Available online at www.elixirpublishers.com (Elixir International Journal)

Civil Engineering

Elixir Civil Engg. 81 (2015) 32059-32065

ISSN: 2229-712X

Application of AHP Model in Selection of Most Appropriate Area to Establish Soil Damp for Artificial Recharge of Underground Aquifers (Case Study: Tabas Basin)

Alireza Arabameri

Department of Civil Engineering, College of Engineering, Buinzahra Branch, Islamic Azad University, Buinzahra, Iran.

ARTICLE INFO

Article history:

Received: 18 November 2014;

Received in revised form: 19 April 2015;

Accepted: 29 April 2015;

Keywords

AHP Model,
Soil damp,
Artificial recharge.

ABSTRACT

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 the suitable position for Artificial Recharge of ground water. One of the management methods for water resources is Multi Criteria Decision Making. The analytic hierarchy process (AHP) is a structured technique for dealing with complex decisions that was developed by Thomas L. Saaty in the 1980 year. It provides a comprehensive and rational framework for structuring a decision problem, for representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions. The base of this model is comparing variables by pair wise by Matrix relationship. In this way, pair wise of the effective variables on the concrete Pavement were considered and based on relative weights the output was extent. In the present research, combination of Indexing system Method with Analytical Hierarchy Process has been applied to assess the Selection of most appropriate area to establish soil damp for artificial recharge of underground aquifers. The findings of the research show that zone 3 with 0/3606 points promotes in first rank among 5 studied zones and thus it is the most appropriate zone for Artificial Recharge of ground waters, in contrast zone 5 with 0/1731 point goes down to the last rank and so it isn`t suitable for Artificial Recharge and zones (2,4,1) are located in next ranks.

Introduction

Iran is one of the arid countries in second world arid continent means Asia The average of world annual rain is almost 860 millimeter. While this numbe in our country is almost 250 millimeter and in Yazd province is almost 61.2 millimeter that means less of ¼ average Iran's rain and less of ¼ average world rain (Ahmadi, 2006) .of course, this amount in consecutive years wouldn't access in steady process and this irregularity in frame work of arid and torrential rains cause wore damage to human and physical environment relative to quantity. Yazd province as a third province content of critic focus for windy erosion after Kerman and Khorasan for reason of region abnormality such as decreasing rainfall and increasing temperature Severely involved with this phenomenon and desert consecutive such as subsidence of underground water sources. Thus it is necessary satiable program which in this way could control one of the biggest obstacles developments (Ali zadeh, 2003). Drought is a generally occurring phenomenon which its effects intensify gradually. In some cases drought continues for longer time and causes destructive damages to human communities. During recent years climate change impacts have been combined with drought effects and caused serious problems in different parts of the World. Characteristics of a drought event are not often easily known until it occurs. During 1967 to 1992, about 50% of the 2.8 billion people who suffered from all natural disasters, have been affected by relatively sever drought. From 3.5 million people who were killed by disasters, about 1.3 million were victims of the drought (Obasi, 1994). About 50% of the World intensive populated regions containing the most agricultural lands are very vulnerable to the drought (USDA, 1994). Since these resources are 99% of whole available fresh water, it is necessary to determine and exploit the ground water (Kouthar, 1986- 19). Furthermore, it includes 80% of being used resources in arid and semi-arid areas in most countries (Sedaghat, 1994). Due to Iran`s situation in desert and semi-desert area and its average annual rainfall about 250 mm, so there were many ways to prepare fresh water for agriculture, drinking and industry in different parts of country from a long time ago. Therefore, determination and zoning the most appropriate area for artificial recharge of underground aquifers should be considered in this plain. There are many examples of applications of artificial recharge of ground water in literature For instance: Saraf and Choudhury (1998) used remote sensing capabilities in extracting different layers like land usage, geomorphology, vegetation, and their integration in GIS environment to determine the most suitable area for artificial recharge of ground water. Mahdavi (1997, 16) investigated water management and artificial recharge of ground water in Jourm city and indicated that controlling usage and recharge of water tables by the watershed management is the main management technique. Abdi and Ghayoumian (2001, 86) prioritized the suitable areas for storing surface water and reinforcing ground water based on geophysics data, land usage,

Tele:

E-mail addresses: alireza.ameri91@yahoo.com

topography, their integration and analysis in GIS environment. The purpose of this study is Application of AHP Model in Selection of most appropriate area to establish soil damp for artificial recharge of underground aquifers.

