Forscher Publication

Water and Environmental Sustainability
ISSN: 2710-3404
DOI: 10.52293/WES.1.2.2332
H o m e p a g e: https://www.journalwes.com/

Research paper

Classification the Shahrekord plain to find the suitable sites for artificial recharge using analytic hierarchy processes

Abdul Qahar Massror
Assistant professor and lecturer of Medical school Alberoni University

A R T I C l E I N F O

Keywords:
Artificial recharge
Aquifer
Geographical Information System
Analytic Hierarchy Process

**Corresponding Author:*
Abdul Qahar Massror
qaharm@yahoo.com

Received: 07January, 2021
Accepted: 13 March, 2021
Available online: 05 April, 2021

A B S T R A C T

During recent years, the shortage of surface water resources is a serious problem facing to the Chaharmahal and Bakhtiari province. Hence, the groundwater exploration should be limited for developing the new water resources such as artificial recharge. One of the main step of this process is locating suitable sites for constructing the artificial recharge structure. The objective of this study is determination of effective parameters on artificial recharge structure construction in Shahrekord plain to propose the best sites. The eight parameters affecting the artificial recharge structure construction are including permeability, hydraulic conductivity, precipitation, land slope, nitrate concentration, salinity, saturated and unsaturated thickness of aquifer. For this purpose, ArcGIS10.3 software for the analytic hierarchy processes (AHP) and Expert Choice 11 software for prioritize suggested areas were used. Weight permeability 0.28 was in the first preference, hydraulic conductivity 0.23 in the second preference, saturation thickness of aquifer 0.17 in the third preference. Permeability, hydraulic conductivity and saturation thickness of aquifer are considered as the main parameters with the weight of 0.28, 0.23 and 0.17, respectively. Moreover, the weights of precipitation, land slope, and unsaturated thickness were obtained o.11, 0.08, and 0.06, respectively. The results show that about 0.089 percent of the study area are suitable for artificial recharge structure construction.

Introduction

With the decrease of precipitation, especially in the last few years in Iran, groundwater has become of special importance as one of the resources that undergoes changes due to drought less than surface water. In this regard, one of the appropriate ways to develop groundwater reserves is the use of artificial recharge by unconventional water (Aminizadeh and Ghasemi 2015). Aquifer and flow simulation due to artificial recharge is one of the most important steps in designing and evaluating these systems.

The construction of any structure that requires relatively high cost and time requires initial studies to identify, evaluate and analyze technical and economic. These studies depend on the scale, nature and cost of the structure and can include simulation, location, physical modeling and so on. For this reason, in the construction of artificial recharge structure, due to the high cost of its executive operations, it is necessary that before implementing the characteristics of the area in terms of technical, geological conditions, availability of materials, benefits of construction on water consumption and water balance, Its effect on runoff control and landslides, etc. should be investigated and then a decision should be made taking into account all related issues (Fakharinia et al. 2012; Jamali et al. 2013). One of the basic studies of projects that require spatial analysis is the location of artificial recharge system with wastewater according to the effective conditions in the design and implementation and based on past experiences and studies is of great importance (Maia et al. 2007; Muhammad et al. 2014; Pinto et al. 2015; Ghezgi et al. 2015; Salahaldin et al. 2018).

The best places to implement artificial recharge schemes are coarse-grained soils, the beginning of sandy alluvium, rocky soils, karst areas, یا problems with sandy beds and alluvial springs of seasonal rivers. Locating artificial recharge systems, especially flood spreading, is one of the basic principles of creating these systems. Site selection based on scientific and natural facts has the greatest role in the strength and use of these systems in order to achieve the relevant goals (Jamali et al. 2014).

Artificial recharge projects have been considered since 1972 in order to maintain the balance of groundwater (Tayari et al. 2006). In the modern era, the first artificial recharge project in Varamin plain was studied and implemented in 1972 and for the first time during the years 56- 50 has been constructed in Varamin, Garmsar and Qazvin irrigation networks by the pool method and then in Sari plain by injection through wells (Hasanaabadi et al., 2006). Annual harvest of about 250 million cubic meters of water resources in Shahrekord plain has caused a sharp drop in water table. In such a way that between the years 72 to 83, the water level has decreased by more than 13 meters and is among the forbidden aquifers. After this year, part of the low water level was compensated by preventing uncontrolled harvesting and controlling the aquifer balance, but with the lack of rainfall and the occurrence of recent droughts, it is still in critical condition. Therefore, feasibility studies have been carried out on the implementation of recharge plans in different parts of the plain (Lalehzari et al., 2008).

