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DAM SITE SELECTION USING GIS-BASED AHP-OWA APPRO CASE STUDY: EL KEBIR SHEMALY RIVER, SYRIA

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التقليدية في اختيار مواقع السدود مكلفة وتتطلب مجهوداً كبيراً. لكن التطور التكنولوجي يمكننا من استخدام تقنية
معلومات الجغرافية و AHP-OWA اللتان تعتبران الطريقتين الأكثر شيوعاً في حل مثل هذا النوع من المسائل.
البحث استخدمنا ميل الحوض، نوع التربة، صلابة الجيولوجية السطحية، استخدامات الأراضي، توزع الأمطار،
التصريف النهري، المسافة إلى الطرق، والمسافة للمناطق المخدمة كمعايير لاتخاذ قرار تحديد المواقع الممكنة
على نهر الكبير الشمالي في سوريا. هذه التقنية تظهر تأثير المعايير البيئية والاقتصادية والهيدرولوجية في تحديد
لسد. كما تسمح هذه التقنية باستخدام التعابير اللفظية في إتخاذ القرار وبالتالي تعطي مجالاً واسعاً من سيناريوهات
لقرار.

ABSTRACT:

Dam site selection is not a new problem; the traditional methods for solving this prol costly and time consuming. Nowadays, advancement in technologies allows us t maximum resources at optimum cost. Geographic Information System (GIS) based mul decision analysis approaches are the common methods used for solving this type of probl In this research, to locate potential dam sites along El Kebir Shemaly River, the criteria soil, geology, landuse, rainfall, drainage network, distance from road, and distance fro area were developed and implemented. The approach is based on the extension of Analytical l Process using fuzzy quantifiers guided by Ordered Weighted Averaging operators (GIS-bas OWA). The outcomes indicate that the developed criteria were sensitive to physical, hydr

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environmental and economical settings on the study area. Furthermore, by changing the l quantifiers, the GIS-based AHP–OWA can generate a wide range of decision strategies.

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KEYWORDS: **Dam Site Selection, Geographic Information System (GIS), Analytical Hierarchy Process (AHP), And Ordered Weighted Averaging (OWA), MCDA.**

1-INTRODUCTION:

In simple terms, a reservoir means a construction that holds a volume of water. This d indicates the need to examine both the reservoir and dam site locations. Therefore, ch suitable site is a crucial phase in reservoir construction. A well-selected site will not only optimum benefits, but its aesthetic value may also create a recreational area surroun reservoir [1].

Dam site selection is considered as a multi-faceted challenge. Not only does it often numerous technical requirements, but it may also contain economic, social, environme political dimensions that may have conflicting values. The process of finding the location that meets the required conditions, is a decision-making process, where a large of information must be gathered, combined, and analyzed to make correct criteria that m the final decision.

Over the past few years, a Geographic Information System (GIS) was an important providing a comprehensive means of managing and handling water resources data in a cannot be accomplished manually. The attribute data in GIS can be accessed by softv used as input to various modeling procedures to generate derived products that can be come up with decisions related to water resource management. These decisions are guided by multiple objectives and multiple stakeholder groups with divergent interest may involve technical, economic, environmental, and/or social issues.

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Decision makers are now using conventional GIS tools by integrating the effici manipulation and visual presentation capabilities of GIS with Multi-criteria Decision (MCDA). MCDA is a group of conventional and tailored techniques that can aid c makers in dealing with the difficulties they encounter in handling large amounts of information at the same time. Decision makers are now integrating the strengths of MCDA in water resource management [2].

Several attempts are made to evolve a decision rule based approach for identifying appropriate site for a dam. For example, GIS was used to select the location of dam according to the results of morphometric analyses of the valley watershed on Wadi Al Iraq [3].Also, a raster calculator in GIS software was used to determine a hydroelectric considering: slope, closeness to road, closeness to cities, larger mean of water discha value of hydraulic head as a criteria of site selection. Additionally AHP and fuzzy AHP were used for pairwise comparison between the criteria [4].Boolean Intersection (AI utilized to identify restricted areas of a dam by environmental and hydrological co considering the factor maps of: slope, elevation, closeness to road, closeness to citie discharge, hydraulic head, geology type, soil type, and rainfall. As criteria of site selectic logic with the Analytic Hierarchy Process (AHP) was integrated to identify the weights maps. The constraints and factor maps were combined to obtain the optimum site of water dam [2]. The GIS overlay method was used in order to locate dams in Wadi D Wadi Umm Qatffa, Jordan, considering the drainage network, geology, and tectonics a for dam site selection [5]. Several previous studies show the use of traditional GIS met dam site selection or GIS-based Analytical Hierarchy Process (AHP) method.