Methods and materials

Mathematical situation of studied area:

Tabas Basin with 5056/9 KM2 Being situated in the Yazd Province, Tabas Basin is bounded by 33º, 15' latitude to 33º, 57' north latitude and 56º, 25' to 57º and 23' longitude (Figure 1).

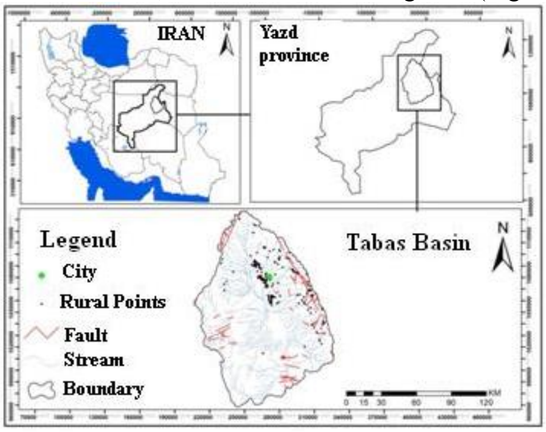


Figure 1. Mathematical situation of area

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 Mapper 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 5 elevation classes based o 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 and their layers prepared separately. After achieving a few numbers in each layer, the numbers were analyzed by AHP method. Then considered watershed was ranked to select the best area for establishing soil damp.

