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Application of One of Multi Attribute Decision Making Models for Site Selection of Damp for the Purpose of Sustainable Development Case Study: (BAKHTIARI Basine)

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ABSTRACT

In recent decades, duo to increase in population, demand for reliable water supplies has increased. The situation is critical in places where groundwater is the only accessible water resource and the discharge rate of water is more than the rate of recharge. In such areas, artificial recharge of groundwater is an important management strategy. In establishing an artificial recharge scheme, site Selection is the prime prerequisite and its success depends on the collection and analysis of a great deal of geographic data. The use of ELECTRE in site selection projects allows the decision-makers to incorporate unquantifiable information into decision model. In new researches of site selection multiple criteria decision- makers methods have been considered. In this paper, site selection of artificial groundwater recharges using an integrated method of ELECTRE has been carried out by raster layers in GIS. The result and findings of Research show that in ELECTRE method, zones (3,4) dominated (5) times and defeated (1) time, so it is located in the first rank with (4) points and is the most suitable zone for establish damp. In contrast, zone (1) defeated (6) time and dominated no time, therefore it is located in the last rank with (-6) points and is not the most suitable zone for artificial recharge. And, zones (5, 6, 7, 2,) dominated (4, 2, 1, 1) times and defeated (2, 4, 5, 5,) and located in other ranks with (2, -2, -4, -4) points respectively. Also, zones (7, 6, 2, 1) should be omitted because their defeated times are more than dominated times.

Introduction

Sustainability and a resilient city is one of the important challenges of humanity in the twenty first century. In other words, today the main world opportunities and challenges are embedded in cities and the rapid growth of urbanization accompanied by industrial activities led to inefficiency of urban infrastructures and an intensive increase of environmental destruction[10]. In the current situation, assessing environmental sustainability is one of the most important tools in the process of planning for sustainable development. This assessment is a type of ecological assessment which would be carried out in different levels in sequential way to present a framework for analyzing and assessing the impacts of plans, strategies and polices on environment in a comprehensive method by offering some recommendations to mitigate environmental pressures. So, providing an appropriate milieu for assessment and measuring environmental sustainability is inevitable in the process of urban development and planning[11]. Water resources management is a set of various management activities aimed at the optimum utilization of water resources and reduction of economical, social and environmental damages and losses. Decision making issue in water resources management is very complex and complicated because of several decision indicators and criteria [9]. Achieving a determine purpose, there are a lot of solutions with different priorities for various issues such as environmental, social, organizational and political problems. These necessities leads to use of multiple criteria decision making aimed at selection of best solution among different solutions. In previous decades, decision making in water management problems and selection of better option among suggested options to solve a watershed problems was only done based on economical criteria - profit in relation to cost- and on changing social and environmental criteria in to the economical criterion. However, today using Multi criteria decision making, it is not necessary to use financial equivalent of social and environmental criteria to select the best option. In fact, various qualitative and quantitative criteria can be used to prioritize and select the best options for water resources management. Electrical Method is a type of available methods in Compensatory Models. In this method whole options evaluate by non-ranked comparisons. All stages of this method are established based on coordinated and uncoordinated sets and thus this method is known as ''Coordination Analysis''. Banayoun established the Electrical Method and Delft, Nijkamp, Roy and their colleagues developed it. In Electrical method, the concept of domination uses implicitly. In this method, options are compared in pairs, then dominant and weak (dominant and defeated) options determined and weak or defeated options omitted [8]. There are several studies on ground water and their artificial recharge all over the world. Noori et al (2005) tried to find the appropriate areas for artificial recharge of ground water by recharge pools and GIS technique in watershed Gavbandi and introduced alluvial fans and pediplain as the best area for artificial recharge[7]. Mousavi et al (2010) found the potential appropriate areas for artificial