The main objective of this paper is to find dam sites by changing the linguistic qu using the GIS-based AHP–OWA (the extension of Analytical Hierarchy Process usi

quantifiers-guided ordered weighted averaging). GIS-based AHP-OWA operators for sol
problem will allow decision-makers to generate a wide range of selection strategies.

2. GIS-based multicriteria decision analysis approach for dam site selection:

2-1 Analytical Hierarchy Process (AHP):

AHP is a powerful tool in applying MCDA that was introduced and developed by S which depends on pairwise comparison of criteria. In this study, the integration betw AHP and GIS for dam site selection is used. Figure(1) describes the steps of dam site using GIS-based AHP,, where the first step starts with building the hierarchy of selection by determining the main criteria under the goal and the sub criteria associated main criteria, then preparing the criteria maps in a GIS environment.

In order to combine these heterogeneous data that result from GIS, it is mandatory to sta all sub-criteria by bringing them into a common domain of measurement. In each hie level, the weights of the elements are calculated based on the pairwise comparison metho the pairwise comparison method employs an underlying scale with odd values from 1 to the relative preferences for two elements of the hierarchy developed by Saaty [6]. If t need, then intermediate values (2, 4, 6, and 8) between two adjacent intensities can be us measures the inconsistency of judgments by calculating the Consistency Index (CI) of th CI must be < 0.10. For the analysis to be valid [6]. The last step of AHP in GIS environn obtain the overall priority score for each alternative. The overall priority score, R_i o alternative is calculated in Equation (1):

$$R_i = \sum_{j=1}^{n} w_j x_{ij} \qquad (1)$$

Where w_j is the aggregated composite weight of objectives and attribute weights. The are calculated by the multiplications of the matrices of relative weights at each hierarchy. X_{ij} is the standardized attribute value for *i-th* alternative.

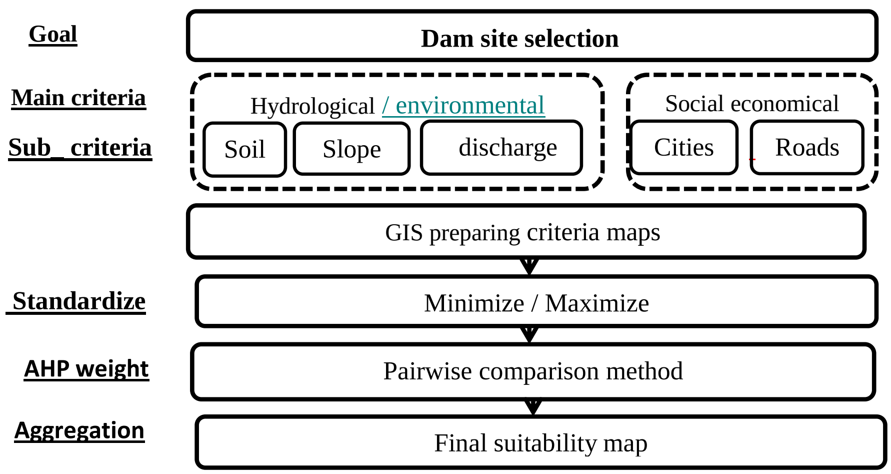

Fig.1.GIS-based AHP

2-2 Ordered Weighted Averaging (OWA):

OWA is a family of multi-criteria aggregation procedures developed by Yager [7] as a decision-making in a fuzzy environment. Yager [9] modified the OWA operators usi linguistic quantifiers. OWA involves two sets of weights: criterion, or importance wei order weights. The critical element of the OWA procedure is the method for obtaining t weights. There are several methods for obtaining the order weights; this study uses linguistic quantifier approach. They can be represented as fuzzy subsets over the unit with proportional fuzzy statements, such as: All of the criteria should be satisfied (' short) [9].