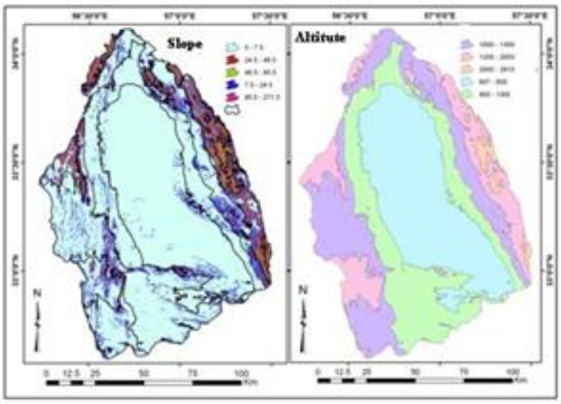


Figure 2 . Slope and Altitude Maps

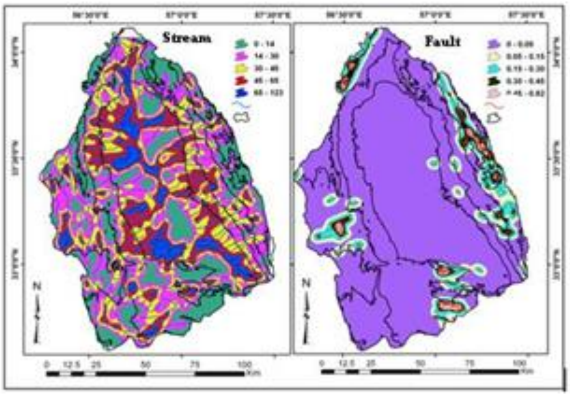


Figure 3 . Stream and Fault Density Maps

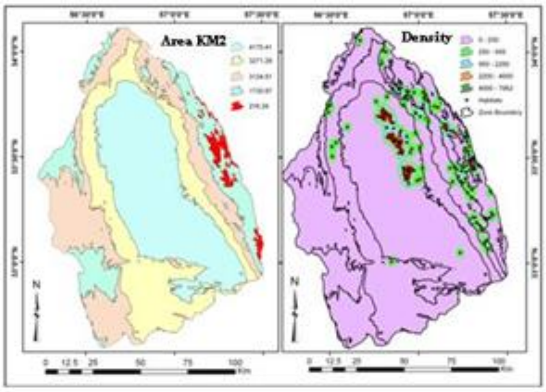


Figure 4. Area and Habitate Density Maps

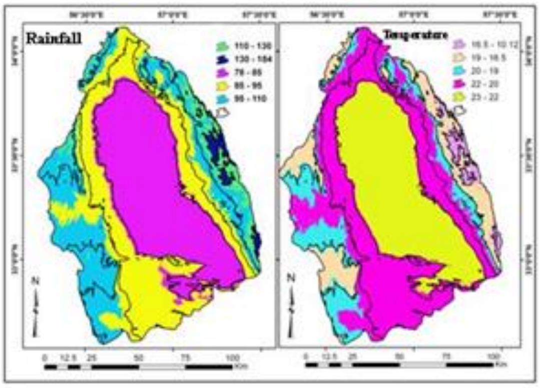


Figure 5. Rainfall and Temperature Maps

Theoretical Basis

Analytic hierarchy process (AHP), as a very popular multiple criteria decision making (MCDM) tool, has been considerably criticized for its possible rank reversal phenomenon, which means changes of the relative rankings of the other alternatives after an alternative is added or deleted. If the weights or the number of criteria are also changed, then rankings might be reversed. Such a phenomenon was first noticed and pointed out by Belton and Gear (Belton & Gear, 1983), which leads to a long-lasting debate about the validity of AHP (Dyer, 1990; Harker & Vargas, 1987; Wang & Liang, 2004; Saaty et al, 1983; Stewart, 1992; Troutt, 1998; Vargas, 1994; Watson & Freeling, 1982; Saaty & Vargas, 1984) especially about the legitimacy of rank reversal (Forman, 1990; Millet & Saaty, 2000; Saaty, 1987; Saaty, 1987;, Saaty & Vargas, 1984, Schoner & Wedley, 1992). In order to avoid the rank reversal, Belton and Gear (Belton & Gear, 1983) suggested normalizing the eigenvector weights of alternatives using their maximum rather than their sum, which was usually called B–G modified AHP. Saaty and Vargas [Saaty & Vargas, 1984] provided a counterexample to show that B– G modified AHP was also subject to rank reversal.

Table 1. Weighting the factors based on preference in paired comparison (Ghodsipoor, 2009)

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

Table 2. Quantity of I.I.R

n	1	2	3	4	5	6	7	...
I.I.R	0	0	0/58	0/9	1/12	1/24	1/32	...

Table 3. Paired comparison table to the criteria according to the purpose

According to Purpose	Slope	Altitude	Stream Density	Fault Density	Area	Habitate Density	Rainfall	Temperature	Wij
slope	1	3	0.20	0.25	5	0.17	0.14	0.20	0.06
Altitude		1	0.25	0.33	2	0.20	0.13	0.33	0.04
Stream Density			1	2	5	3	2	6	0.27
Fault Density				1	3	0.50	0.25	5	0.12
Area					1	0.25	0.17	0.50	0.03
Habitate Density						1	0.33	3.00	0.15
Rainfall							1	4	0.26
Temperature								1	0.07
Sum	27.53	27.50	3.15	10.12	28.00	8.45	4.27	20.03	1

Table 4. Paired comparison table to the options according to Rainfall

According to Rainfall	Region 1	Region 2	Region 3	Region 4	Region 5	Wij
Region 1	1	0.33	0.20	0.14	0.11	0.034137
Region 2		1	0.33	0.20	0.14	0.066919
Region 3			1	0.20	0.33	0.141229
Region 4				1	0.33	0.258897
Region 5					1	0.498817
Sum	25	16.33	9.53	4.54	1.92	1

