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

Civil Engineering

Elixir Civil Engg. 81 (2015) 32022-32029

Elixir ISSN: 2229-712X

Zoning Mashhad Watershed for Artificial Recharge of Underground Aquifers Using Topsis Model and GIS Technique

Alireza Arabameri

Ph.D Candidate of Geomorpholog, Faculty of Humanities, Department of Geography, Tarbiat Modares University, Tehran, Iran.

ARTICLE INFO

Article history:

Received: 15 November 2014;
Received in revised form:
19 April 2015;
Accepted: 28 April 2015;

Keywords

Groundwater,
Aquifer,
Algorithm TOPSIS,
Artificial recharge,
Zoning,
Watershed Mashhad.

ABSTRACT

In recent years, coincide with population growth and industrial expansion, in many countries in the world, Extract water of underground sources expanded and annual withdrawal of ground water is higher than the annual feeding. This means extracting and using the water in layers that has been saved over thousands of years in the underground. Consequently groundwater levels in the area will be extracted every day and eventually drop where the water will not exist. While proper management and control of these resources will eliminate the problems of drop in water level. One way to managing groundwater resources is artificial recharge of groundwater and determine suitable locations for these purpose. growth and development trend of Mashhad city and excessive Extracting of ground water in recent years, has been essential groundwater resources management strategy in the region more than ever implied. The purpose of this study is Zoning Mashhad watershed for artificial recharge of underground aquifers using TOPSIS Model and GIS technique. TOPSIS algorithm is a Multi Criteria Decision Making, a type of compensatory model and an adaptable subgroup with strong ability to solve multi alternative problems because of having ability to overlap indicators in weak and power points . In this model, if quantitative criteria can change in to qualitative criteria, qualitative criteria can be used besides quantitative criteria. In aforementioned model, it is supposed that each indicator and criterion has steady increasing and decreasing utility in decision making matrix; it means if criteria gain more positive amount, they will be more appropriate, on the contrary the more negative amount, the less appropriate. The result and findings of different studies show that in TOPSIS method, zone 3 with (0/669) point promotes in first rank among 5 studied zones and thus it is the most appropriate zone to establish the proper area for artificial recharge of underground aquifers , in contrast zone 1 with (0/302) point goes down to the last rank and so it isn`t suitable for establishing damp and zones (4,2,5) with (0/650, 0/450, 0/325) points are located in next ranks.

Introduction

Nowadays, shortage and decrease in fresh water is approximately under increased all over the world. Based on the statistics published by FAO (Food and Agriculture organization), need for fresh water has almost become double per 21 years, while useful water resources have been reduced by half in relation to 30 years ago. It seems that useful water resources will become one fourth up to 2025 than useful water resources in 1960. Meanwhile, danger of various pollutions for water resources frequently increased the value and importance of them. Due to mentioned cases, if water resources aren't managed in better way, the life of human being will be threatened by the shortage of water. 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. since, the group decision making, evaluation is resulted from different evaluator's view of linguistic variables, its evaluation must be conducted in an uncertain, fuzzy environment . 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. Due to continuous decline in per capita water and the importance of nutritious preparation for people it is necessary to control the surface water using damp building or artificial recharge methods. Researchers of water sciences have studied the damp building and artificial recharge projects all over the world, drawn logarithm curve for cost against the amount of savable running water and concluded that it is frugal economically to accomplish artificial recharge projects especially flood distribution instead of damp building for the volume less than 30 million cube meter (Bize, et al., 1972). the experiences of under developed countries show that compressing the agriculture caused quick output purposes but they destroy the basic resources for a long term. It can be noticed in pasture destruction, forest resources reduction, deserts increase, reduction and destruction of surface water resources and ground water and exponential compress to the basic resources. In our country, planning in agricultural, rural and natural resources development has always been founded at the level of political development. This traditional attitude toward planning and development caused instability in using basic resources. During

