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An Integrated Fuzzy Multi-Criteria Decision-Making Method Combined with the WEAP Model for Prioritizing Agricultural Development, Case Study: Hirmand Catchment

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ABSTRACT

Aims Water is a basic demand of sustainable development in every region of the world. Hirmand catchment is one of the most important cross-border of Iran basins affected by the recent drought periods from water scarcity and caused severe crisis in the Sistan region. Fuzzy theory is able to convert most incorrect and enigmatic concepts, variables and systems into a mathematical form and set the context for reasoning, deduction and decision making at uncertainty conditions. The aim of this study was to simulate the Hirmand catchment by Water Evaluation and Planning System (WEAP) model and prioritization of the implementation of agriculture development projects in Hirmand catchment.
Materials & Methods In this analytical-computational study, water development projects in the study area were predicted. The effects of the water development projects predicted using WEAP model and the projects according to the economic criteria was evaluated and prioritized with Fuzzy Technique for Order Preference by Similarity to Ideal Situation (TOPSIS). Ten water development projects and criteria including 5 economic indexes were considered.
Findings Water transfer project to agricultural field called Zehak and Sistan were the first priorities which is needed for noticing target population to these projects. Irrigation efficiency (70%) was in the third rank among the options. Water transfer project to agricultural field called Zehak and Sistan were the first priorities which is needed for noticing target population to these projects. Irrigation efficiency (70%) was in the third rank among the options.
Conclusion The remarkable thing in the ranking of scenarios is that the current account scenario (SC1) is lasted ranking that shows Sistan region's water status, according to the study criteria is not good.

Keywords Fuzzy Multiple Attribute Decision Making; WEAP Model; Prioritize; Agriculture; Development Project; Hirmand Catchment

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Introduction

Due to the relative constancy of the water resources in the world, water crises can occur because of the population growth, increasing pollution of water resources, changing of the consumption patterns, challenges of the climate change and also lack of the water resource allocation mechanism [1]. Moreover, shared water resources which are used by two or more beneficiaries lead to intensifying complexity in optimal allocation of water resources planning and management [2].

Hirmand River is the only main source of water in the Sistan region where any changes in the entrance of the river will have significant effects in this region. In recent years, the amount of the water enters by the river has fallen in Sistan and has created a critical situation in the region. Due to the critical situation in the Sistan region, water plans that reduce the water stress in the area were failed. Hence, studying their effects and prioritizing them are very important.

On the other hand, the development of water projects is very important in this region and requires a comprehensive review according to various indicators and prioritizes these projects.

Hirmand catchment in Sistan region (30°5' N-31°28' N and 61°15' E-61°50' E) is located close to border of Iran and close to Pakistan and Afghanistan, in the southeastern part of Iran (Figure 1). There are 5 cities with 1050 villages and approximately a population of 0.4 million in Sistan region. The climate of the region is rather arid with an annual average of precipitation that is 60mm occurring mainly in winter while the mean of evaporation exceeding 4000mm yr^{-1} because of high temperatures. Hirmand River (sometimes called Helmand River) is considered as a source of life. This river emanates from Afghanistan's Helmand Province in Baba-Yaghma Mountain and comes across the border of Iran (Sistan region) and divides into two main branches (Paryan and Sistan) and eventually releases into the Hamoon Wetland. Chahnimeh reservoirs are the other important sources of water storage in the Sistan region. The main occupation of the region is agriculture, therefore the reservoirs can play an important role in the life of these people [3].

Water is a finite resource in the Sistan region and also it is a very important economic and social resource for the people that living in this region. It is essential to explore how the future water resources of the catchment will look like in order to have a better plan for sustainable social-economic development. There is a wide variety of users of water with apparently different interests, influences and objectives. The Hirmand River supplies for drinking water source of one million people in the Sistan region. Farming is the main occupation of the Sistan people which is highly influenced by the Hirmand River. Hamoon Lake (e.g. Hamoon Saburi, Hamoon Puzak) is the largest freshwater ecosystem in the Iranian Plateau, and one of the first wetlands identified in the Ramsar convention that its conservation is important. Investigate of the effects of water development projects envisaged by the government in the Sistan region on agriculture farms and wetlands are very important (Figure 1) [4].