The weights of OWA are obtained by multiplying the criterion weights by order weigh and GIS for dam site selection (Figure (2)) start by identifying dam site selection criter on dam purpose, then creating Standardized Criterion Maps. After that, the decisio estimates the criterion weights using Equation (2):

$$w_i = \frac{(n - r_i + 1)^p}{\sum_{k=1}^{n}(n - r_i + 1)^p} \qquad (2)$$

Where, n is number of criteria, r_i is the rank number of criterion I, P is a parameter descr weights distribution.

The decision maker generates a set of order weights associated with Q specifying tl linguistic quantifier. The order weights can be derived from attribute weights using Equ as follows:

$$V_j = \left(\sum_{k=1}^{j} u_k\right)^{\propto} - \left(\sum_{k=1}^{j-1} u_k\right)^{\propto} \qquad (3)$$

Where u_k is the reordered j-th attribute weight, w_j;

Given the attribute weights, w_j, attribute values x_{ij}, and the parameter α, Z_{IJ} is is obt
reordering the attribute values x_{i1}, x_{i2}, …, x_{in}, the linguistic quantifier-guided OWA can be
using Equation (4) as follows:

$$OWA_{(I)} = \sum_{J=1}^{N}\left(\left(\sum_{k=1}^{j} u_k\right)^{\propto} - \left(\sum_{k=1}^{j-1} u_k\right)^{\propto}\right) Z_{IJ} \qquad (4)$$

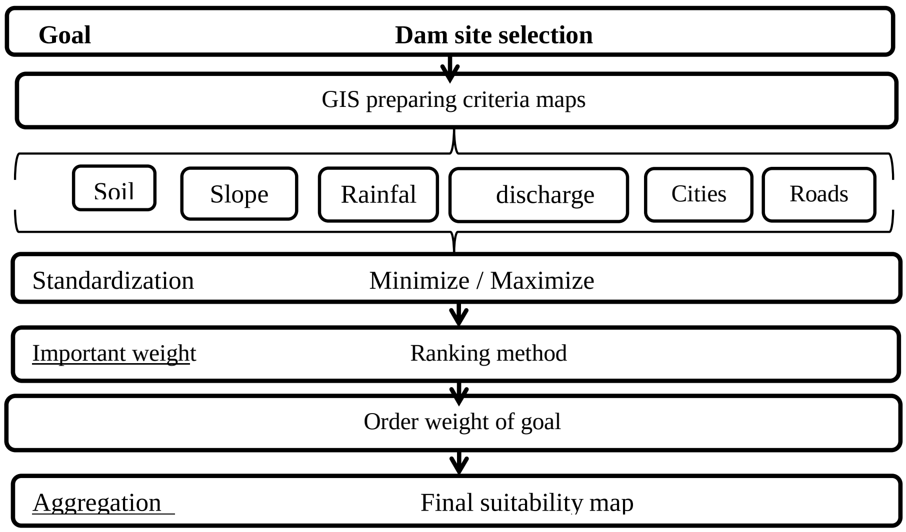

Fig.2.GIS-based OWA

2-3 AHP-OWA Procedures:

Yager and Kelman developed the capabilities of AHP as a comprehensive tool for
making by integration of the fuzzy linguistic OWA operators in ArcGIS environment [
inclusion of AHP and OWA can provide a more powerful multicriteria decision making
structuring and solving decision problems including spatial decision problems.

In this method (AHP-OWA), we used the first two steps in AHP method to cons
hierarchical structure, and obtain weights for objectives and attributes by conducting
comparisons.

Then, linguistic quantifier-guided OWA is used to support user's decision-makin
main steps are involved at this stage: 1) specifying a linguistic quantifier Q, 2) generating
order weights associated with Q, and 3) calculating the overall score for each alternati
linguistic quantifier-guided OWA [12].Figure (3) describes the steps of dam site selecti
GIS-based AHP –OWA.