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

2 previous decades, our country has taken activities to develop agriculture and natural resources comprehensively. Although these activities were slow and sluggish, they can develop a new attitude among experts, connoisseurs and decision makers in agriculture section. Based on this attitude, casual, one-direction and one-dimensional activities can solve part of short term problems and difficulties related to agriculture section and have pathetic effects on this section in long term. 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. There are many examples of applications of TOPSIS 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, topography, their integration and analysis in GIS environment.Kia Heyrati (2004) studied the function of flood distribution system in recharge of ground water in Moughar plain in Isfahan. Mahdavi et.al (2005) attempted to find the best position for artificial recharge of ground water by RS and GIS techniques in watershed Shahr Reza in Isfahan and introduced this tool for this case efficiently. Also, Noori et al (2004, 635) tried to find the appropriate areas for artificial recharge of ground water by recharge pools (recharge pools) and GIS technique in watershed Gavbandi and introduced alluvial fans and plain head (Dashtsar) as the best area for artificial recharge. Mousavi et al (2010) found the potential appropriate areas for artificial 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. 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 (Mianabadi, 2008: 34-45). Limon and Martinez (2006) used Multi Attribute Utility theory for optimum allocation of agriculture water in north of Spain (Limon, 2006: 313-336). Ahmadi et al (2002) used multiple criteria decision making to rank different projects of refining agriculture water to reuse them (Ahmadi, 2002: 339-352). Also, Anand Raj and Kumar (1996) ranked management options of river basin by ELECTRE method (Anand, 1996: 326-335). The purpose of this study is zoning the best area for artificial recharge of underground basins in Mashhad watershed using effective factors in recharging underground water table by TOPSIS and GIS technique. In another way, this study aimed at the selection of most appropriate area to establish soil damps for the purpose of sustainable development of water resources using TOPSIS Method.

Methods and materials

Mathematical situation of studied area:

Being situated in the northeastern part of countery, Mashhad province is bounded by 35º, 43' latitude to 37º, 8' north latitude and 59º, 15' to 60º and 36' longitude. It has access to Semnan Province in the East. Globally, Mashhad Basin is located at 985 meter height above sea level and its extent is 204 square kilometers.

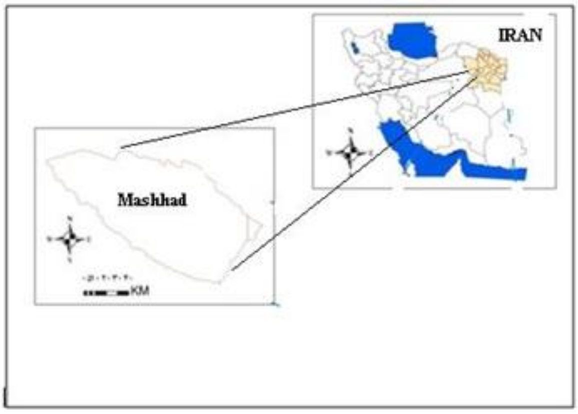


Figure 1. Geographical position of Mashhad Basin

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 7 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 o 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 , 10) and their layers prepared separately. After achieving a few numbers in each layer, the numbers were analyzed by TOPSIS method. Then considered watershed was ranked to select the best area for establishing soil damp.

Multi Attribute Decision Making (MADM)

The MCDM problems may be divided into two kinds of problem. One is the classical MCDM problems [Hwang &Yoon 1981, Keeney & Raiffa 1976, Feng & Wang 2000] among which the ratings and the weights of criteria are measured in crisp numbers. Another is the fuzzy multi-criteria decision-making (FMCDM) problems [Bellman & Zadeh 1970, Boender et al 1989, Chang & Yeh 2002, Chen 2000, Chen & Hwang 1992, Hsu & Chen 1996, Hsu & Chen 1997, Jain 1978, Kacprzyk et al 1992, Lee 1999, Liang 1999, Nurmi 1981, Raj & Kumar 1999, Tsaur et al 2002, Tanino 1984, Wang et al 2003], among which the ratings and the weights of criteria evaluatedon imprecision, subjective and vagueness are usually