Therefore, the purpose of this study is to classify the priorities affecting the construction of artificial recharge system using hierarchical analysis method and GIS to locate the best point in the Shahrekord wastewater treatment plant. Infiltration, hydraulic conductivity, saturation layer thickness, rainfall, slope, unsaturated layer thickness, nitrate concentration and salinity (Electrical conductivity) were the eight parameters studied for the purpose of which their information has been collected.

Material and Methods

Shahrekord plain with an area of about 551 square kilometers in Chaharmahal and Bakhtiari province is located in latitude 707 ° 32 to ´35 ° 32 to longitude ´38 ° 50 to ´10 ° 51. This plain has 417 agricultural wells, 59 drinking water wells, 159 industrial wells, 79 aqueducts and 40 active springs that annually drain 230 million cubic meters of groundwater resources from the plain. A very high percentage of it (more than 90%) is used in agriculture during the growing season. Part of the drinking water of the people of Shahrekord is also supplied from the same wells (Mahab Ghods Consulting Engineering Company, 2000).

The northern boundary of the aquifer, which is the groundwater inlet front, is of the boundary type with known hydraulic potential. The southwest and southeast border, which is the groundwater outlet area, is also considered as a border type with known hydraulic potential. In terms of geological structure, Shahrekord aquifer is a layered and free type. Shahrekord aquifer is hydrologically part of Behesht Abad watershed (North Karun basin). More than 85% of the plain is cultivated and 15% of urban and industrial land (Tabatabaei et al., 2010).

In this study, first the parameters required to locate the artificial recharge structure (Fig. 1) were identified and evaluated in 8 locations. Various parameters were prepared as thematic layers and converted to raster data in ArcGIS software and then weighted using hierarchical analysis. One of the most efficient decision-making techniques is the hierarchical analysis process is based on pairwise comparisons and allows managers to make different studies (Ghodrati, 2014). Then, the final map of the area is obtained by using the weighted sum method and the area is divided into several areas in terms of the potential of constructing an artificial recharge structure, and finally a part is determined as a suitable place for constructing the structure.

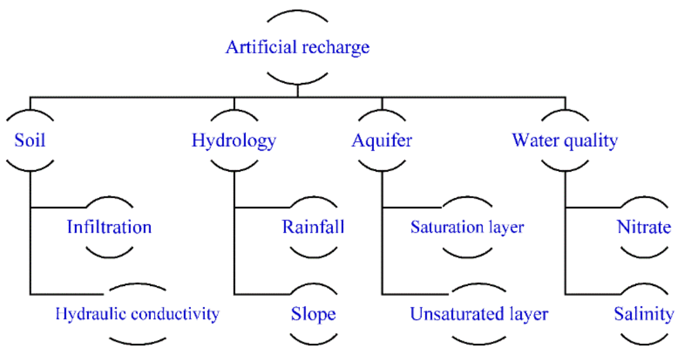

Fig. 1. Schematic of the hierarchical analysis method

Hierarchical analysis method can systematically include quantitative and qualitative factors in the decision model. In this way, first the structure of the decision problem is designed, then the different options are compared based on the criteria in the decision, and finally the priority of selecting each of them is determined. In general, this method is used in ranking, selection, evaluation and forecasting issues, all of which require decision-making (Ghaffari et al., 2010). The hierarchical analysis process, as a multi-criteria decision-making method, uses two-way comparison of criteria to rank the priorities of different options.

In this method, first a hierarchy of comparisons is made in the highest part of the target, where the selection of areas with high potential for the construction of artificial recharge system and then the effective parameters in decision-making are considered. In this study, the parameters of permeability, hydraulic conductivity, saturation layer thickness, rainfall, slope, unsaturated layer thickness, nitrate concentration and salinity have been considered. According to each criterion, the preference of the options is compared in pairs and their preference is specified as a phrase and is assigned to the options for each numerical expression. The preference values of the options are according to Table 1. At this stage, the parameters are compared and scored in a two-way manner. How to compare options and score them is shown in Table 2. The resulting matrix is then formed by comparing all the options.