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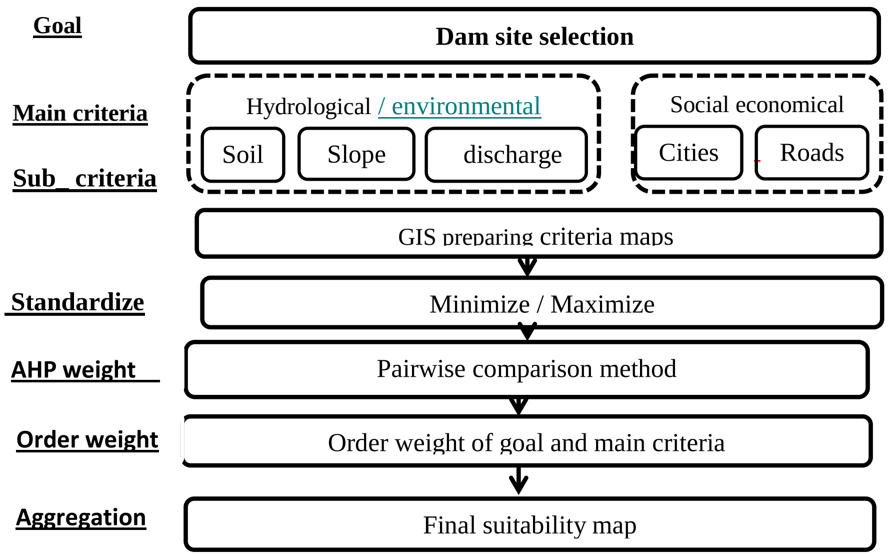

Fig.3.GIS-based AHP -OWA

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To implement the proposed GIS-based MCE approach for dam site selection, we had mo tool developed by [11] to be useful for dam site selection, so the tool is able to use the thr methods of multi criteria (AHP, OWA, AHP-OWA) to find the dam site selection in GIS environment.
The tool was written using C# programming language in Visual Studio 2008 environmer toolbar within ArcGIS desktop. As shown in Figure (5) a Dam Site Selection Toolbar is comprised of three main menus (data standardization, and AHP, OWA, AHP/OWA meth

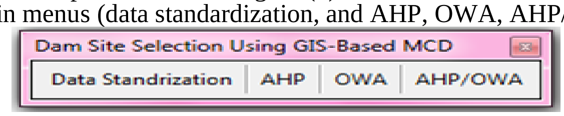

Fig.5 Dam Site selection using GIS-based MCE toolbar.

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3- CASE STUDY:

The study area is located in the Northeast part of Latakia city, Syria, as part of the Sahe Figure (4). The basin is located in a tropical area affected by the Mediterranean climate. in the study area is subtropical with distinct lack of rain and high temperatures in sum moisture in winter.

Fig.4. Location of El Kebir Sheemaly basin

The objective of this study is to suggest the optimum site of a dam in El Kebir basin for i and water supply. In order to evaluate the dam sites, the factors that influence dam site include environmental (slope, soil, geology, landuse), hydrologic (rainfall, drainage r socio-economic (distance from road, distance from target area) factor as in Table (1).

Table (1) shows the criteria of dam site selection and their description.

Criterion	Description
Ground Slope	The medium ground, the better
Soil Type	The closer from good soil, the better
Geology bed rock type	The dam must be built on stable foundation
Rainfall/ discharge	The larger mean of rainfall and water discharge, the better
River/stream	The dam must be built on a stream or near it
Roads	The closer to the road, the better
Urban places	The closer to the cities, the better

After preparing and standardizing criterion maps, the next step is using the AHP-OWA m identify the most suitable locations for the dam. The core of AHP-OWA model is bui decision hierarchy structured of dam site criteria, Figure (6).

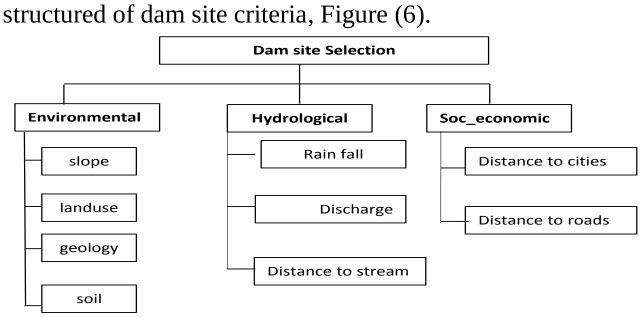

Fig.6. Hierarchy model for dam siting

~~**Fig.6. Hierarchy model for dam siting**~~

The relative weights for all objective clusters and their related attributes are then calculat the pairwise comparisons Saaty [6]. The pairwise comparison method requires an exper planning to provide best judgments regarding the relative importance of objectives and a In this paper, since the dam is built for agriculture and drinking water supply, we depend expert questionnaire to set the main and sub-criteria as well as their relative importance (2) to (5) show the Pairwise comparison matrix of criteria.