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recharge of ground water in the vicinity of Kamestan anticline by integration of remote sensing and GIS techniques and introduced broken formations, alluviums and river canals as the best position for artificial recharge[5]. Mianabadi and Afshar (2008) investigated and ranked the project of water supply in Zahedan using three methods: Induced Ordered Weighted Averaging (IOWA), Linear Assignment and TOPSIS methods, and then they compared the findings of these methods with the results of adaptable planning method [4]. Limon and Martinez (2006) used Multi Attribute Utility theory for optimum allocation of agriculture water in north of Spain [6]. Ahmadi et al (2002) used multiple criteria decision making to rank different projects of refining agriculture water to reuse them [1]. Also, Anand Raj and Kumar (1996) ranked management options of river basin by ELECTRE method [2]. There are many examples of applications of Multi Criteria Decision Making in literature (For instance: The evaluation of service quality [14]; Inter company comparison [15]; The applications in aggregate production planning [16], Facility location selection [17] and large scale nonlinear programming [18]. The purpose of this study is zoning the best area for artificial recharge of underground basins in BAKHTIARI watershed using effective factors in recharging underground water table by ELECTER method. In another way, this study aimed at the selection of most appropriate area to establish damp for the purpose of sustainable development of water resources using Multi Criteria Decision Making methods (ELECTRE) and classify the best areas in considered watershed.

Methods and materials

Mathematical situation of studied area

Being situated in the center part of Lorestan province, Charmahal and Bakhtiari is bounded by 31º, 09' latitude to 32º, 48' north latitude and 49º, 28' to 51º and 25' longitude. It has access to Lorestan province in north, to Khozestan provinces in south, to Isfahan province in east and to Charmahal and Bakhtiari province in west. Globally, Bakhtiari is located at 1850 meter height above sea level.

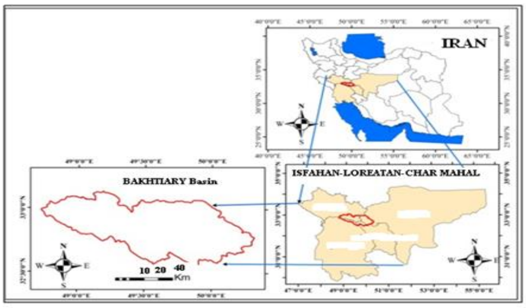

Figure 1. Mathematical situation of studied area

Research Methodology

Firstly, studied area was investigated by the satellite images of Google Earth and its limitations were determined. Then digital elevation model of area was separated from its digital elevation model in Iran in the environment of soft ware GlOBAL MAPER and the output was received. Required data layers for zoning in the environment of software Arc GIS 9.3 was prepared as following:

First, digital elevation model classified in to 7 elevation classes based on natural breaks in the heights of the area. Mentioned classes represent the studied zones in the area and subsequent calculations were done in each of these classes. Slope layer prepared base on digital elevation model on the area by surface analyses tool in 3D analyses. There were different processes to prepare drainage density layer and habitual density such as digitizing main and minor waterways layers on the topographical map1:50000 of the area, digitizing main and minor fault on geological map 1:100000 of area and density tool in Spatial Analyses. Iso-Precipitation layer prepared by interpolating method like cringing technique and linear relationship between rain-height using Interpolate tools in 3D analyses.

Second, the investigated criteria for each height zones were calculated (Tables 2) and their layers prepared separately. After achieving a few numbers in each layer, the numbers were analyzed by ELECTRE method. Then considered watershed was ranked to select the best area for establishing damp.

Applying ELECTRE Technique for site selection of damp

1. Establishing Decision Making Matrix:

According to the criteria and numbers of options and evaluation of whole options for the different criteria, Decision Making Matrix develops as follow;

$$X = \begin{bmatrix} x_{11} & \dots & x_{1n} \\ \vdots & \dots & \dots \\ x_{1m} & \dots & x_{mn} \end{bmatrix}$$

In which the Function of Xij (i = 1,2, ..., M) is in relation to the criteria I j (j = 1,2,3, ..., n).

2. Scale down the Decision Making Matrix

In this stage, all criteria with different dimensions is changed into the dimensionless criteria and matrix R defined as follows. There are several methods to scale down, but generally the following equation used in electrical method [13].

$$R = \begin{bmatrix} r_{11} & \dots & r_{1n} \\ \vdots & \dots & \dots \\ r_{m1} & \dots & r_{mn} \end{bmatrix} \qquad r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \tag{1}$$

3. Determining Weighted Matrix of criteria

$$W = \begin{bmatrix} w_1 & \dots & 0 \\ \vdots & w_2 & \dots \\ 0 & \dots & w_n \end{bmatrix}$$

As you can see, Weighted Matrix (W) is diagonal matrix in which the elements on main diameter are not zero and amount of these elements equal to importance coefficient of the related vector.