Table 5. Paired comparison table to the options according to Stream Density

According to Stream Density	Region 1	Region 2	Region 3	Region 4	Region 5	Wij
Region 1	1	0.33	0.20	3	5	0.13435
Region 2		1	0.33	5	7	0.260232
Region 3			1	7	9	0.502819
Region 4				1	3	0.067778
Region 5					1	0.034821
Sum	9.53	4.68	1.79	16.33	25	1

Table 6. Paired comparison table to the options according to Area

According to Area	Region 1	Region 2	Region 3	Region 4	Region 5	Wij
Region 1	1	0.14	0.11	0.20	0.33	0.034821
Region 2		1	0.33	3	5	0.260232
Region 3			1	5	7	0.502819
Region 4				1	3	0.13435
Region 5					1	0.067778
Sum	25	4.68	1.79	9.53	16.33	1

Table 7. Paired comparison table to the options according to Fault Density

According to Fault Density	Region 1	Region 2	Region 3	Region 4	Region 5	Wij
Region 1	1	0.14	0.11	0.20	0.33	0.037844
Region 2		1	0.33	3	5	0.205806
Region 3			1	5	7	0.530032
Region 4				1	3	0.149469
Region 5					1	0.076849
Sum	18.14	4.68	1.79	9.53	16.33	1

Table 8. Paired comparison table to the options according to Slope

According to Slope	Region 1	Region 2	Region 3	Region 4	Region 5	Wij
Region 1	1	0.20	0.14	0.33	3	0.067778
Region 2		1	0.33	3	7	0.260232
Region 3			1	5	9	0.502819
Region 4				1	5	0.13435
Region 5				0	1	0.034821
Sum	16.33	4.68	1.79	9.53	25	1

Table 9. Paired comparison table to the options according to Temperature

According to Temperature	Region 1	Region 2	Region 3	Region 4	Region 5	Wij
Region 1	1	0.33	0.20	0.14	0.11	0.034821
Region 2		1	0.33	0.20	0.14	0.067778
Region 3			1	0.33	0.20	0.13435
Region 4				1	0.33	0.260232
Region 5					1	0.502819
Sum	25	16.33	9.53	4.68	1.79	1

Table 10. Paired comparison table to the options according to Altitute

According to Altitute	Region 1	Region 2	Region 3	Region 4	Region 5	Wij
Region 1	1	0.20	0.14	0.33	3	0.067778
Region 2		1	0.33	3	7	0.260232
Region 3			1	5	9	0.502819
Region 4				1	5	0.13435
Region 5					1	0.034821
Sum	16.33	4.68	1.79	9.53	25	1

Table 11. Paired comparison table to the options according to Habitate Density

According to Habitate Density	Region 1	Region 2	Region 3	Region 4	Region 5	Wij
Region 1	1	9	7	3	5	0.502819
Region 2		1	0.33	0.14	0.20	0.034821
Region 3			1	0.20	0.33	0.067778
Region 4				1	3	0.260232
Region 5					1	0.13435
Sum	1.79	25	16.33	4.68	9.53	1

Table 12. The weight matrix of options according to the criteria table

Criteria / Options	Rainfall	Stream Density	Area	Fault Density	Slope	Temperature	Altitute	Habitate Density
Region 1	0.0341	0.1344	0.0348	0.0378	0.067	0.0348	0.0678	0.5028
Region 2	0.0669	0.2602	0.2602	0.2058	0.260	0.0678	0.2602	0.0348
Region 3	0.1412	0.5028	0.5028	0.5300	0.502	0.1344	0.5028	0.0678
Region 4	0.2589	0.0678	0.1344	0.1495	0.134	0.2602	0.1344	0.2602
Region 5	0.4988	0.0348	0.0678	0.0768	0.034	0.5028	0.0348	0.1344