Table 2. Pairwise comparison matrix of main criteria.

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	Environmental	hydrologic	Socio-economic	**Weight**
Environmental	1	1	3	**0.634**
hydrologic	1	1	2	**0.260**
Socio-economic	0.33	0.5	1	**0.106**

Table3- Environmental- criterion paired comparison

	Weight
soil	**0.104**
landuse	**0.470**
slope	**0.278**
geology	**0.148**

Table4- hydrological criterion paired comparison

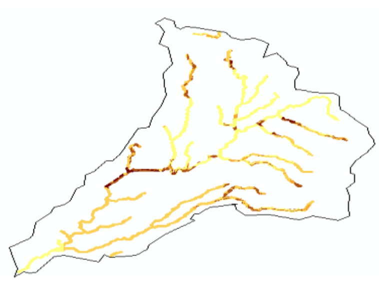
	Weight
Distribution of rain	**0.106**
distance to stream	**0.633**
discharge	**0.261**

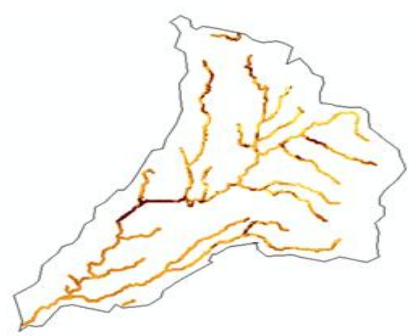
Table5- Economic-social paired comparison

	Weight
distance to roads	**0.249**
distance to cities	**0.751**

Different outcomes can be generated by varying the linguistic quantifiers in the AH procedures. One can obtain a very large number of evaluation outcomes by varyi parameter associated with the linguistic quantifiers. There are 7 linguistic quantifiers as with the goal and three objectives; thus, theoretically, $7^{(1+3)}$ alternative evaluation scen be generated for this case study.

In this paper, since the dam is built for agriculture and drinking water supply, we analysis to a selection of three linguistic quantifiers: "Most" is assigned to environmental is assigned to hydrological, and "Most" is assigned to accessibility to socio-economic We applied selected fuzzy linguistic quantifiers ("Few", "Some", "Half", "Most", and " the goal of the decision-making to obtain a series of accessibility evaluation outcomes. A in Fig (7) the results of these scenarios were assigned a class between 1 and 5 depending suitability for siting a water reservoir. The higher the score is, the more suitable the ar siting a water reservoir.





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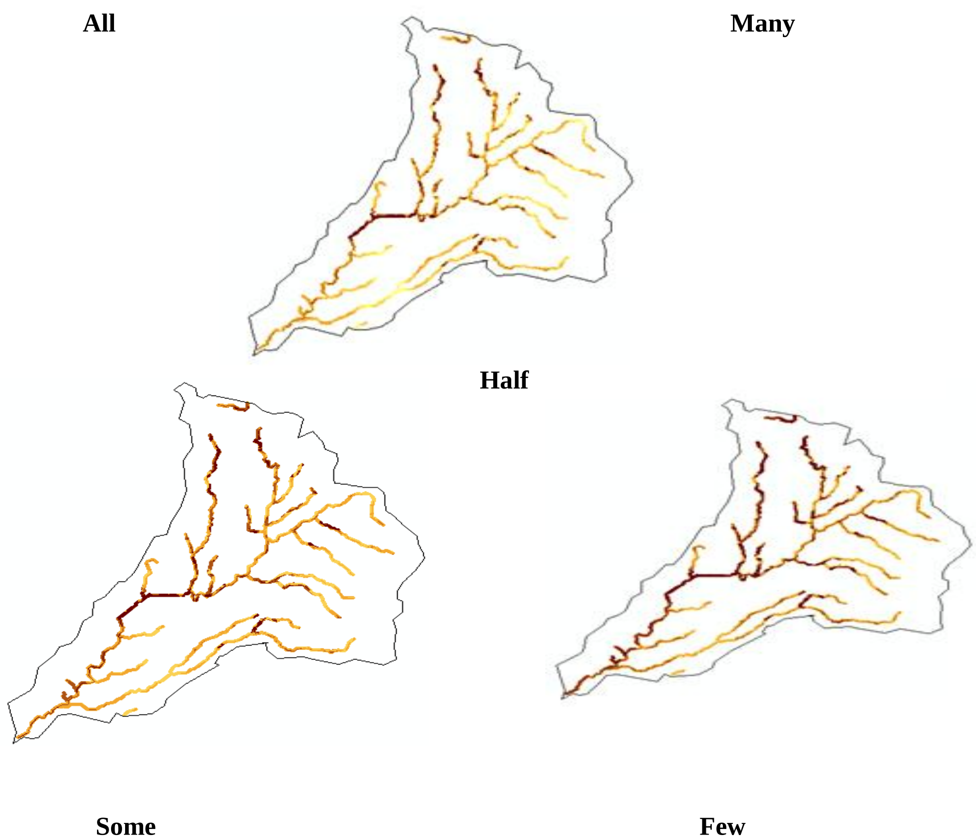