Table 1. Determination of the parameter ranges

prefer	Value
Extremely preferred	9
Very strongly preferred	7
strongly preferred	5
Moderately preferred	3
Equally preferred	1

Table 2. Comparison between decision parameters

Parameters	Infiltration	Hydraulic conductivity	Saturation thickness layer	Rainfall	Slope	Unsaturated thickness layer	Nitrate	EC
Infiltration	1	2	2	3	4	5	6	6
Hydraulic conductivity	1.2	1	2	3	4	4	6	6
Saturation thickness layer	1.2	1.2	1	2	3	4	5	5
Rainfall	1.3	1.3	1.2	1	2	3	4	4
Slope	1.4	1.4	1.3	1.2	1	2	3	4
Unsaturated thickness layer	1.5	1.4	1.3	1.2	1	1	3	4
Nitrate	1.6	1.6	1.5	1.4	1.3	1.3	1	3
EC	1.6	1.6	1.5	1.4	1.4	1.4	1.3	1

To determine the relative value of each of the comparisons in each category of the table, the geometric mean method for each row of the matrix is used. In this method, according to the following equation, first the geometric mean of the elements of each row is calculated and then the resulting vector is normalized and thus the relative value of each criterion is obtained.

$$\begin{bmatrix} a11 & \dots & a1n \\ \dots & \dots & \dots \\ an1 & \dots & ann \end{bmatrix}_{n\times n} \quad (1)$$

$$W_1 = [(a11)(a12)\dots\dots(a1n)]^\wedge(1/n)/[(a11)+(a12)\dots\dots+(a1n)]$$
$$W_2 = [(a21)(a22)\dots\dots(a2n)]^\wedge(1/n)/[(a21)+(a22)\dots\dots+(a2n)] \quad (2)$$
$$W_n = [(an1)(an2)\dots\dots(ann)]^\wedge(1/n)/[(an1)+(an2)\dots\dots+(ann)]$$

$$\begin{bmatrix} \sqrt[8]{1*3*3*5*5*7*9*9} \\ \sqrt[8]{\frac{1}{3}*1*3*5*5*7*9*9} \\ \sqrt[8]{\frac{1}{3}*\frac{1}{3}*1*3*3*5*7*7} \\ \sqrt[8]{\frac{1}{5}*\frac{1}{5}*\frac{1}{3}*1*3*5*7*7} \\ \sqrt[8]{\frac{1}{5}*\frac{1}{5}*\frac{1}{3}*\frac{1}{3}*1*3*5*5} \\ \sqrt[8]{\frac{1}{7}*\frac{1}{7}*\frac{1}{5}*\frac{1}{5}*\frac{1}{3}*1*5*5} \\ \sqrt[8]{\frac{1}{9}*\frac{1}{9}*\frac{1}{7}*\frac{1}{7}*\frac{1}{5}*\frac{1}{5}*1*3} \\ \sqrt[8]{\frac{1}{9}*\frac{1}{9}*\frac{1}{7}*\frac{1}{7}*\frac{1}{5}*\frac{1}{5}*\frac{1}{3}*1} \end{bmatrix} = \begin{bmatrix} 4.35 \\ 3.03 \\ 1.99 \\ 1.33 \\ 0.87 \\ 0.54 \\ 0.27 \\ 0.21 \end{bmatrix} \rightarrow normalize \begin{bmatrix} 0.346 \\ 0.241 \\ 0.158 \\ 0.106 \\ 0.069 \\ 0.043 \\ 0.021 \\ 0.017 \end{bmatrix} \quad (3)$$

The final weight of each option in a hierarchical process is obtained from the sum of the product of the importance of the criteria in the weight of the options. The value of the incompatibility index is calculated from the following equation

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

where λ_{max} is the best specific value of matrix, n is the matrix size. The incompatibility rate is obtained from the following formula:

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

where I.I.R is the incompatibility.

Result and discussion

Classification for 8 artificial recharge system location options is given below and the evaluation of areas has been done based on different parameters

Infiltration

Permeability indicates the movement of water in porous media. The susceptible site will have higher permeability. Permeability makes rainwater penetrate the soil faster and easier to harvest. The classification map of the permeability layer is shown in Fig. 2.