Table 13. Points and Ranks

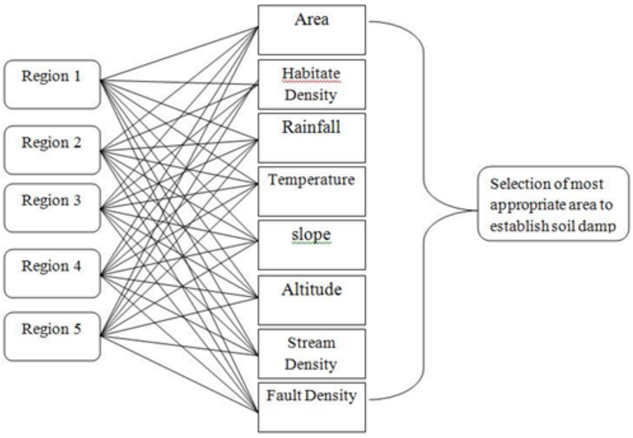
Indexes	Region 1	Region 2	Region 3	Region 4	Region 5
point	0/1743	0/1770	0/3606	0/1750	0/1731
Rank	Fourth	Second	First	Third	Fifth

Belton and Gear (Belton & Gear, 1985) argued that their procedure was misunderstood and insisted that their approach would not result in any rank reversal if criteria weights were changed accordingly. Schoner and Wedley (Schoner & Wedley, 1989) presented a referenced AHP to avoid rank reversal phenomenon, which requires the modification of criteria weights when an alternative is added or deleted. Schoner et al. (Schoner, B., Wedley, W, 1993) also suggested a method of normalization to the minimum and a linking pin AHP (see also (Schoner & Wedley, 1997)), in which one of the alternatives under each criterion is chosen as the link for criteria comparisons and the values in the linking cells are assigned a value of one, with proportional values in the other cells. Barzilai and Golany (Barzilai et al, 1987) showed that no normalization could prevent rank reversal and suggested a multiplicative aggregation rule, which replaces normalized weight vectors with weight–ratio matrices, to avoid rank reversal. Lootsma (Lootsma, 1993) and Barzilai and Lootsma (Barzilai & Lootsma, 1997) suggested a multiplicative AHP for rank preservation. Vargas (Mianabadi & Afshar, 2007) provided a practical counterexample to show the invalidity of the multiplicative AHP. Triantaphyllou (Triantaphyllou, 2001) offered two new cases to demonstrate that the rank reversals do not occur with the multiplicative AHP, but do occur with the AHP and some of its additive variants. Leung and Cao (Leung & Cao, 2001) showed that Sinarchy, a particular form of analytic network process (ANP), could prevent rank reversal. As an integrative view, the AHP now supports four modes, called Absolute, Distributive, Ideal and Supermatrix modes, respectively, for scaling weights to rank alternatives (Millet & Saaty, 2000; Saaty, 1986; Saaty, 1994; Saaty & Vargas, 1993). In the absolute mode, alternatives are rated one at a time and there is no rank reversal when new alternatives are added or removed. The distributive mode normalizes alternative weights under each criterion so that they sum to one, which does not preserve rank. The ideal mode preserves rank by dividing the weight of each alternative only by the weight of the best alternative under each criterion. The supermatrix mode allows one to consider dependencies between different levels of a feedback network. More recently, Ramanathan (Ramanathan, 2006) suggested a DEAHP, which is claimed to have no rank reversal phenomenon. But in fact, it still suffers from rank reversal. Wang and Elhag suggested an approach in which the local priorities remained unchanged. So, the ranking among the alternatives would be preserved.

Analytical Hierarchy process (AHP)

The Analytic Hierarchy Process (AHP) is an approach that is suitable for dealing with complex systems related to making a choice from among several alternatives and which provides a comparison of the considered options. This method was first presented by Saaty (Saaty, 1980). The AHP is based on the subdivision of the problem in a hierarchical form. The AHP helps the analysts to organize the critical aspects of a problem into a hierarchical structure similar to a family tree. By reducing complex decisions to a series of simple comparisons and rankings, then synthesizing the results, the AHP not only helps the analysts to arrive at the best decision, but also provides a clear rationale for the choices made. The objective of using an analytic hierarchy process (AHP) is to identify the preferred alternative and also determine a ranking of the alternatives when all the decision criteria are considered simultaneously (Saaty, 1980). Process steps are as follows:

Step 1: building a hierarchy.