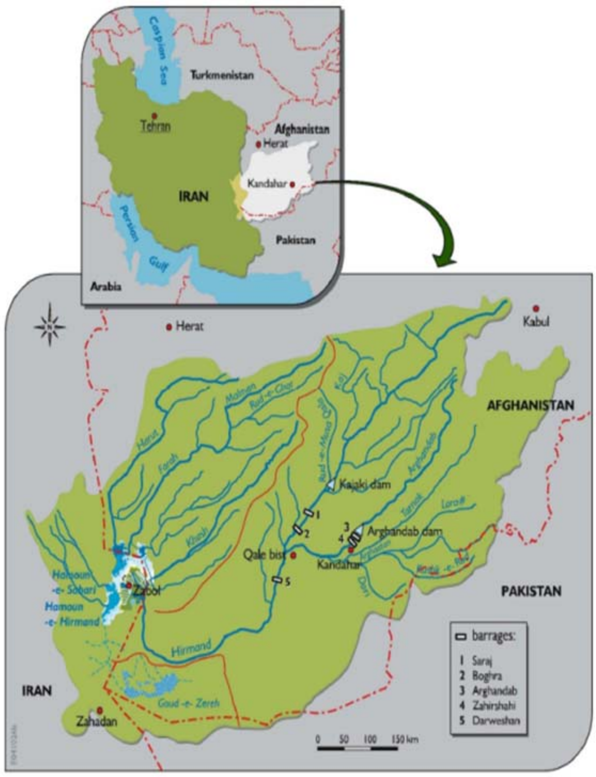

Figure 1) Hirmand Catchment located in Sistan region, south-east Iran

The aim of water-efficient management in a catchment is to increase water productivity, social justice, and protection of ecosystems in the environment and to require the identification and understanding a set of water-related interaction in different levels, spatial, and temporal in the catchment. Lack of knowledge about the mentioned relationships, poor management of water supply and demand and actions of the management are the main causes of the water crisis in many catchments.

Nowadays water resources planning using multi-attribute decision making has attracted the attention of many decision-makers. This indicates that these methods provide the perfect solution for complex decision making of water [5].

Always implementing these projects and management plans include many relevant factors and options that require appropriate management, adoption and use of all factors or as much as possible more effective and more important factors and evaluate them for the selection of projects. In this context, in the Sistan area according to the water conditions, different scenarios of water resources management by the consult with the department of energy are forecasted. Each of these scenarios will have a major impact on water consumption in the region.

In the present study, the superior options for water development in Hirmand catchment using fuzzy multi-criteria decision analysis were determined.

Fuzzy theory is used while there are some uncertainties about the determination of an effective action. The theory has this ability to specify most inaccurate and ambiguous concepts, variable and systems into a mathematical form and provide the problem for analysis then conclusion and in terms of uncertainty conditions decisions can be made. Fuzzy logic is considered as the state of reasoning with fuzzy sets. With the application of fuzzy management science, constructed models are nearly the same as human processes with qualitative data intelligently.

Thus management systems become more flexible and it is possible to organize large and complex organizations in variable environments [6]. Russel and Skibniewski [7] gave high priority to the factors including measures of reputation, past performance, financial condition, workload, and technical expertise. Studies related to the discussion of water by using multiple attribute decision making, it can be noted as follows:

Shafaiyan fard *et al.* [8] were examined superior options exploitation of water resources using Water Evaluation and Planning System (WEAP) model, analysis and multiple attribute decision making. According to the results of this research, the scenario of further development in summer planting was selected. Talebi *et al.* [9] in water allocation priorities of dam Sanandaj using fuzzy analytic hierarchy process (FAHP) concluded that economic criteria with a part weight of 0.351 compared to the other two criteria have the greatest importance. Abrishamchi *et al.* [10] using multi-criteria decision were examined urban water management and selected the best water distribution in Zahedan city.

Group fuzzy multi-criteria decision by Razavi Toosi *et al.* [11] is an examination to prioritize projects of transferring water between basins. Sasikumar and Mujomdar [12] proposed a fuzzy multi-objective model for water quality management in river systems. In this study, qualitative targets of organizations responsible for river water quality protection and pollutants discharge was considered in fuzzy form. To manage water resources in times of flood was used fuzzy multi-criteria optimization model by Chuntian [13]. Fuzzy multi-criteria decision making methods and its application in management and flood control reservoirs were also used by Fu [14].

In the present study, Fuzzy Technique for Order Preference by Similarity to Ideal Situation (F-TOPSIS) method for ranking scenarios of water projects is used in the Sistan region to evaluate different scenarios of water management and prioritize them with some different objectives. The WEAP model is used to simulate the water resource engineering system in the Hirmand catchment. WEAP has been developed by Stockholm Environment Institute's U.S. Center and the special support of the Engineering and Hydrology Center of the American Army Engineers Association. A number of institutions, including the World Bank and the Global Fund for Japan's Global Fund, are sponsoring it. In many studies, a WEAP model has been used to simulate and manage water resources. For example, applications of WEAP technique can be seen in similar researches like Leevite *et al.* [15], Musota [16], Hollerman *et al.* [17], Mutiga *et al.* [18], Mounir *et al.* [19], Hadded *et al.* [20], Vonk *et al.* [21], Dimova *et al.* [22], Li *et al.* [23], Yaqob *et al.* [24], Huang *et al.* [25], Esteve *et al.* [26], Mourad and Alshihabi [27], Mishra *et al.* [28], Rafiee Anzab *et al.* [29].