Fig.7. Site suitability for dam site: the results of AHP–OWA procedures

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The scenario associated with the “Half” (α = 1.0) represents the scenario correspondin conventional weighted linear combination on the level of objectives. The decision-r characterised by neutral attitudes. It implies a situation in which an equal probability is as with all possible outcomes at that location.

Finally we suggested four locations of dams in Kabeer Al Shemaly River as shown in Figure

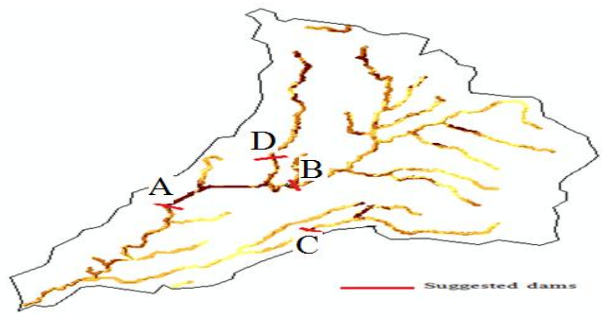

Fig.8. suggested locations dams (AHP procedures)

Addition of criteria of engineering, hydrology, and economic evaluations, to cho optimum location such as storage capacity, construction cost, height of dam, length, r area …etc. was done. Using AHP, we compare between them. The decision- make imagined many sites known as A, B, C, and D. Their evaluation in relation to each cri represented in the following Table (6).

Table (6) Hydrological information about the sites

Sites \ Criteria	A	B	C	D
Reservoir area (km^2)	11.2	3.47	2.8	1.67
Actual storage (MCM)	210.00	5.49	3.96	5.34
Width of the valley(m)	42	16	30	15
Height of the valley (m)	52	40	38	60

The following phase is using the AHP method to calculate the weight of every criterion shows the calculation.

Table (7) AHP method to calculate the weight of every criterion.

Criteria \ Criteria	Reservoir area	Actual storage	width of the valley	Height of the valley	Vector weights
Reservoir area	1	1	3	2	0.377
Actual storage	1	1	2	2	0.285
width of the valley	0.333	0.5	1	2	0.205
Height of the valley	0.5	0.5	0.5	1	0.132

The weights of the criteria having been calculated, we then proceed to the normalizatio criteria values. This normalization is obtained by dividing the value of the crit corresponding to action *J* by the sum of the criterion value *I* of all actions 1, 2, 3, 4, 5, Se (8).