Step 2: determining the coefficients of the importance standards and sub-criteria: To determine the coefficients (weights) of the criteria and sub-criteria to compare the two to two. Judgment based on the quantitative comparison table below (Table 1).

Step 3: Preparation of paired comparisons matrices and normalization factors:Then the values for each pairwise comparison matrix columns together and each element in matrix paired comparisons were divided into the sum of a column that normalized the paired comparison matrix normalized (Equation 1). Then calculate mean of the elements in each row of the matrix that results in is created normalized weight vector (Equation 2).

$$r_{ij} = \frac{a_{ij}}{\sum_{i=1}^{m} a_{ij}} \quad (1)$$

$$W_i = \frac{\sum_{i=1}^{n} r_{ij}}{n} \quad (2)$$

In these equations m: number of columns, n: number of rows, aij: paired comparison of matrix elements rij: Options for normalization of matrix elements i, j index i, and Wi: weight of i-th item.

Step 4: Determine the final score factors (preferences and priorities): At this stage, the fusion coefficients are determined by the final score of each of the options. For this purpose, can be used the hierarchical composition of the resulting priority vector with respect to all judges at all levels of the hierarchical (Bertolini et al, 2006; Moreno-Jiminez et al, 2005) .

In other words, the final score of each of the routes be determined of the sum of the coefficients of integration options and criterion (Equation 3).

$$V_H = \sum_{k=1}^{n} W_k \left(g_{ij}\right) \quad (3)$$

In this respect is: VH: My final choice j, WK: The weight of each criterion and gij: weighing the options regarding the criteria.

Step 5: Calculate the compatibility or incompatibility system: To calculate the rate of adaptability must first paired comparison matrix (A) of the weight vector (W) is multiplied to obtain a good approximation of λ max W λ max W that is A × W = λ max W. Dividing the λ max value of λ max W of W is calculated. Then inconsistency index is calculated of the equation (4) (Ghodsipoor, 2009)

$$I.I. = \frac{\lambda \max - n}{n - 1} \quad (4)$$

Inconsistency rate is calculated via equation (5):

$$I.R. = \frac{I.I.}{I.I.R.} \quad (5)$$

Quantity of I.I.R extracted from this table. If the inconsistency rate less than or equal to 0.1, system consistency is acceptable, If more than 0.1 is better to reconsider its decision on the judgment (Dey & Ramcharan , 2000).

Discussion

The analytical hierarchy procedure (AHP) is proposed by Saaty (Saaty, 1980). AHP was originally applied to uncertain decision problems with multiple criteria, and has been widely used in solving problems of ranking, selection, evaluation, optimization, and prediction decisions. The AHP method is expressed by a unidirectional hierarchical relationship among decision levels. The top element of the hierarchy is the overall goal for the decision model. The hierarchy decomposes to a more specific criterion in which a level of manageable decision criteria is met (Mianabadi & Afshar, 2008]. Under each criteria, sub-criteria elements related to the criterion can be constructed. The AHP separates complex decision problems into elements within a simplified hierarchical system (Limon & Martinez, 2006). The AHP usually consists of three stages of problem solving: decomposition, comparative judgment, and synthesis of priority. The decomposition stage aims at the construction of a hierarchical network to represent a decision problem, with the top level representing overall objectives and the lower levels representing criteria, subcriteria and alternatives. With comparative judgments, expert users are requested to set up a comparison matrix at each hierarchy by comparing pairs of criteria or sub-criteria. Finally, in the synthesis of priority stage, each comparison matrix is then solved by an eigenvector method for determining the criteria importance and alternative performance. The purpose of the AHP Method in this paper is Application of AHP Model in Selection of most appropriate area to establish soil damp for artificial recharge of underground aquifers. The results of AHP method for This Purpose showed in tables (3) to (13) and figures (7,8).