In this study, for the first step, models of water resources engineering (WEAP) and fuzzy multiplier decision making have been integrated. Both techniques have been used separately in many studies, but so far, this technique has not utilized in compilation models. In this study, the combination of these techniques had been considered and applied to the Hirmand River in the Sistan region.

The main aim of this research was to simulate the Hirmand catchment by WEAP model and prioritization of the implementation of agricultural development projects in Hirmand catchment.

Materials and Methods

The present study is analytical-computational.

Sistan region is formed from 3 important agricultural sector (agriculture demand), 6 urban sectors and one rural sector (drinking demand) and one environmental section (Hamoon wetland). Priority of water supply in this region is urban, agricultural and environmental demands respectively.

In this study, the combination of the simulation model of water resources (WEAP) and fuzzy multiple attribute decision making (F-TOPSIS) in furtherance of the objectives of the project were performed that, so far, in other studies have not been conducted with this form of water resource management technique.

The number of 45 experts of people living in the region was selected in managing water and agriculture resources in the study area.

The distance of each option was calculated from both positive and negative ideal. In the final step, distance options calculated into the ratio of the ideal solution. Whatever options are closer to the ideal solution, the value of CC_i will be closer to the value of one. Then the value of CC_i in order to show the ranking options should be arranged.

Therefore, first the water resource and planning system (WEAP) in Hirmand catchment for different scenarios was simulated. Then with the application of certified experts opinions were determined 10 different scenarios of water resources in the coming years. In the next step, scenarios were simulated by WEAP model.

Eventually, by using these results and the integration with fuzzy multiple attribute decision analysis the superior management options were determined (Figure 2).

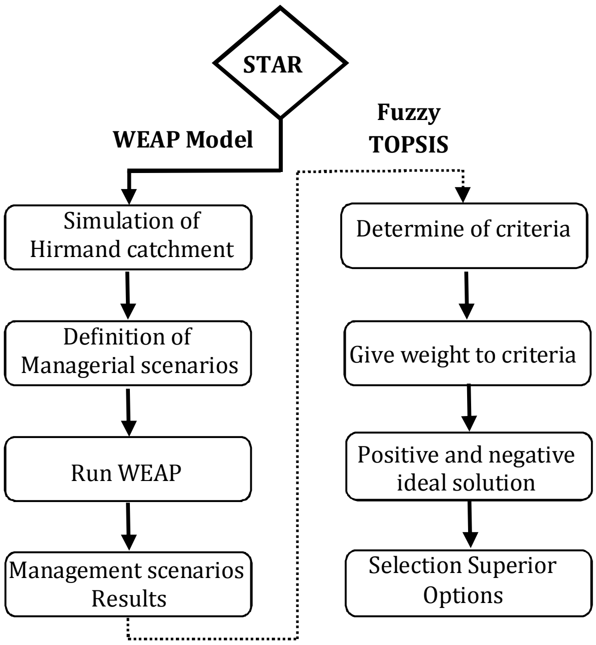

Figure 2) The conceptual model of the simulation methodology

WEAP Model: WEAP Model is developed by the Stockholm Environment Institute and is based on the water balance and requires the agricultural, domestic and environmental demands in one side and on the other side some factors such as sources of supply (e.g. rivers, reservoirs and groundwater), withdrawals, water demands, water quality, economic assessment and ecosystem requirements are important. Accordingly, a comprehensive tool for planning and policy analysis can be applied. The most important feature of this tool is its application for all single watersheds, complex trans-boundary river basin system or the agricultural and municipal systems [30]. This model has great ability to simulate a broad range of engineered and natural components of the systems including water demand analyses, water conservation, hydropower generation, water quality and pollution tracking, water allocation priorities, vulnerability assessments, rainfall runoff, base flow and groundwater recharge from precipitation, ecosystem requirements and reservoir operations [30]. Amount supplied to irrigation, calculated by WEAP allocation, Then an optimization problem can be solved according to the below:

$$
\begin{array}{ll}
For\ each\ p = 1\ to\ P & For\ each\ demand\ priority \\
For\ each\ f = 1\ to\ F \in (D_k^{P,t-n}) & For\ each\ supply\ preference\ to\ demand, k \\
Max\ \ Z = C_P & Coverage\ to\ all\ demand\ sites\ k \in N\ with\ priority\ \ p \\
Subject\ to & \\
\sum_{j=1}^{n} x_{j,i}^{p} - \sum_{r=1}^{m} x_{i,r}^{p} + S_i^{t-1} = S_i^{t} & Mass\ balance\ constraint\ with\ storage\ for\ node\ i\ to\ node\ r \\
\sum_{j=1}^{F} x_{j,i}^{p} = D_k^{p,t-n} & Demand\ node\ constraint\ for\ demand\ k\ from\ j\ sources \\
\sum_{j=1}^{F} x_{j,i}^{p} = D_k^{p,t-n} \times c_k^{p} & Coverage\ constraint\ for\ demand\ k\ from\ j\ sources \\
\sum_{j=1}^{F} x_{j,i}^{p} \ge D_k^{p,t-n} \times c_k^{p} & Coverage\ constraint\ for\ ifr\ and\ reservoirs\ k\ from\ j\ sources \\
c_k^{p} = C & Equity\ constraint\ for\ demand\ site\ k\ with\ priority\ \ p \\
c_k^{p} \ge C & Equity\ constraint\ for\ ifr\ and\ reservoirs\ with\ priority\ \ p \\
0 \le c_k^{p} \le 1 & Bound\ for\ demand\ site\ coverage\ variables\ (not\ ifr\ or\ reservoirs) \\
\begin{cases} x_{i,1}^{\succ p} = 0 \\ x_{i,1}^{p} \ge 0 \end{cases} & \begin{array}{l} For\ Demand\ Site\ I\ with\ priority \succ P \\ For\ Demand\ Site\ k\ with\ priority = P \end{array} \\
\begin{cases} x_{i,k}^{\succ f} = 0 \\ x_{i,k}^{f} \ge 0 \end{cases} & \begin{array}{l} For\ Demand\ Site\ k\ with\ priority \succ f \\ For\ Demand\ Site\ k\ with\ priority = f \end{array} \\
next\ f & \\
next\ p &
\end{array}
$$

Fuzzy TOPSIS Method: In the TOPSIS method, accurate and definite values are applied to determine criteria and weighted options. In most cases, human assumptions are accompanied by indeterminacy and this fact influences decision making. Therefore, it is better to use fuzzy methods which the method of the similarity to fuzzy ideal option is one of such methods. In this term, variables which are presented by fuzzy numbers are used to evaluate the factors of decision-making matrix or the criteria of weight; hence there are possible solutions for the problems relating to the similarity method for the ideal option.

Fuzzy TOPSIS Method Steps: Chen and Huang have described the stages of fuzzy TOPSIS method in the multi-criteria decision making with n criterion and m option as follows:

Stage 1: The formation of decision matrix

Considering the number of criteria and options and the evaluation of all options for different criteria, decision matrix was formed as follows:

$$
\tilde{D} = \begin{bmatrix} \tilde{\chi}_{11} & \tilde{\chi}_{12} & \cdots & \tilde{\chi}_{1n} \\ \tilde{\chi}_{21} & \tilde{\chi}_{22} & \cdots & \tilde{\chi}_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ \tilde{\chi}_{m1} & \tilde{\chi}_{m2} & \cdots & \tilde{\chi}_{mn} \end{bmatrix}
$$

When fuzzy numbers are used, $\tilde{\chi}_{ij} = (a_{ij}, b_{ij}, c_{ij})$ is the function of the option i (i=1,2,…,m) with n relation to the criterion j (j=1,2,…,m). If decision maker committee has k member and fuzzy ranking k is of decision maker $\tilde{\chi}_{ijk} = (a_{ijk}, b_{ijk}, c_{ijk})$ (triangular fuzzy number) for (j=1,2,…,n) and (i=1,2,…,m), considering integrated fuzzy ranking criteria $\tilde{\chi}_{ij} = (a_{ij}, b_{ij}, c_{ij})$, therefore the options could be obtained as follows. Along with triangular fuzzy numbers, there is another type of trapezoidal fuzzy number used in this study for its triangular type. Trapezoidal fuzzy numbers in most time avoid due to the difficulty in modeling and implementation of this study. Nevertheless, the results of two types of fuzzy numbers are close and reliable:

$$
a_{ij} = \underset{k}{Min}\left\{a_{ijk}\right\}
$$

$$
b_{ij} = \frac{\sum_{k=1}^{k} b_{ijk}}{k}
$$

$$
c_{ij} = \underset{k}{Max}\left\{c_{ijk}\right\}
$$

Stage 2: Determining the matrix of criteria weight

In this stage, different criteria significance coefficient in decision making was defined as follows:

$$
\tilde{W} = \left[\tilde{W}_1, \tilde{W}_2, \ldots, \tilde{W}_n\right]
$$

Which if triangular fuzzy numbers are used, each component w_j (the weight of each criterion) is defined as $\tilde{W}_j = (\tilde{W}_{j1}, \tilde{W}_{j2}, \tilde{W}_{j3})$. If the decision-making committee has k member and the k^th^ significance coefficient of the decision maker $\tilde{W}_{jk} = (\tilde{W}_{jk1}, \tilde{W}_{jk2}, \tilde{W}_{jk3})$ (triangular fuzzy number) for j=1,2,…,n the integrated fuzzy ranking $\tilde{W}_j = (\tilde{W}_{j1}, \tilde{W}_{j2}, \tilde{W}_{j3})$ could be obtained as follows:

$$
W_{j1} = \underset{k}{Min}\left\{W_{jk1}\right\}
$$

$$
W_{j2} = \frac{\sum_{k=1}^{K} W_{jk2}}{k}
$$

$$
W_{j3} = \underset{k}{Max}\left\{W_{jk3}\right\}
$$

Stage 3: The normalization of fuzzy decision matrix

When every X_{ij} is fuzzy, every r_{ij} is undoubtedly fuzzy, as well. To normalize, linear scale change for transforming different criteria scale into applicable criterion is used. If fuzzy number is triangular, it will be calculated in non-scale decision arrangements for criteria with negative and positive dimensions as follows:

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c^*_j}, \frac{b_{ij}}{c^*_j}, \frac{c_{ij}}{c^*_j} \right)$$

$$\tilde{r}_{ij} = \left(\frac{a^-_j}{c_{ij}}, \frac{a^-_j}{b_{ij}}, \frac{a^-_j}{a_{ij}} \right)$$

Which in these equations:

$$c^*_j = \underset{i}{Max}\ c_{ij}$$

$$a^-_j = \underset{i}{Min}\ a_{ij}$$

Therefore, non-Scale fuzzy decision matrix ($\tilde{R}$) obtain as follows:

$$\tilde{R} = \left[\tilde{r}_{ij} \right]_{m \times n} ; i = 1, 2, \ldots, m \ ; \ j = 1, 2, \ldots, n$$

That m is the number of alternatives and n is the number of criteria.

Stage 4: Determining weighted fuzzy decision matrix

Given the weight of different criteria, weighted fuzzy decision matrix is obtained through multiplying significance coefficient related to each criterion in fuzzy normalized matrix as follows:

$$\tilde{V}_{ij} = \tilde{r}_{ij} . \tilde{w}_j$$

That $\tilde{w}_j$ demonstrates the coefficient of criteria important C_j. Therefore, weighted fuzzy decision matrix will be as follows:

$$\tilde{V} = \left[\tilde{v}_{ij} \right]_{m \times n} ; i = 1, 2, \ldots, m \ ; \ j = 1, 2, \ldots, n$$

If fuzzy numbers are triangular, for criteria with a positive and negative dimension, theN:

$$\tilde{V}_{ij} = \tilde{r}_{ij} . \tilde{w}_j = \left(\frac{a_{ij}}{c^*_j}, \frac{b_{ij}}{c^*_j}, \frac{c_{ij}}{c^*_j} \right) . (w_{j1}, w_{j2}, w_{j3})$$

$$= \left(\frac{a_{ij}}{c^*_j} . w_{j1}, \frac{b_{ij}}{c^*_j} . w_{j2}, \frac{c_{ij}}{c^*_j} . w_{j3} \right)$$

$$\tilde{V}_{ij} = \tilde{r}_{ij} . \tilde{w}_j = \left(\frac{a^-_j}{c_{ij}}, \frac{a^-_j}{b_{ij}}, \frac{a^-_j}{a_{ij}} \right) . (w_{j1}, w_{j2}, w_{j3})$$

$$= \left(\frac{a^-_j}{c_{ij}} . w_{j1}, \frac{a^-_j}{b_{ij}} . w_{j2}, \frac{a^-_j}{a_{ij}} . w_{j3} \right)$$

Stage 5: Finding ideal fuzzy solution (FPIS, A*) and anti-ideal fuzzy solution (FNIS, A^-)

