$$

$X_{ij}, i = 1,2,\dots,n; j = 1,2,\dots,m$

Step 2. Determine preferences for the alternatives:

The MAIRCA method assumes that decision-makers are neutral in their preferences for selecting alternatives, indicating that all proposed alternatives are considered equally important. The method does not consider any assigned probability values for an alternative selection.

$$PA_i = \frac{1}{m},\ \sum_{i=1}^{m} PA_i \tag{1}$$

Step 3. Create the theoretical ranking matrix:

The theoretical ranking matrix is calculated by using the following equation.

$$T_p = PA_i\left[t_{p1}\, t_{p2}\, \dots\, t_{p1n}\right] = PA_i[PA_1W_1\; PA_2W_2 \dots\, PA_nW_n] \tag{2}$$

Step 4. Create the real ranking matrix:

The real ranking matrix is calculated by using the following equations, use Equation 3 for the benefit type criterion and Equation 4 for the cost type criterion.

$$t_{rij} = t_{pij} * \frac{(X_{ij} - X_{min})}{(X_{max} - X_{min})} \tag{3}$$

$$t_{rij} = t_{pij} * \frac{(X_{max} - X_{ij})}{(X_{max} - X_{min})} \tag{4}$$

$$T_r = \begin{bmatrix} t_{r11}\ t_{r12} \cdots t_{r1n} \\ t_{r21}\ t_{r22} \cdots t_{r2n} \\ \cdots\cdots\cdots\cdots\cdots\cdots \\ t_{rm1}\ t_{rm2} \cdots t_{rmn} \end{bmatrix} \quad (5)$$

Step 5. Calculate the Total Gap Matrix:

The total difference matrix is derived by subtracting the theoretical evaluation matrix (Tp) from the actual evaluation matrix (Tr). This process involves subtracting the corresponding values in each cell of Tp from the corresponding values in the Tr to determine the differences between the theoretical and actual assessments for each attribute.

$$G = T_p - T_r = \begin{bmatrix} g_{11}\ g_{12} \cdots g_{1n} \\ g_{21}\ g_{22} \cdots g_{2n} \\ \cdots\cdots\cdots\cdots\cdots\cdots \\ g_{m1}\ g_{m2} \cdots g_{mn} \end{bmatrix} = \begin{bmatrix} t_{p11} - t_{r11}\ t_{p12} - t_{r12} \cdots t_{p1n} - t_{r1n} \\ t_{p21} - t_{p21}\ t_{r22} - t_{r22} \cdots t_{p2n} - t_{r2n} \\ \cdots\cdots\cdots\cdots\cdots\cdots \\ t_{pm1} - t_{rm1}\ t_{pm2} - t_{rm2} \cdots t_{pmn} - t_{rmn} \end{bmatrix} \quad (6)$$

Step 6. Calculate the criteria function and obtain the rankings:

The criterion function values for each alternative are calculated individually by summing up the difference values, as depicted in Equation 7. This process involves adding the respective difference values across all attributes for a particular alternative, resulting in a single criterion function value that represents the overall performance or evaluation of that alternative.

$$Q_i = \sum_{j=1}^{n} g_{ij} \quad (7)$$

The alternative with the smallest value is determined as the best alternative.

EDAS Method

In a groundbreaking contribution to the literature on Multi-Criteria Decision-Making (MCDM) methods, Keshavarz Ghorabaee et al. [36] introduced the EDAS method as a ranking approach for complex decision-making problems that involve prioritizing multiple criteria among a set of alternatives. The steps of the EDAS method is as follows:

Step 1. Construct the decision matrix:

Identify the criteria and alternatives.

Create a decision matrix (X) with rows representing alternatives and columns representing criteria.

Step 2. Calculate the average solution:

Compute the average value for each criterion across all alternatives.

Calculate the average solution vector (AS) using the equation:

$$\mathrm{AV}_j = \frac{\sum_{i=1}^{n} X_{ij}}{n} \quad (8)$$

where AV_j is the average solution value for the j-th criterion, n is the total number of alternatives, and X_{ij} is the value of the i-th alternative on the j-th criterion.

Step 3. Compute the positive distance matrix (PDA) and negative distance matrix (NDA) from the average solution:

If criteria j is a benefit criteria,

$$\mathrm{PDA}_{ij} = \frac{\max(0, (X_{ij} - \mathrm{AV}_j)}{\mathrm{AV}_j} \quad (9)$$

$$\mathrm{NDA}_{ij} = \frac{\max(0, (\mathrm{AV}_j - X_{ij})}{\mathrm{AV}_j} \quad (10)$$

If criteria j is a cost criterion,

$$\mathrm{PDA}_{ij} = \frac{\max(0, (\mathrm{AV}_j - X_{ij})}{\mathrm{AV}_j} \quad (11)$$

$$\mathrm{NDA}_{ij} = \frac{\max(0, (x_{ij} - \mathrm{AV}_j)}{\mathrm{AV}_j} \quad (12)$$

where AV_j is the average solution value for the j-th criterion and X_{ij} is the value of the i-th alternative on the j-th criterion.