4. Determining Weighted Normalized Decision Matrix

Weighted Normalized Decision Matrix is obtained by multiplying Scale down Decision Making Matrix into the Weighted Matrix of criteria.

$$V = R \times W = \begin{bmatrix} v_{11} & \dots & v_{1n} \\ \vdots & \dots & \dots \\ v_{m1} & \dots & v_{mn} \end{bmatrix}$$

5. Establishing agree and disagree criteria set

The criteria set J = (1, 2... m) divides into two subsets; agree and disagree for each pair of options e, k (k, e = 1,2, ..., M, k # e) . Agree Set (S_{Ke}) is a set of criteria in which option K is preferred to option e. and its complementary set is the opposite set (I_{Ke}) in mathematical language;

$$S_{ke} = \{ j | v_{kj} \geq v_{ej} \} \tag{2}$$

$$I_{ke} = \{ j | v_{kj} \ \pi \ v_{ej} \} \quad (3)$$

6. Establishing Agree Matrix:

To establish agree matrix, its elements, agree indicators, should be calculated. Agree indicator is sum of weight of criteria in agree set. Thus, indicator C_{ke} is between option k and option e equals to [8]:

$$c_{ke} = \frac{\sum_{j \in s_{ke}} W_j}{\sum_{j=1} W_j} : \quad (4)$$

For total normalized weights $\sum_{j \in 1} W_j$ equals 1 so:

$$c_{ke} = \sum_{j \in s_{ke}} W_j : \quad (5)$$

Agreement represents the superiority of options k on option e which its amount changes in the range of zero to one (0-1). After calculating agree indicator for all options, matrix which is a m * m matrix is defined as follows. Generally, this matrix is not symmetrical.

$$C = \begin{bmatrix} - & c_{12} & ... & c_{1m} \\ c_{21} & - & ... & c_{2m} \\ M & M & - & M \\ c_{m1} & ... & c_{m(m-1)} & - \end{bmatrix}$$

7. Determining Opposite Matrix

Disagreement indicator (opposite) is described as follows [9].

$$d_{ke} = \frac{\max_{j \in I_{ke}} |v_{kj} - v_{ej}|}{\max_{j \in J} |v_{kj} - v_{ej}|} \quad (6)$$

The amount of disagreement indicator changes from zero to one. After calculating disagree indicator for all options, matrix which is a m * m matrix is defined as follows. Generally, this matrix is not symmetrical.

$$D = \begin{bmatrix} - & d_{12} & ... & d_{1m} \\ d_{21} & - & ... & d_{2m} \\ M & M & - & M \\ d_{m1} & ... & d_{m(m-1)} & - \end{bmatrix}$$

It noticed that the data including in agreement matrix, are different from data in opposite matrix and in fact these data are completed each other. The difference between the weight is developed through agreement matrixes, while the difference between determined values is obtained through opposition matrix.

8. Establishing agree dominant matrix:

In the sixth step, it indicated how to calculate agreement indicator C_{ke}. Now there is a determined amount for agreement indicator in this step which is called agreement threshold $\bar{c}$. If C_{ke} is larger $\bar{c}$, option k is preferred on option e, otherwise it is not. Agreed threshold is calculated by the following equation. [8]

$$\bar{c} = \sum_{\substack{k=1 \\ k \neq e}}^{m} \sum_{\substack{e=1 \\ e \neq k}}^{m} \frac{c_{ke}}{m(m-1)} : \quad (7)$$

Agree Dominated Matrix (F) is developed based on the amount of agreement threshold and its elements determined in the equation bellow [12]

$$f_{ke} = \begin{cases} 0 & c_{ke} \geq \bar{c} \\ 1 & c_{ke} < \bar{c} \end{cases} \quad (8)$$

9. Establishing Opposed Dominance Matrix :

Opposed Dominance Matrix (G) is established the same as Agree Dominated Matrix. First, decision makers should express opposite threshold $\bar{d}$ which is for example the mean of opposite indicators (disagreement) [8].