Fuzzy Positive Ideal Solution (FPIS, A^*) and fuzzy Negative Ideal Solution (FNIS, A^-) are solved as follows:

$$A^* = \left\{ \tilde{v}^*_1, \tilde{v}^*_2, \ldots, \tilde{v}^*_n \right\}$$

$$A^- = \left\{ \tilde{v}^-_1, \tilde{v}^-_2, \ldots, \tilde{v}^-_n \right\}$$

Which $\tilde{v}^*_i$ is the best value of i among all option and $\tilde{v}^-_1$ is the worst value among of all option. The values are obtained through the following equation:

$$\tilde{v}^*_j = \underset{i}{Max} \left\{ \tilde{v}_{ij3} \right\} ; i = 1, 2, \ldots, m \ ; \ j = 1, 2, \ldots, n$$

$$\tilde{v}^-_j = \underset{i}{Min} \left\{ \tilde{v}_{ij1} \right\} ; i = 1, 2, \ldots, m \ ; \ j = 1, 2, \ldots, n$$

The options which are placed in A^* & A^-, show better and worse options respectively. In this study, $A^* = (1,1,1)$ is considered as positive ideal reply and $A^- = (0,0,0)$ as negative ideal reply.

Stage 6: Calculating distance between fuzzy ideal solution and fuzzy anti-ideal solution

The distance of each option from fuzzy ideal solution and fuzzy anti-ideal solution could be obtained as follows:

$$S^*_i = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}^*_j \right) \quad , \quad i = 1, 2, \ldots, m$$

$$S^-_i = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}^-_j \right) \quad , \quad i = 1, 2, \ldots, m$$

d (.,.) is the distance between two fuzzy numbers, which if (a_1, b_1, c_1) and (a_2, b_2, c_2) are two triangular fuzzy numbers, the distance between two numbers is:

$$d_v(\tilde{M}_1, \tilde{M}_2) = \left(\frac{1}{3} \left[(a_1 - a_2)^2 + (b_1 - b_2) + (c_1 - c_2) \right] \right)^{1/2}$$

It could be said that $d(\tilde{v}_{ij}, \tilde{v}^-_{ij})$ and $d(\tilde{v}_{ij}, \tilde{v}^+_{ij})$ are crisp number.

Stage 7: Similarity attributes calculations

Similarity attribute is obtained by the following equation:

$$CC_i = S^-_i \Big/ S^+_i + S^-_i \quad ; \ i = 1, 2, \ldots, m$$

Stage 8: Ranking the options

In this stage, considering the amount of the similarity attribute, the options are ranked, so that the options with similarity attribute are prioritized [31, 32].

Table 1, 2 and 3 show the steps of fuzzy TOPSIS method.

The definition of scenarios and criteria: Water resource management scenarios that have been predicted in the Sistan region and as options of fuzzy multi-attribute model in this study are considered as follows. These scenarios are most important options in the study area (Table 4).

In Sistan, water inflow is the most important input in agricultural production. With regard to the criticality of water status and the job of the majority of people in the area and the role of water in the economy of this region, five indicators are determined with regard to economic aspects.

Table 1) Total decision matrix

	C_1	C_2	C_3	C_4	C_5
SC_1	(3,5,7)	(5,7,9)	(3,5,7)	(7,9,10)	(1,3,5)
SC_2	(7,9,10)	(9,10,10)	(7,9,10)	(3,5,7)	(3,5,7)
SC_3	(9,10,10)	(0,1,3)	(9,10,10)	(3,5,7)	(3,5,7)
SC_4	(9,10,10)	(0,1,3)	(9,10,10)	(3,5,7)	(3,5,7)
SC_5	(9,10,10)	(9,10,10)	(9,10,10)	(3,5,7)	(0,0,1)
SC_6	(9,10,10)	(9,10,10)	(9,10,10)	(3,5,7)	(0,1,1)
SC_7	(7,9,10)	(9,10,10)	(7,9,10)	(3,5,7)	(5,7,9)
SC_8	(9,10,10)	(9,10,10)	(9,10,10)	(3,5,7)	(5,7,9)
SC_9	(5,7,9)	(9,10,10)	(5,7,9)	(3,5,7)	(5,7,9)
SC_{10}	(3,5,7)	(9,10,10)	(3,5,7)	(3,5,7)	(5,7,9)

Table 2) Normalized Matrix

	C_1	C_2	C_3	C_4	C_5
SC_1	(0.3,0.5,0.7)	(0,0,0)	(0.3,0.5,0.7)	(0.3,0.33,0.43)	(0.11,0.33,0.56)
SC_2	(0.7,0.9,1)	(0,0,0)	(0.7,0.9,1)	(0.43,0.6,1)	(0.33,0.56,0.78)
SC_3	(0.9,1,1)	(0,0,0)	(0.9,1,1)	(0.43,0.6,1)	(0.33,0.56,0.78)
SC_4	(0.9,1,1)	(0,0,0)	(0.9,1,1)	(0.43,0.6,1)	(0.33,0.56,0.78)
SC_5	(0.9,1,1)	(0,0,0)	(0.9,1,1)	(0.43,0.6,1)	(0,0,0.11)
SC_6	(0.9,1,1)	(0,0,0)	(0.9,1,1)	(0.43,0.6,1)	(0,0.11,0.11)
SC_7	(0.7,0.9,1)	(0,0,0)	(0.7,0.9,1)	(0.43,0.6,1)	(0.56,0.78,1)
SC_8	(0.9,1,1)	(0,0,0)	(0.9,1,1)	(0.43,0.6,1)	(0.56,0.78,1)
SC_9	(0.5,0.7,0.9)	(0,0,0)	(0.5,0.7,0.9)	(0.43,0.6,1)	(0.56,0.78,1)
SC_{10}	(0.3,0.5,0.7)	(0,0,0)	(0.3,0.5,0.7)	(0.43,0.6,1)	(0.56,0.78,1)