Step 4. Determine the weighted sum of PDA and NDA for all alternatives:

Assign weights to each criterion to reflect their relative importance.

$$\mathrm{SP}_i = \sum_{i=1}^{n} \mathrm{W}_j PDA_{ij} \quad (13)$$

$$\mathrm{SN}_i = \sum_{i=1}^{n} \mathrm{W}_j NDA_{ij} \quad (14)$$

where W_j is the weight of the j-th criterion.

Step 5. Normalize the SP and SN values:

$$\mathrm{NSP}_i = \frac{(\mathrm{SP}_i)}{\max(\mathrm{SP}_i)} \quad (15)$$

$$\mathrm{NSN}_i = 1 - \frac{(\mathrm{SN}_i)}{\max(\mathrm{SN}_i)} \quad (16)$$

Step 6. Calculate the Appraisal Score (AS) value of all alternatives.

$$AS_i = \frac{1}{2}(\mathrm{NSP}_i + \mathrm{NSN}_i) \quad (17)$$

Step 7. Rank the alternatives:

Rank the alternatives based on their AS values.

The alternative with the highest AS value is considered the most favorable.

Through its distinctive normalization procedure, the EDAS method sets itself apart from other conventional techniques like TOPSIS and VIKOR. The best alternative is typically determined by how close it is to the ideal solution and how far it is from the anti-ideal solution, but in practical decision-making situations, having a lower distance from the ideal solution and a higher distance from the anti-ideal solution does not always mean that it is the best option. The best option is chosen using the EDAS method, which instead uses an average solution-based normalizing strategy. The EDAS method is a useful tool for handling complicated decision-making problems because of its departure from conventional methods.

The paper utilizes the EDAS method to evaluate and rank sites for an underground dam construction.

2. Application

In this part, an underground dam site selection problem in Izmir is solved with the proposed method. In this way, the applicability of the integrated method is illustrated. 3 experts determine 10 criteria namely, amount of precipitation (C_1), groundwater level (C_2), flow gradient (C_3), flow distance (C_4), alluvial texture (C_5), distance to villages and agricultural lands (C_6), area of agricultural lands affected by the project(C_7), fault line distance (C_8), engineering opportunities (C_9), evaporation rate (C_{10}) and 5 alternatives namely, Bergama (A_1), Kınık (A_2), Bayındır (A_3), Tire (A_4) and Kiraz (A_5). While C_7 and C_{10} are cost criteria, the others are benefit criteria. These criteria have been determined as the criteria taken into consideration by companies that will invest in dams. At first experts fill in the pairwise comparison matrixes. The pairwise comparison matrixes are illustrated in Table 1-Table3.

Then the arithmetic mean of these three pairwise comparison matrixes is computed. In the pairwise comparison matrix, experts are recommended to use a scale ranging from 1 to 10. In this suggested scale, 1 represents the lowest value, while 10 represents the highest value. The average pairwise comparison matrix is illustrated in Table 4.

After aggregating the expert opinions, the MAIRCA method is utilized the find criteria weights. The obtained criteria weights are given in Table 5.

Table 1. Pairwise comparison matrix of Expert 1.

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
C_1	-	1	1	9	9	5	3	4	5	4
C_2		-	1	5	4	6	5	5	3	3
C_3			-	5	4	3	2	5	2	2
C_4				-	5	5	3	2	2	4
C_5					-	5	4	7	9	10
C_6						-	1	5	3	5
C_7							-	1	8	10
C_8								-	2	3
C_9									-	9
C_{10}										-

Table 2. Pairwise comparison matrix of Expert 2.

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
C_1	-	10	9	8	9	4	5	3	4	4
C_2		-	9	4	3	6	4	4	3	2
C_3			-	4	3	2	1	4	2	2
C_4				-	4	4	2	1	1	3
C_5					-	4	3	6	8	9
C_6						-	1	4	2	4
C_7							-	9	7	9
C_8								-	1	2
C_9									-	8
C_{10}										-

Table 3. Pairwise comparison matrix of Expert 3

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
C_1	-	8	9	7	8	3	1	3	3	2
C_2		-	8	3	3	4	3	3	1	1
C_3			-	3	2	1	2	3	2	2
C_4				-	4	3	2	2	1	2
C_5					-	3	2	5	7	8
C_6						-	2	4	1	3
C_7							-	8	7	8
C_8								-	2	2
C_9									-	6
C_{10}										-

Table 4. Average pairwise comparison matrix

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
C_1	-	9,33	9,33	8	8,66	4	3	3,33	4	3,33
C_2		-	9	4	3,33	5,33	4	4	2,33	2
C_3			-	4	3	2	1,66	4	2	2
C_4				-	4,33	4	2,33	1,66	1,33	3
C_5					-	4	3	6	8	9
C_6						-	1,33	4,33	2	4
C_7							-	9	7,33	9
C_8								-	1,66	2,33
C_9									-	7,66
C_{10}										-

Table 5. Criteria weights

Criteria	Weight	Criteria	Weight
C_1	0.0367	C_6	0.0973
C_2	0.0806	C_7	0.0851
C_3	0.0934	C_8	0.0927
C_4	0.0972	C_9	0.0998
C_5	0.0947	C_{10}	0.0901

Experts also evaluate the alternatives. Experts' decision matrixes are depicted in Table 6-7-8 respectively.