Hydraulic conductivity

Hydraulic conductivity indicates the ability to conduct water in the aquifer environment; In other words, it can be said that it indicates the ability of aquifer components to pass water (Rangzan et al., 2013). The higher the hydraulic conductivity, the greater the water transfer resulting in more water being stored in the soil. The classified map of the hydraulic conductivity layer is shown in Fig. 3.

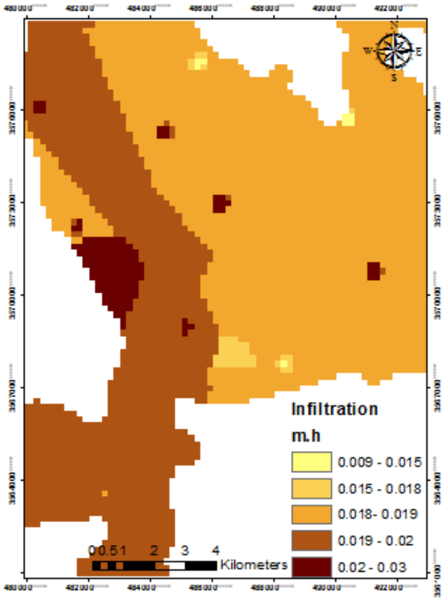

Fig. 2. Infiltration interpolated map

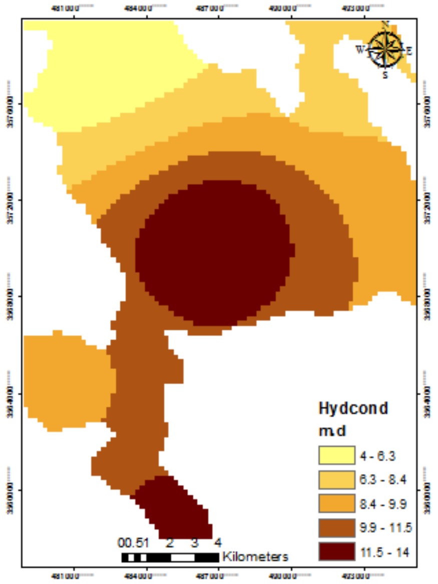

Fig. 3. Hydraulic conductivity map

Saturation layer thickness

Water from rain or melting snow, after penetrating into the soil, continues to move deep inside the soil until it finally hits the impermeable layer and stops. Infiltration water on these layers fills all pores and creates a saturation zone called the aqueous layer (Alizadeh, 2011). As the thickness of the saturation layer increases, the amount of groundwater storage increases. Saturation layer thickness is another important factor in locating an artificial recharge system. The thickness of the saturation layer of Shahrekord plain varies from 1 meter to 67 meters. The classification map of the saturation layer thickness layer is shown in Fig. 4.

Rainfall

Artificial recharge structures store sufficient amounts of water for drinking and irrigation. These structures, if built in the right place, can be a good answer to water needs. Whenever the intensity of rainfall is greater than the capacity to penetrate into the soil, part of the rainwater remains at the basin level. This water, after filling the holes in the ground, flows along the slope of the earth and flows out of the basin through a network of waterways and then the main river. Rainfall in 9 stations in the study area is a minimum of 21 mm and a maximum of 214 mm. The rainfall layer classification map is shown in Fig. 5.