$$\bar{d} = \sum_{\substack{k=1 \\ k \neq e}}^{m} \sum_{\substack{e=1 \\ e \neq k}}^{m} \frac{d_{ke}}{m(m-1)} \quad (9)$$

Similar to seventh step, it is better that the amount of opposite indicator (d_{ke}) become less, because opposite amount (disagreement) expresses superiorities dimension of option k on option is acceptable. In contrast, if (d_{ke}) were larger than $\bar{d}$, opposite amount would be very great and it would not be ignored. Thus, Opposed Dominance Matrix is defined as follows [8]

$$g_{ke} = \begin{cases} 0 & d_{ke} \geq \bar{d} \\ 1 & d_{ke} < \bar{d} \end{cases} \quad (10)$$

Each element in the matrix (G) shows the dominant relationship between options.

10. Establishing Final Dominant Matrix:

Final Dominant Matrix (H) is developed after multiplying each element in Agree Dominated Matrix (F) into elements in Opposed Dominance Matrix (G) [8].

$$h_{ke} = f_{ke} . g_{ke} \quad (11)$$

11. Removing less satisfaction options and selecting the best option:

Final Dominant Matrix (H) indicates detail preferences of options. For example, when amount of h_{ke} equals 1, it means that option k is preferred on option e in both agree and disagree situation (it means its preference is larger than the agree threshold and its opposite or weakness is less than disagree threshold), but option k may be dominated by other options yet. The options should be ranked in a way that the more dominated options are selected than the more defeated one.

Determining the importance coefficient of options than the other, criteria are compared in pair by time suggested method.

Table 1. Weighting the factors based on preference in paired comparison [13]

Numerical values	Preferences (judging verbal)
9	Extremely preferred
7	Very strongly preferred
5	Strongly preferred
3	Moderately referred
1	Equally preferred
8،6،4،2	Intervals between strong preferences

After the formation of paired comparison matrix, relative weights of criteria can be calculated. There are different methods to calculate the relative weight based on paired comparison matrix. The most important ones are the "least squares method, least squares logarithmic method, special vector method and approximate method. The special vector method is the most accurate one. In this method, Wi is determine in the equation12:

$$A \times W = \lambda max W \quad (12)$$

In this equation, λ and W are special amount and special vector of paired matrix respectively. If dimensions of matrix were

Table 2. Decision Matrix (X)

Regions	Materials	Precipitation	Stream density	Slope	fault density	Elevation	area
1	1	105.6	63.84	113.32	45.7	886.5	547.46
2	5	140.3	61.6	115.81	65.85	1436	751.98
3	9	156.78	62.62	121.08	71.98	1821	826.96
4	7	207.87	63.75	121.35	85.52	2191.5	903.06
5	5	252.94	58.97	114.17	82.91	2547.5	1150.03
6	3	304.84	62.79	101.52	68.06	2921.5	820.33
7	1	392.14	62.04	93.52	64.79	3581.5	328.82

Table 3. Scale down Decision Matrix (R)

Regions	Materials	Precipitation	Stream density	Slope	fault density	Elevation	area
1	0.0724	0.1651	0.3876	0.3826	0.2456	0.1423	0.2590
2	0.3618	0.2193	0.3740	0.3910	0.3539	0.2305	0.3557
3	0.6512	0.2451	0.3802	0.4088	0.3868	0.2923	0.3912
4	0.5065	0.3249	0.3871	0.4097	0.4596	0.3517	0.4272
5	0.3618	0.3954	0.3581	0.3855	0.4456	0.4089	0.5441
6	0.2171	0.4765	0.3813	0.3428	0.3658	0.4689	0.3881
7	0.0724	0.6129	0.3767	0.3157	0.3482	0.5748	0.1556

Table 4. Paired Comparison Matrix of different criteria (S)