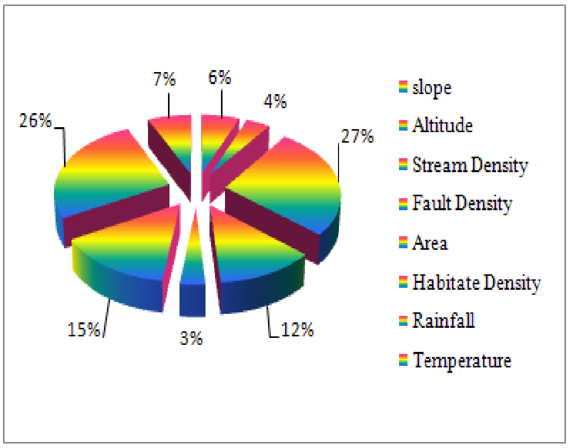


Figure 7. The weight matrix of criteria according to Purpose

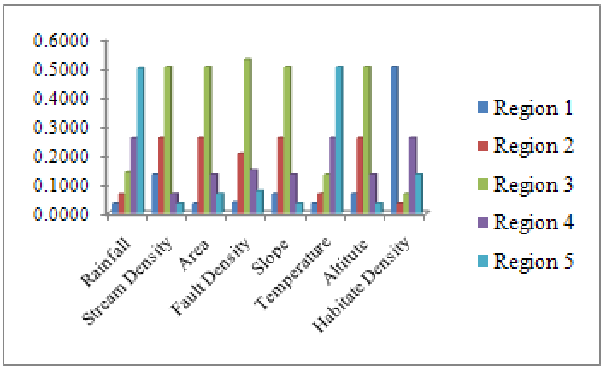


Figure 8. The weight matrix of option according to criteria

Conclusion

Decision making problem is the process of finding the best option from all of the feasible alternatives. In almost all such problems the multiplicity of criteria for judging the alternatives is pervasive. That is, for many such problems, the decision maker wants to solve a multiple criteria decision making (MCDM) problem. A survey of the MCDM methods has been presented by Hwang and Yoon (Hwang, 1981). The analytic hierarchy process (AHP) is one of the extensively used multi-criteria decision-making methods One of the main advantages of this method is the relative ease with which it handles multiple criteria. In addition to this, AHP is easier to understand and it can effectively handle both qualitative and quantitative data. The use of AHP does not involve cumbersome mathematics. AHP involves the principles of decomposition, pairwise comparisons, and priority vector generation and synthesis. Though the purpose of AHP is to capture the expert's knowledge, the conventional AHP still cannot reflect the human thinking style. Therefore, fuzzy AHP, a fuzzy extension of AHP, was developed to solve the hierarchical fuzzy problems. In the fuzzy-AHP procedure, the pairwise comparisons in the judgment matrix are fuzzy numbers that are modified by the designer's emphasis . The findings of the research show that zone 3 with 0/3606 points promotes in first rank among 5 studied zones and thus it is the most appropriate zone for Artificial Recharge of ground waters, in contrast zone 5 with 0/1731 point goes down to the last rank and so it isn`t suitable for Artificial Recharge and zones (2,4,1) are located in next ranks.