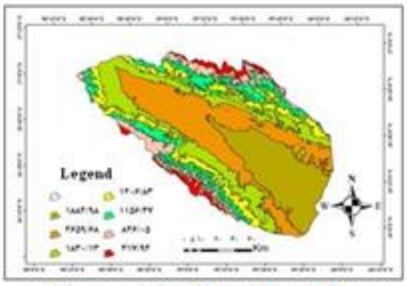


Figure (2): Rainfall Map

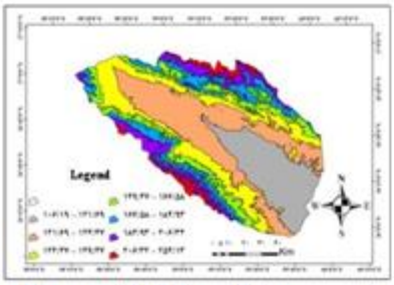


Figure (3): Area Map

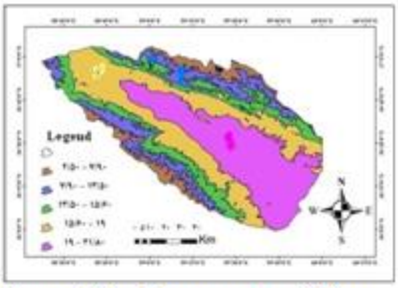


Figure (4): Temperature Map

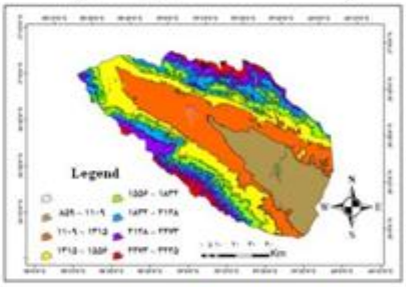


Figure (5): Elevation Map

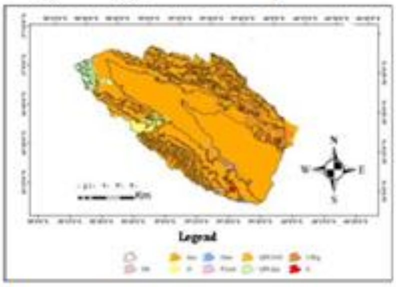


Figure (6): Lithology Map

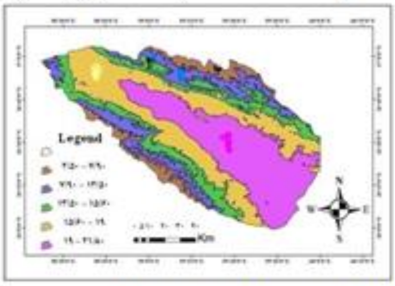


Figure (7): Habitual Density Map

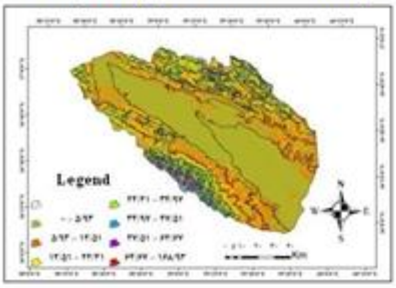
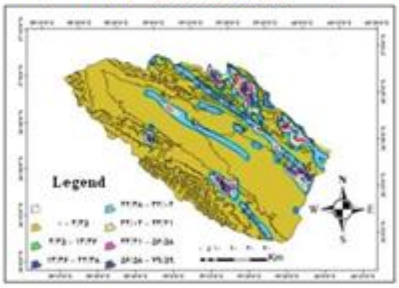
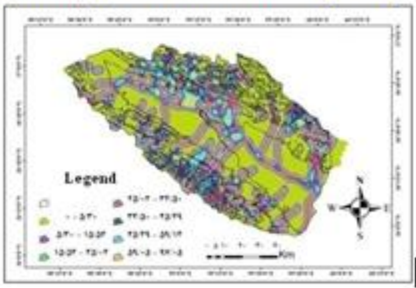