Table 3) Weighted Matrix

	C_1	C_2	C_3	C_4	C_5
SC_1	(0.02,0.03,0.05)	(0,0,0)	(0.21,0.35,0.49)	(0.01,0.02,0.02)	(0.05,0.15,0.26)
SC_2	(0.05,0.06,0.07)	(0,0,0)	(0.49,0.63,0.7)	(0.02,0.03,0.05)	(0.15,0.26,0.36)
SC_3	(0.06,0.07,0.07)	(0,0,0)	(0.63,0.7,0.7)	(0.02,0.03,0.05)	(0.15,0.26,0.36)
SC_4	(0.06,0.07,0.07)	(0,0,0)	(0.63,0.7,0.7)	(0.02,0.03,0.05)	(0.15,0.26,0.36)
SC_5	(0.06,0.07,0.07)	(0,0,0)	(0.63,0.7,0.7)	(0.02,0.03,0.05)	(0,0,0.05)
SC_6	(0.06,0.07,0.07)	(0,0,0)	(0.63,0.7,0.7)	(0.02,0.03,0.05)	(0,0.05,0.05)
SC_7	(0.05,0.06,0.07)	(0,0,0)	(0.49,0.63,0.7)	(0.02,0.03,0.05)	(0.26,0.36,0.46)
SC_8	(0.06,0.07,0.07)	(0,0,0)	(0.63,0.7,0.7)	(0.02,0.03,0.05)	(0.26,0.36,0.46)
SC_9	(0.03,0.05,0.06)	(0,0,0)	(0.35,0.49,0.63)	(0.02,0.03,0.05)	(0.26,0.36,0.46)
SC_{10}	(0.02,0.03,0.05)	(0,0,0)	(0.21,0.35,0.49)	(0.02,0.03,0.05)	(0.26,0.36,0.46)

Table 4) Introducing used criteria

Options (Scenarios)	
SC_1	Current account
SC_2	Increasing the agricultural water irrigation efficiency up to 50% using sprinkler irrigation system
SC_3	Increasing the agricultural water irrigation efficiency up to 70% using Pressurized irrigation system
SC_4	Minimum water storage reduces to the amount of 170 million cubic meters in reservoir
SC_5	Losses Management (30% reduction of evaporation)
SC_6	Losses Management (70% reduction of evaporation)
SC_7	Direct transfer of water to Zehak agriculture sector
SC_8	Direct transfer of water to Sistan agriculture sector
SC_9	Direct transfer of water to Miyankangi agriculture sector
SC_{10}	The operation of the second water pipeline
Criteria	
C_1	The ratio of profit to cost
C_2	The initial cost of the project
C_3	The possibility of developing Area under cultivation
C_4	Instability and effectiveness of uncertainty
C_5	Availability of funds

Findings

Schematic water distribution (resources and demands) in Sistan under the WEAP model was shown in Figure 3.

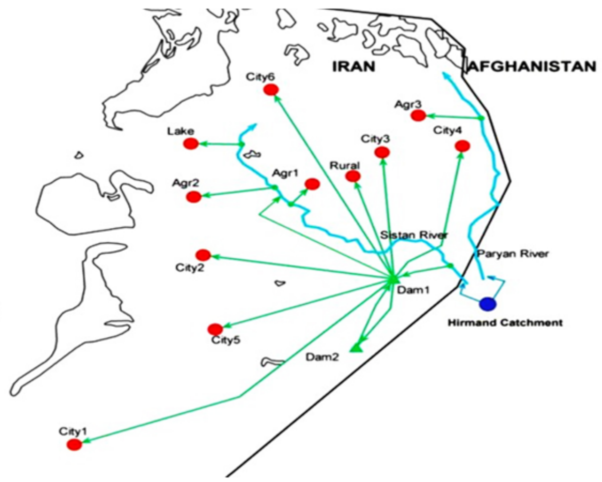

Figure 3) Schematic perception in Hirmand catchment

Based on Shannon entropy, the criterion No.5 had most weight. Criterion No.2 was in second place, and criteria No.1, 3 and 4 were next in the ranking respectively (Table 5).