Criteria	Materials	Precipitation	Stream density	Slope	fault density	Elevation	area	Wij
Materials	1	3	5	5	7	7	9	0/3868
Precipitation	0.33	1	3	5	5	7	7	0/2349
Stream density	0.2	0.33	1	3	5	7	7	0/1585
Slope	0.2	0.2	0.33	1	3	5	7	0/1028
fault density	0.14	0.2	0.2	0.33	1	3	5	0/0603
Elevation	0.14	0.14	0.14	0.2	0.33	1	3	0/0353
area	0.11	0.14	0.14	0.14	0.2	0.33	1	0/0214
Inconsistency rate: 0/0252 (due to being less than 0/1 compatibility matrix indices are acceptable)								

Table 5. Weighted Normalized Decision Matrix (V)

Regions	Materials	Precipitation	Stream density	Slope	fault density	Elevation	area
1	0.0279	0.0388	0.0614	0.0393	0.0149	0.0051	0.0056
2	0.1397	0.0515	0.0592	0.0402	0.0214	0.0082	0.0076
3	0.2515	0.0576	0.0602	0.0420	0.0234	0.0104	0.0084
4	0.1956	0.0763	0.0613	0.0421	0.0278	0.0125	0.0092
5	0.1397	0.0929	0.0567	0.0396	0.0270	0.0146	0.0117
6	0.0838	0.1119	0.0604	0.0352	0.0221	0.0167	0.0083
7	0.0279	0.1440	0.0597	0.0325	0.0211	0.0205	0.0033

Table 6. Agreement Matrix (C)

Regions	Materials	Precipitation	Stream density	Slope	fault density	Elevation	area
1	0.0000	0.1584	0.1584	0.1584	0.1584	0.2612	0.6689
2	0.8415	0.0000	0.0000	0.0000	0.6474	0.4890	0.5710
3	0.8415	0.9999	0.0000	0.3862	0.6474	0.5710	0.7294
4	0.8415	0.9999	0.6137	0.0000	0.7079	0.7294	0.7294
5	0.8415	0.7387	0.3525	0.2920	0.0000	0.5710	0.5710
6	0.7387	0.5109	0.4289	0.2705	0.4289	0.0000	0.7294
7	0.7172	0.4289	0.2705	0.2705	0.4289	0.2705	0.0000

Table 7. Opposite Matrix (D)

Regions	Materials	Precipitation	Stream density	Slope	fault density	Elevation	area
1	0	1	1	1	1	1	1
2	0.019274	0	1	1	1	1	0.827234
3	0.005249	0	0	0.335637	0.315863	0.324228	0.386551
4	0.000516	0	1	0	0.296088	0.318523	0.403522
5	0.041903	0.061162	1	1	0	0.340958	0.457239
6	0.055985	0.925113	1	1	1	0	0.573519
7	0.06532	1	1	0.1028	1	1	0

Table 8. Agree Dominated Matrix (F)

Regions	Materials	Precipitation	Stream density	Slope	fault density	Elevation	area
1	0	0	0	0	0	0	1
2	1	0	0	0	1	0	1
3	1	1	0	0	1	1	1
4	1	1	1	0	1	1	1
5	1	1	0	0	0	1	1
6	1	0	0	0	0	0	1
7	1	0	0	0	0	0	0

Table 9. Opposite Dominated Matrix (G)

Regions	Materials	Precipitation	Stream density	Slope	fault density	Elevation	area
1	0	0	0	0	0	0	0
2	1	0	0	0	0	0	0
3	1	1	0	1	1	1	1
4	1	1	0	0	1	1	1
5	1	1	0	0	0	1	1
6	1	0	0	0	0	0	1
7	1	0	0	1	0	0	0

Table 10. Final Dominated Matrix (H)

Regions	Materials	Precipitation	Stream density	Slope	fault density	Elevation	area
1	0	0	0	0	0	0	0
2	1	0	0	0	0	0	0
3	1	1	0	0	1	1	1
4	1	1	0	0	1	1	1
5	1	1	0	0	0	1	1
6	1	0	0	0	0	0	1
7	1	0	0	0	0	0	0