Figure (8): slope Map


(9): Fault Density Map


(10): Stream Density Map

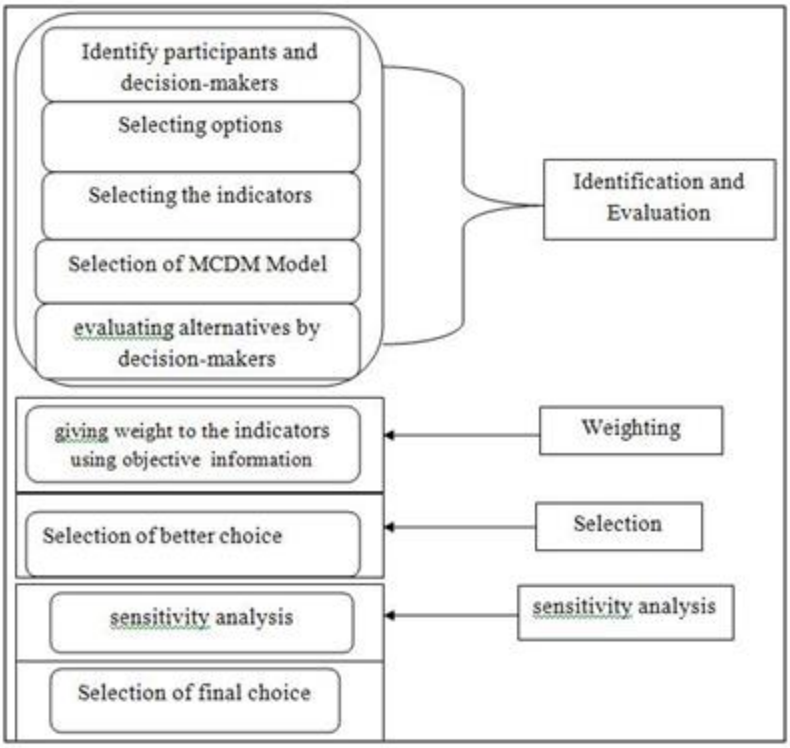


Figure 11. Multi Attribute Decision Making process

expressed by linguistic terms and then set into fuzzy numbers [Zadeh 1965, Zimmermann 1987, Zimmermann 1991]. multiple criteria decision making models are divided into two major categories, including Multi Attribute Decision Making (MADM) and Multi Objective Decision Making (MODM). Multi-criteria decision-making process involves four basic steps, which are 1- Identification and Evaluation, 2- Weighting, 3- Select option using one of the methods of multi-criteria decision making, 4 - Sensitivity analysis and final choices. Multi Attribute Decision Making process in Figure (11) is shown.

TOPSIS

The technique for order preference by similarity to ideal solution (TOPSIS) proposed Hwang and Yoon [Hwang &Yoon 1981] is one of the well-known methods for classical MCDM. The underlying logic of TOPSIS is to define the ideal solution and negative ideal solution. The ideal solution is the solution that maximizes the benefit criteria and minimizes the cost criteria, whereas the negative ideal solution is the solution that maximizes the cost criteria and minimizes the benefit criteria. In short, the ideal solution consists of all of best values attainable of criteria, whereas the negative ideal solution is composed of all worst values attainable of criteria. The optimal alternative is the one which has the shortest distance from the ideal solution and the farthest distance from the negative ideal solution. situation of TOPSIS method among the other Multi Criteria Decision Making showed in Figure (12).

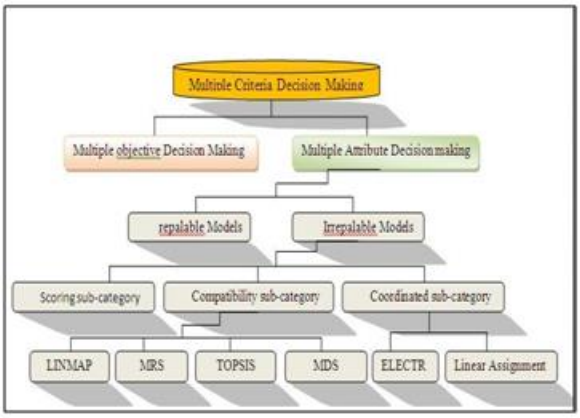


Figure 12. Situation of TOPSIS method among the other Multi Criteria Decision Making

Problem solving process using TOPSIS method:

TOPSIS model includes 8 processes which are described in the following parts (Olson, 2003-2).