To aggregate experts' decision matrixes, geometric mean of the matrixes is computed. The aggregate decision matrix is given in Table 9.

After that, EDAS method is utilized to rank the alternatives. The obtained AS values are illustrated in Table 10. The alternative with the highest value is selected as the best alternative.

Table 6. Expert 1 Decision Matrix

Criteria	A_1	A_2	A_3	A_4	A_5
C_1	8	3	10	9	5
C_2	7	3	9	9	4
C_3	7	1	9	8	4
C_4	6	3	10	8	5
C_5	7	2	8	8	4
C_6	5	4	9	9	4
C_7	5	2	10	7	3
C_8	5	1	10	8	5
C_9	6	2	9	7	4
C_{10}	6	1	9	7	3

Table 7. Expert 2 Decision Matrix

Criteria	A_1	A_2	A_3	A_4	A_5
C_1	7	4	9	10	6
C_2	8	1	9	8	5
C_3	7	2	7	8	5
C_4	6	2	9	9	4
C_5	7	1	8	7	3
C_6	6	3	10	8	5
C_7	9	3	10	8	4
C_8	5	2	10	9	4
C_9	5	1	9	7	3
C_{10}	5	2	10	9	5

Table 8. Expert 3 Decision Matrix

Criteria	A_1	A_2	A_3	A_4	A_5
C_1	7	1	10	8	5
C_2	6	3	10	9	6
C_3	9	2	9	10	6
C_4	8	2	10	9	7
C_5	8	3	10	9	5
C_6	6	1	9	8	5
C_7	5	5	9	8	4
C_8	7	2	8	7	3
C_9	5	3	9	9	5
C_{10}	5	1	9	8	5

Table 9. Aggregate Decision Matrix

	A_1	A_2	A_3	A_4	A_5
C_1	7.318611	2.289428	9.654894	8.962809	5.313293
C_2	6.952053	2.080084	9.321698	8.653497	4.932424
C_3	7.611663	1.587401	8.276773	8.617739	4.932424
C_4	6.603854	2.289428	9.654894	8.653497	5.192494
C_5	7.318611	1.817121	8.617739	7.958114	3.914868
C_6	5.646216	2.289428	9.321698	8.320335	4.641589
C_7	6.082202	3.107233	9.654894	7.651725	3.634241
C_8	5.593445	1.587401	9.283178	7.958114	3.914868
C_9	5.313293	1.817121	9.000000	7.611663	3.914868
C_{10}	5.313293	1.259921	9.321698	7.958114	4.217163

Table 10. Obtained AS Values and Ranking

Alternative	AS value	Rank
A1	0.4830	4
A2	0.5000	1
A3	0.4927	2
A4	0.4846	3
A5	0.4763	5

The alternative A2 is chosen to construct the underground dam.

3. Conclusion

Underground dams are widely acknowledged as facilities designed for storing water beneath the surface, particularly in regions with semi-arid climates. In areas where the utilization of surface water has reached sustainable levels, exploiting groundwater resources emerges as a favorable complementary option. Additionally, in arid regions where surface water is scarce or absent, groundwater serves as the sole available source for domestic needs. Presently, there is increasing emphasis on managing these resources in a sustainable manner. It is evident that establishing boundaries for the development and utilization of groundwater is crucial to ensure its long-term viability and prevent adverse environmental, economic, and social impacts. In the forthcoming decades, the sustainability of surface water resources is anticipated to become a pivotal concern, leading to an inevitable shift towards groundwater utilization.

This study addresses the problem of site selection for an underground dam. Multiple criteria decision-making methods are employed in this study. Firstly, three decision-makers are identified for the study. These individuals determine the criteria required for the selection of an underground dam site. The MAIRCA method is utilized to assign weights to the identified criteria. Subsequently, alternative locations for the dam site are determined using this method. The EDAS method is employed to evaluate the five different alternative locations. Based on the results of the EDAS method, the most suitable location among the five alternatives is selected. The purpose of using MAIRCA and EDAS is to fill the gap in this field because these methods have not been used before. Furthermore, as mentioned in the introduction section, both EDAS and MAIRCA have advantages compared to other methods, such as robustness, flexibility and transparency.

One constraint of this study is that the number of alternatives and experts relatively small. Additionally, future research could explore the use of fuzzy-based algorithms, apart from the methods employed in this study, to provide decision-makers with more flexibility in decision-making.

Author Contribution Statement

All authors are contributed to the paper equally and they have accepted responsibility for the entire content of this manuscript and approved its submission.

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