Table 11. Number of dominant and recessive of each selected areas

Difference	Number being defeated	Rule number	Regions
-6	6	0	1
-4	5	1	2
4	1	5	3
4	1	5	4
2	2	4	5
-2	4	2	6
-4	5	1	7

larger, calculation would be too time consuming. So, to calculate λ, the amount of Dtrmynal λIA-matrix will be equaled to zero. Considering the greatest value of λ in equation (13), the amount of wi is calculated. [11]

$$A - \lambda_{max}.I = 0 \qquad (13)$$

Discuss

In recent years, water exploitation has become greater for many reasons such as population growth, industrial development, urbanization growth and consequently increased demand for food products. Hence the rate of exploitation and consumption ground water become greater than recharge of them, in other words input of ground water system is less than its output and system with negative balance sheet has positive feedback and it is collapsing. Thus it is very significant to determine and assign the suitable position for this case. Water resources management is a set of various management activities aimed at the optimum utilization of water resources and reduction of economical, social and environmental damages and losses. Decision making issue in water resources management is very complex and complicated because of several decision indicators and criteria. Achieving a determine purpose, there are a lot of solutions with different priorities for various issues such as environmental, social, organizational and political problems. These necessities leads to use of multiple criteria decision making aimed at selection of best solution among different solutions. Sustainable development is the management and conservation of basic natural resources and direction of technical and organizational changes to achieve and prepare requirements for generations at the present and in future. Such a development in agriculture section leads to the conservation of water, soil and plants and it is nondestructive environmentally, proper technically, frugal economically and acceptable socially. Similar to under development countries, our country needs to compress and develop agriculture in order to carry out enormous requirements of under growth population. Thus, it is necessary to acquire the exact and up to date information about the condition of water resources and prediction of their situation in future in order to achieve optimum management for water resources. One of the management methods for water resources is Multi Criteria Decision Making. In recent decades, several researchers attempt to use Multi Criteria Decision Making in complex and complicated decisions. These decision methods divide into two parts; Multi Objective Decision Making , Multi Attribute Decision Making. Multi Criteria Models use to select the best options. Evaluative Models for MADM classify into two models; Compensatory Model, Non- Compensatory Model. Non-compensatory model includes methods which don`t need to achieve data from DM and lead to objective answer. Exchanging between indictors is permitted in Compensatory model. It means that for example, a weakness in a indicator may be compensated by option of other indicator. Electrical Method is a type of available methods in Compensatory Models. In this method whole options evaluate by non-ranked comparisons. All stages of this method are established based on coordinated and uncoordinated sets and thus this method is known as ‘’Coordination Analysis’’. Banayoun established the Electrical Method and Delft, Nijkamp, Roy and their colleagues developed it. In Electrical method, the concept of domination uses implicitly. In this method, options are compared in pairs, then dominant and weak (dominant and defeated) options determined and weak or defeated options omitted [14]. Linear Assignment is one of the Multi Criteria Decision Making combines qualitative and quantitative indicators, weights criteria based on their importance and helps decision makers to select the best options at the same time. In this method, supposed options are ranked based on their points in each available indicator and then the final rank of the options determined by the Linear Compensatory Process. The results of ELECTRE method to find the most suitable area for artificial recharge of groundwater aquifers of BAKHTIARI watershed showed in tables (2) to (11). Therefore, a matrix is formed with rank (49) for data matrix, with 7 alternatives (height zones) and 7 related indicators (Materials, Precipitation, stream density, fault density, slope, Elevation) (Table 2).

Conclusion

The increasing trend in (urban) water demand due to population growth places a growing stress on available water resources and calls for an efficient and acceptable long-term management of the resources. Hence, application of multi-attribute decision-making systems is essential for evaluating urban water supply schemes. A number of multi-attribute decision-making methods have been developed. This paper aims to survey the application of such systems to urban water supply problems and the effects of each multi-attribute decision-making method selected on the final ranking of alternatives. Three methods of Induced Ordered Weighted Averaging (IOWA), ELECTRE and TOPSIS have been considered for a real urban water management case study in the city of Bakhtiari in Iran. The results revealed that the multi-attribute decision-making method selected had a considerable effect on the final ranking of a finite set of alternatives such that different MADM techniques yielded different results for the same problem. It is, therefore, necessary to select the method according to the specific characteristics of the problem at hand, type of data available, and the assessments made. The ultimate alternative must be, thus, selected once evaluations have been made of the results obtained from applying different decision-making methods to the problem

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