1. Establishing data matrix based on alternative n and indicator k:

Generally, in TOPSIS model, matrix **n×m** with **m** alternative and **n** criteria is evaluated. In this algorithm, it is supposed that each indicator and criterion in Decision Making matrix has steady increasing and decreasing utility.

$$A_{ij} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ . & . & & . \\ . & . & & . \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix}$$

2. Standardizing data and preparing normalized matrix (matrix R) by Equation (1):

Since it is possible that quantitative amount of criteria and indicators don`t have equal unit , the dimensions of their units should be omitted. Thus, all amounts of entries of Decision Making matrix should be changed into dimensionless amount with following formula:

$$R_{IJ} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^{2}}} \quad (1)$$

$$\begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ . & . & & . \\ . & . & & . \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix}$$

3. Determining weights for whole indicators (w_j) by equation (2) and modifying calculated (w_j) by equation (3):

In this process, the weights of all indicators are calculated by expertise theories and approaches, Linmap method, AHP model, Antropi model and based on the importance of criteria. It is considerable that sum of criteria weights should be equal to 1. In this study, AHP model has been used to calculate the amount of (w_j)

$$\sum_{j=1}^{n} w_j = 1 \qquad (2)$$

$$w'_j = \frac{\lambda_j . w_j}{\sum_{j=1}^{n} \lambda_j . w_j} \qquad (3)$$

4. Creating dimensionless weighted matrix (V) to implement vector W as an input for algorithm:

In order that the amounts of entries in matrix R gain equal value, , sum of weights of parameter (w_j) are multiplied to the column of this matrix one by one. The acquired matrix is normalized and weighted matrix which is shown by sign (V) (Table 4).

$$V_{ij} = R_{ij} . W_{n\times n} = \begin{bmatrix} v_{11,\dots} & v_{1j,\dots} & v_{1n} \\ . & . & . \\ . & . & . \\ v_{m1,\dots} & v_{mj,\dots} & v_{mn} \end{bmatrix}$$

5. Determining positive ideal (A^+) and negative ideal (A^-) by equations (4) and (5) respectively:

$$d_{i+} = \sqrt{\sum_{j=1}^{n} \left(V_{ij} - V^{+}_{j}\right)^2} \; ; \; i = 1,2,\dots,m \qquad (4)$$

$$d_{i-} = \sqrt{\sum_{j=1}^{n} \left(V_{ij} - V^{-}_{j}\right)^2} \; ; \; i = 1,2,\dots,m \qquad (5)$$

6. Calculating distance size of i-alternaive with ideals and using Euclidean method, by equations (6) and (7):

$$d_{i+} = \text{dictance of i} - \text{alternative from positive ideal} = \sqrt{\sum_{j=1}^{n} \left(V_{ij} - V^{+}_{j}\right)^2} \; ; i = 1,2,\dots,m \qquad (6)$$

$$d_{i-} = \text{distance of i} - \text{alternative from negative ideal} = \sqrt{\sum_{j=1}^{n} \left(V_{ij} - V^{-}_{j}\right)^2} \; ; i = 1,2,\dots,m \qquad (7)$$

7. Calculating relative closeness for i-alternative (A_i) i to ideal solution using equation (8):

$$cl_{i+} = \frac{d_{i-}}{d_{i+} + d_{i-}} \; ; 0 \le cl_{i+} \le 1 \; ; i = 1,2,\dots,m \qquad (8)$$

Table 1. Decision Matrix (X)