Table 5) Criteria weighted matrix based on Shannon entropy

Criterion	C_1	C_2	C_3	C_4	C_5
Weight	0.069586	0.346476	0.069586	0.049903	0.464449

The ranking options (scenarios) were identified as followed:
Scenario No.8 was in the first rank. Scenario No.7 was located in second rank, Scenario No.3 and 4 of equal value in ranking were located in third and fourth and the latest ranking related to scenario No.1 (Diagram 1).

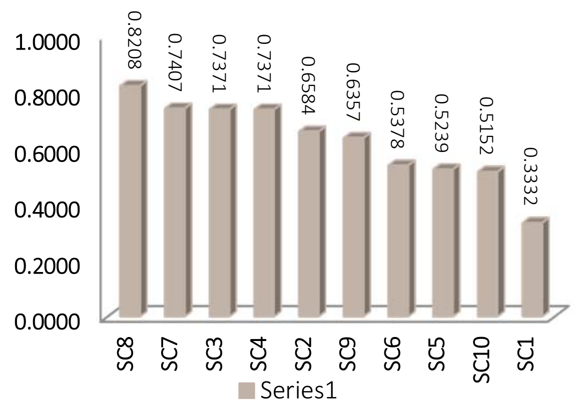

Diagram 1) Options ranking (scenarios)

The demand of the agricultural sector in Sistan was more than most other sectors because the surrounding lands of this section were located at the end of the Sistan River and little water was transported to it. So that a large percentage of the water comes from a semi-well, which, if the water in the well became half-low, the agricultural lands of the area also face the problem of water scarcity. For this reason, a drain outlet plan that transfers water separately to this area will have a positive effect on the increase in the area of the crop in this region.

Discussion

The aim of this research was to simulate the Hirmand catchment by WEAP model and prioritization of the implementation of agricultural development projects in Hirmand catchment.

In recent years, the inevitable outcomes of rising demand, as well as the reduction of various natural resources, especially water, have raised controversy over the exploit and allocate them to different stakeholders. The approach of water allocation based solely on the initial entitlement does not usually cause in the efficient use of water in the entire basin. In the meantime, it is necessary to have a comprehensive and sustainable approach to allocate in such a way that all stakeholders groups feel the highest level of satisfaction.

In the event of an increase in water consumption in the agricultural and domestic sector, the environmental demand will not provide and the main damage to this sector will be introduced. For this reason, a supply management will be efficient and possible without the considering of the demand management.

Therefore, it is recommended that the supply and demand policies be implemented in order to increase the water flow into the wetland.

One way to get out of deadlock in the management of water resources is the application of systems analysis tools and managerial decision making in discussions of water simulation. After each simulation selection of preferred option is required. In Sistan region, according to available resources and the results of the simulation catchment is essential, So that in water resources management should be done with appropriate policy.

In this study, combining the WEAP model and fuzzy multi-criteria analysis, a tool for decision support system was created. According to results Scenario No.8 had the highest value and so considered as the preferred option than the other options. On this basis, it was recommended that transfer water to lands in Sistan agriculture sector to be in government agenda. After that, scenario No.7 was in second ranking that required proper planning was considered for transmission direct of water to this agricultural sector.

Irrigation efficiency (70%) was in the third rank among the options. Based on the results, to implement this scenario, the government financial support is needed. The remarkable thing in the ranking of scenarios is that the current account scenario (SC_1) is lasted ranking that shows the Sistan region's water status, according to the study criteria is not good.

Based on the obtained results and evidences, the evaporation rate in the Sistan region is one of the main problems of water scarcity in this region that distinguishes the climate of Sistan from other parts of Iran and perhaps the world. The results from technical degradation scenarios show that physical and chemical floats and coatings prevent the amount of water lost to a great extent, which needs to be specified in Sistan.

Multi-index decision-making models provide the ability to create an appropriate decision-making environment, as well as the context for developing various management scenarios. Therefore, it is recommended that water allocators at the district level pay attention to these methods in order to manage and optimize the use of reservoirs and other water resources. By interviewing the relevant experts, it was revealed that there is no curriculum to be launched, given the critical water conditions in the Sistan region. Therefore, it is suggested that policies, long-term strategies, and future plans regarding allocation and exploitation of the water be developed according to the current situation in the region.

The limitation of the study was to achieve data.

Conclusion

The remarkable thing in the ranking of scenarios is that the current account scenario (SC_1) is lasted ranking that shows Sistan region's water status, according to the study criteria is not good.

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