References

1. Ahmadi, H. (2006), applied geomorphology, volume 2, desert -wind erosion, Tehran University publication.
2. Ali zadeh, A, (2003), principals of applied hydrology, 16th print, Emmam Reza University publication, 233.
3. Barzilai, J, Cook, W, Golany, B, 1987, Consistent weights for judgment matrices of the relative importance of alternatives. Operations Research Letters 6 , 131-134.
4. Barzilai, J., Lootsma, F.A, 1997, Power relations and group aggregation in the multiplicative AHP and SMART. Journal of Multi-Criteria Decision Analysis 6, 155-165.
5. Belton, V., Gear, T., 1983, On a shortcoming of Saaty's method of analytic hierarchies . Omega 11 , 228-230.
6. Belton, V., Gear, T, 1985, The legitimacy of rank reversal - a comment. Omega 13 , 143-144.
7. Dyer, J, 1990, A clarification of 'Remarks on the Analytic Hierarchy Process'. Management Science 36 , 274-275.
8. Forman, E, 1990, AHP is intended for more than expected value calculationS. Decision Sciences 36 671–673.
9. Harker, P., Vargas, L, 1987, The theory of ratio scale estimation: Saaty's analytic hierarchy process. Management Science 33 , 1383-1403.
10. Hwang, C.L., Yoon, K., ''Multiple Attributes Decision Making Methods and Applications'', Springer, Berlin Heidelberg, 1981
11. Kouthar, Ahang, 1986,'Application of flood development methods in artificial recharge of ground water tables' , Olive magazine, 46 and 47, pp 16 23.
12. Sedaghat, M, 2009, ''Earth and its water resources'', Tehran, Payam Noor University Press
13. Leung, L., Cao, D, 2001, On the efficacy of modeling multi-attribute decision problems using AHP and Sinarchy. European Journal of Operational Research 132 , 39-49.
14. Lootsma, F, 1993, Scale sensitivity in the multiplicative AHP and SMART. Journal of Multi-Criteria Decision Analysis 2, 87-110.

15. Millet, I, Saaty, T, 2000, On the relativity of relative measures – accommodating both rank preservation and rank reversals in the AHP. European Journal of Operational Research 121 , 205–212.
16. Mianabadi,H,Afshar,A, 2007,Fuzzy group Decision Making and its Application in water Resource Planning and Management, Oral Presentation Iran Water Resource Management Conference, January 12-13,Isfahan.Iran.
17. Ramanathan, R, 2006, Data envelopment analysis for weight derivation and aggregation in the analytic hierarchy process. Computers and Operations Research 33 , 1289-1307.
18. Saaty, T, 1986, Axiomatic foundation of the analytic hierarchy process. Management Science 32 , 841-855.
19. Saaty, T. 1994, Highlights and critical points in the theory and applicationof the Analytic Hierarchy Process. European Journal , 426-447.
20. Saaty, T., Vargas, L. 1993, Experiments on rank preservation and reversal in relative measurement. Mathematical and Computer Modelling 17,13-18.
21. Saaty, T., Vargas, L., Wendell, R, 1983, Assessing attribute weights by ratios. Omega 11 , 9-13.
22. Saaty, T, 1987, Decision making, new information, ranking and structure.Mathematical Modelling 8 , 125–132.
23. Saaty, T, 1987, Rank generation, preservation, and reversal in the analytichierarchy decision process. Decision Sciences 18 , 157–177.
24. Saaty, T., Vargas, L, 1984, The legitimacy of rank reversal. Omega 12 (5) , 513–516.
25. Schoner, B., Wedley, W, 1992, E.U. Choo, A rejoinder to Forman on AHP, with emphasis on the requirements of composite ratio scales.Decision Sciences 23 , 509–517, 1992.
26. Schoner, B., Wedley, W, 1993, E.U. Choo, A unified approach to AHP with linking pins. European Journal of Operational Research , 384-392.
27. Schoner, B., Wedley, W, 1997, E.U. Choo, A comment on Rank disagreement:a comparison of multicriteria methodologies. Journal of Multi-Criteria Decision Analysis 6, 197-200.
28. Stewart, T, 1992, A critical survey on the status of multiple criteria decision making theory and practice. Omega 20, 569–586.
29. Troutt, M, 1998, Rank reversal and the dependence of priorities on the underlying MAV function. Omega 16, 365–367.
30. Triantaphyllou, E, 2001, Two new cases of rank reversal s when the AHP and some of its additive variants are used that do not occur with the multiplicative AHP. Journal of Multi-Criteria Decision Analysis 10,11-25.
31. Vargas, L, 1994, Reply to Schenkerman's avoiding rank reversal in AHP decision support models. European Journal of Operational, 420–425.
32. Wang, R.C., Liang, T.F, 2004, Application of fuzzy multi-objective linear programming to aggregate production planning, Computers & Industrial Engineering, 46, pp. 17–25.