Regions	Materials	Precipitation (mm)	Stream density	area (km2)	Fault density	Slope	Heat	height	habitual density
1	3	108.85	48.52	3090	39.84	20.34	20.4	1028	7552.5
2	5	122.1	36.68	2977	38.79	22.59	17.3	1348	3916.14
3	9	146.56	41.73	1629	38.1	27.37	14.55	1675	2504.49
4	7	189.4	41.74	1439	38.26	29.22	10.7	2058	1448.65
5	1	283.59	36.5	764	39.26	26.01	5.2	2755	1590.05

Table 2. Dimensionless Matrix (Matrix R)

Regions	Materials	Precipitation (mm)	Stream density	area (km2)	Fault density	Slope	Heat	height	habitual density
1	0.2335	0.2684	0.5258	0.6345	0.4585	0.3594	0.6240	0.2457	0.8276
2	0.3892	0.3010	0.3975	0.6112	0.4465	0.3991	0.5292	0.3222	0.4291
3	0.7006	0.3613	0.4522	0.3345	0.4385	0.4836	0.4451	0.4003	0.2744
4	0.5449	0.4669	0.4523	0.2955	0.4404	0.5163	0.3273	0.4919	0.1587
5	0.0778	0.6991	0.3955	0.1570	0.4519	0.4595	0.1591	0.6585	0.1742

Table 3. Paired Comparison Matrix of different criteria (S)

Parameters	Materials	Precipitation (mm)	Stream density	area (km2)	Fault density	Slope	Heat	height	habitual density	Wij
Materials	1	2	3	4	5	6	7	8	9	0.307
Precipitation (mm)	0.5	1	2	3	4	5	6	7	8	0.2182
Stream density	0.33	0.5	1	2	3	4	5	6	7	0.1543
Area(km2)	0.25	0.33	0.5	1	2	3	4	5	6	0.1089
Fault density	0.2	0.25	0.33	0.5	1	2	3	4	5	0.0764
Slope	0.16	0.2	0.25	0.33	0.5	1	2	3	4	0.0533
Heat	0.14	0.16	0.2	0.25	0.33	0.5	1	2	3	0.037
height	0.12	0.14	0.16	0.2	0.25	0.33	0.5	1	2	0.0259
habitual density	0.11	0.12	0.14	0.16	0.2	0.25	0.33	0.5	1	0.0189
Sum	2.81	4.7	7.58	11.44	16.2	22	28.8	36.5	45	1

Table 4. Weighted dimensionless Decision Matrix (V)

Regions	Materials	(mm) Precipitation	Stream density	(km2) area	Fault density	Slope	Heat	height	habitual density
1	0.0717	0.0586	0.0811	0.0691	0.0350	0.0192	0.0231	0.0064	0.0156
2	0.1195	0.0657	0.0613	0.0666	0.0341	0.0213	0.0196	0.0083	0.0081
3	0.2151	0.0788	0.0698	0.0364	0.0335	0.0258	0.0165	0.0104	0.0052
4	0.1673	0.1019	0.0698	0.0322	0.0336	0.0275	0.0121	0.0127	0.0030
5	0.0239	0.1526	0.0610	0.0171	0.0345	0.0245	0.0059	0.0171	0.0033

Table 5. Amounts of positive and negative ideals (highest and lowest function of indicator)

Ideals	habitual density	height	Heat	Slope	Fault density	(km2) area	Stream density	(mm) Precipitation	Materials
A+	0.215	0.152	0.081	0.069	0.035	0.019	0.005	0.017	0.015
A-	0.023	0.058	0.061	0.017	0.032	0.027	0.023	0.006	0.003

Table 6. Distance o^{i}-alternative from ideals

regions / Distance	1	2	3	4	5
D_i^+	0.1727	0.1319	0.0833	0.0814	0.1996
D_i^-	0.0750	0.1083	0.1936	0.1513	0.0962

Table 7. relative distance of i-alternative(A_i) to ideal solution

Cl_i	C1	C2	C3	C4	C5
Amount	0.3028	0.4515	0.7003	0.6502	0.3227

Table 8. Points and Ranks of zones

Region	1	2	3	4	5
Point (Fuzzy Logic)	0.3036	0.4507	0.6691	0.6502	0.3252
Rank	Fifth	Third	First	Second	Fourth

As you can see, if $A_i=A^+$, then $d_{i+}=1$ and $cl_{i-}=0$, on the contrary if $A_i=A^-$, then $d_{i+}=1$ and $cl_{i-}=0$. In sum, the more alternative A_i is closer to ideal solution, the more value of cl_{i+} is closer to unit.