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Table (8) Normalisation Matrix of the criteria

Sites \ Criteria	A	B	C	D
Reservoir area	0.585	0.18	0.146	0.087
Actual storage	0.936	0.024	0.017	0.023
width of the valley	0.408	0.155	0.29	0.145
Height of the valley	0.273	0.211	0.2	0.316

The last phase of the process is the final assessment of actions. These assessments are calcu
the following way:

$$0.377 * \begin{bmatrix} 0.585 \\ 0.18 \\ 0.146 \\ 0.087 \end{bmatrix} + 0.285* \begin{bmatrix} 0.936 \\ 0.024 \\ 0.017 \\ 0.023 \end{bmatrix} + 0.205* \begin{bmatrix} 0.408 \\ 0.155 \\ 0.29 \\ 0.2 \end{bmatrix} + 0.13* \begin{bmatrix} 0.273 \\ 0.211 \\ 0.2 \\ 0.316 \end{bmatrix} = \begin{bmatrix} 0.606 \\ 0.141 \\ 0.145 \\ 0.121 \end{bmatrix}$$

The synthesis of the results obtained has resulted in the following assessments:

Alternative(A)	alternative(B)	alternative(C)	alternative(D)
0.606	0.141	0.145	0.121

This assessment allows to order the actions in the following way: Alternative A proves to be the most suitable, followed by alternative C (0.145). Alternative B (0.141) is in the middle of the ordering, and alternative D (0.121) is placed at the end of the order result shows well the precision obtained from the proposed analysis as well as th significance of the values obtained.

4- SUMMARY, CONCLUSIONS, and RECOMMENDATIONS

Developing and using GIS-based MCDA tools for site selection is a complex pro needs well trained GIS developers and analysts to carry out these projects.

In this study, a GIS-based MCDA site selection tool has been developed to overc above limitations. This tool has been developed as a toolbar in ArcGIS9.3 to achieve interoperability. The following conclusions can be made from this study:

1. Geographical information systems are very useful tools to determine the best loca water harvesting projects. The application of multi-criteria increases the accurac results and limits the appropriate areas of the sites selected carefully to ensure the su the project
2. The study showed that geographic information systems open the door to the introdu new criteria for locating dam projects, and largely help to take the deci implementation of water harvesting projects.
3. It has also been found that this module is a valuable and user-friendly tool. In comp the conventional GIS-based multicriteria evaluation methods, it gives more flexib

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high efficiency for evaluating land suitability of dams. The capability of it to gene visualise a range resultant scenarios is particularly useful.

4. This integration allows decision-makers to define a decision strategy on a cc between pessimistic (risk-averse) and optimistic (risk-taking) strategies. Moreover, t has demonstrated how, by applying different linguistic quantifiers, decision-make obtain a wide range of decision strategies and scenarios taking into account the leve the decision-makers wish to assume in their MCE.
5. The paper has suggested a possible combination of AHP using fuzzy linguisti operators instead of a simple weighted average in the process of aggregation of co satisfactions, which in turn brings natural language quantification to spatial decision
6. Several alternative scenarios of site suitability for a dam have been developed in th The alternatives show how the decision-maker's attitude involved in suitability decision-making process can influence the outcomes.
7. As a result, this work could be taken further by conducting field validation in compare and technically evaluate all the candidate sites in terms of their enviro impact assessment, from which the top ranking sites will undergo further geotechn hydro-geological detailed investigations.

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~~إيجاد مواقع السدود باستخدام تقنية التحليل الهيكلي ومتوسط الأوزان المرتبة~~
~~(AHP-OWA) في بيئة نظم المعلومات الجغرافية~~
~~حالة دراسية: نهر الكبير الشمالي، سوريا~~

~~ـ التقليدية في اختيار مواقع السدود مكلفة وتتطلب مجهوداً كبيراً. لكن التطور التكنولوجي يمكننا من استخدام تقنية~~
~~علومات الجغرافية وAHP-OWA اللتان تعتبران الطريقتين الأكثر شيوعاً في حل مثل هذا النوع من المسائل. في~~
~~حث استخدمنا ميل الحوض، نوع التربة، صلابة الجيولوجية السطحية، استخدامات الأراضي، توزع الأمطار،~~
~~التصريف النهري، المسافة إلى الطرق، والمسافة للمناطق المخدمة كمعايير لاتخاذ قرار تحديد المواقع الممكنة~~
~~على نهر الكبير الشمالي في سوريا. هذه التقنية تظهر تأثير المعايير البيئية والاقتصادية والهيدرولوجية في تحديد~~
~~لسد. كما تسمح هذه التقنية باستخدام التعابير اللفظية في إتخاذ القرار وبالتالي تعطي مجالاً واسعاً من سيناريوهات~~
~~لقرار.~~