8. Ranking alternatives based on descending order of cl_{i+} :

This amount is fluctuating between 0 and 1. Thus, cl_{i+} =1 represents the highest rank and cl_{i+} =0 the lowest rank.

Discussion

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. Nowadays, because of uncontrolled exploitation of ground water, water shortage is became doubled. Accurate control and management of these water resources can alleviate the problem of drought approximately. One of the management techniques of ground water resources is artificial recharge of basins and determination of the most appropriate place for it. The ground water resources are the largest and most importance reservoirs of fresh water on the earth for human being after glaciers and glacial zones (Freeze, 1979). 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.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. The Purpose of This Study is Zoning Mashhad watershed for artificial recharge of underground aquifers using TOPSIS Model and GIS technique The results of TOPSIS method to find the most suitable area for artificial recharge of groundwater aquifers of Mashhad Basin showed in tables (1) to (8). Therefore, a matrix is formed with rank (81) for data matrix, with 9 alternatives (height zones) and 9 related indicators (Materials, Precipitation , (mm), Stream density, area(km2), Fault density, Slope, Heat,) (Table 1).

Conclusion

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. The result and findings of different studies show that in TOPSIS method, zone 3 with (0/669) point promotes in first rank among 5 studied zones and thus it is the most appropriate zone to establish the proper area for artificial recharge of underground aquifers , in contrast zone 1 with (0/302) point goes down to the last rank and so it isn`t suitable for establishing damp and zones (4,2,5) with (0/650, 0/450, 0/325) points are located in next ranks.

References

1. Abdi, P and Ghayoumian J., 2001,‘ Determining the appropriate area for Flood distribution in Zanjan plain using geophysical data and GIS’’, articles of public seminar on Achievements of Aquifer Project, pp 86-99.

2. Anand,Raj,P.A., Kumar, D.N. (1996),”Ranking of niver basin alternative using ELECTRE, Hydrological Science, V41,PP326-335

3. Bellman R.E, Zadeh L.A (1970). Decision-making in a fuzzy environment, Management Sciences 17 141–164.

4. Bellman R.E, Zadeh L.A (1970). Decision-making in a fuzzy environment, Management Sciences 17 141–164.

5. Boender C.G.E, de Graan J.G, Lootsma F.A (1989). Multi-attribute decision analysis with fuzzy pairwise comparisons, Fuzzy Sets and Systems 29 133–143.

6. Chang Y.H, Yeh C.H (2002). A survey analysis of service quality for domestic airlines, European Journal of Operational Research 139 166–177.

7. Chen C.T (2000). Extensions to the TOPSIS for group decision-making under fuzzy environment, Fuzzy Sets and Systems 114 1–9.

8. Chen S.J, Hwang C.L (1992). Fuzzy multiple attribute decision making methods and application, in: Lecture Notes in Economics and Mathematical Systems, Springer, New York.

9. Freeze, R.A, Cherry, J.A., (1979), Groundwater, prentice-Hall, Englewood Cliffs, New Jersey

10. Hsu H.M, Chen C.T (1996). Aggregation of fuzzy opinions under group decision making, Fuzzy Sets and Systems 79 279–285.

11. Hsu H.M, Chen C.T (1997). Fuzzy credibility relation method for multiple criteria decision-making problems, Information Sciences 96 79–91.

12. Hwang C.L, Yoon K (1981). Multiple Attribute Decision Making: Methods and Application, Springer, New York.

13. Hwang C.L, Yoon K (1981). Multiple Attribute Decision Making: Methods and Application, Springer, New York

14. Jain R (1978). A procedure for multi-aspect decision making using fuzzy sets, The International Journal of Systems Sciences 8 1–7.

15. Jain R (1978). A procedure for multi-aspect decision making using fuzzy sets, The International Journal of Systems Sciences 8 1–7.

16. Kia Heyrati, J., 2004, ‘‘Investigating the function of Flood distribution system in recharge of ground water table in Moughar Plain in Isfahan’’, MA Thesis for Irrigation and Drainage, Isfahan University of Technology.

17. Kacprzyk J, Fedrizzi M, Nurmi H (1992). Group decision making and consensus under fuzzy preferences and fuzzy majority, Fuzzy Sets and Systems 49 21–31.
18. Keeney R, Raiffa H (1976). Decision with Multiple Objective: Preference and Value Tradeoffs, Wiley, New Work.
19. Kouthar, Ahang, 1986,'Application of flood development methods in artificial recharge of ground water tables' , Olive magazine, 46 and 47, pp 16 23.
20. Limon,G.A,Martinez, Y, (2006), Multi0criteria modeling of irrigation water Marked at basin level : aspsnish Case Study, Eropiangeornal of operational of Research , V173,PP 313-336
21. Lee H.S (1999). Optimal consensus of fuzzy opinions under group decision making environment, in: IEEE International Conference on Systems, Man and Cybernetics, Tokyo, Japan 1999, pp. 314–319.
22. Liang G.S (1999). Fuzzy MCDM based on ideal and anti-ideal concepts, European Journal of Operational Research 112 682–691.
23. Liang G.S (1999). Fuzzy MCDM based on ideal and anti-ideal concepts, European Journal of Operational Research 112 682–691.
24. Mianabadi, H, Afshar, A, (2008)."Multi attribute Decision Making to rank urban water supply Scheme" water and watershed journal, v19, n66, pp 34 – 45
25. 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
26. Mousavi, S.F; Chitsazan, M; Mirzaei, Y; Shaan, M; B Mohammadi, H.R, 2010, Integrating remote sensing and GIS to find potential suitable areas for ground water: Kamestan Anticline area, Conference articles and Geomantic exhibition.
27. Noori, B.; Ghayoumian, J.; Saravi Mohseni, M; Darvish-Sefat, A.A; Feiz-Nia, Sadat,2005,' determining suitable areas for artificial recharge of groundwater in recharge pools using GIS, Journal of Natural Foundations of Iran, Volume 57, Number 3, pp 635-647.
28. Nurmi H (1981). Approaches to collect decision making with fuzzy preference relations, Fuzzy Sets and Systems 6 249–259.
29. Olson D. L (2004) "Comparison of weights in TOPSIS models", Mathematical and Computer Modeling, 40, (7) 21-727.
30. Raj P.A, Kumar D.N (1999). Ranking alternatives with fuzzy weights using maximizing set and minimizing set, Fuzzy Sets and Systems 105 365–375.
31. Sedaghat, M, 2009, ''Earth and its water resources'', Tehran, Payam Noor University Press
32. Saraf, A.K & P.R. Choudhury, (1998). Integrated Remote Sensing and GIS for Ground Water Exploration and Identification of Artificial Recharge Sites, INT.J
33. Saraf, A.K & P.R. Choudhury, (1998). Integrated Remote Sensing and GIS for Ground Water Exploration and Identification of Artificial Recharge Sites, INT.J. Remote Sensing, 19 (10): 1825-1841.
34. Tsaur S.H, Chang T.Y, Yen C.H (2002). The evaluation of airline service quality by fuzzy MCDM, Tourism Management 23 107–115.
35. Wang Y.J, Lee H.S, Lin K (2003). Fuzzy TOPSIS for multi-criteria decision-making, International Mathematical Journal 3 367–379.
36. Zadeh L.A (1965). Fuzzy sets, Information and Control 8 338–353.
37. Zimmermann H.J (1987). Fuzzy Set, Decision Making and Expert System, Kluwer, Boston.
38. Zimmermann H.J (1991). Fuzzy Set Theory – And its Application, 2nd ed., Kluwer, Boston,