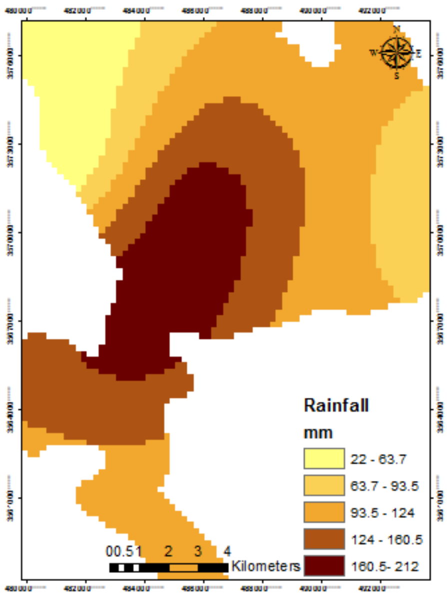

Fig. 4. Rainfall interpolated map

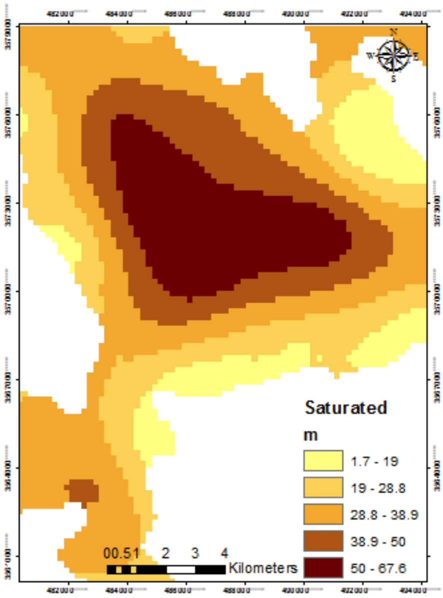

Fig. 5. Saturation thickness layer map

Land slope

Land slope is one of the effective factors in choosing a suitable place for artificial recharge system. The lower the slope of the area, the more runoff will have to flow to the surface, and as a result, the probability of water penetrating into the ground increases, and thus the amount of water storage will increase. On the other hand, the lower the slope, the larger the water storage tank (Rangzan et al., 2013). Higher slope causes more runoff and as a result more erosion rate and less recharge (Alambazzadeh et al., 2014). The classification map of the slope layer is shown in Fig. 6

Unsaturated thickness layer

When rainwater penetrates the subsoil, it forms an unsaturated and saturated layer. In the unsaturated zone, there is some water in the openings between the rocks but no water below it. There is a layer of soil on top of the unsaturated area. The soil layer has intervals created by the roots of plants and will cause rainfall to penetrate. Water in this area is consumed by plant roots. The thickness of the unsaturated layer of Shahrekord aquifer varies from 1 meter to 37 meters. The minimum thickness of the unsaturated aquifer layer is suitable for the construction of an artificial recharge system (Rangzan et al., 2013). This layer describes how groundwater flows in the aquifer. The classification map of the unsaturated section thickness layer is shown in Fig. 7.

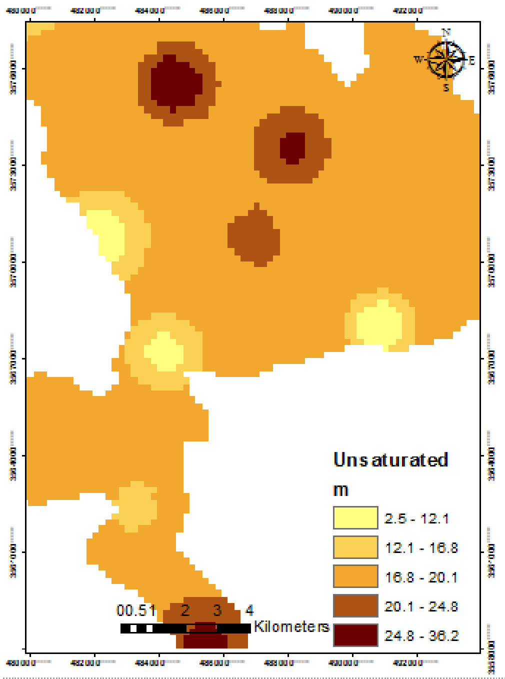

Fig. 6. Unsaturated thickness layer map

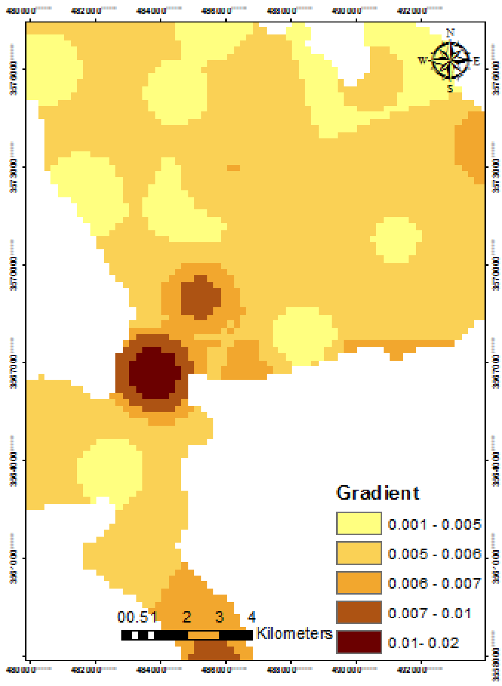

Fig. 7. Land slope interpolated map

Fathi Hafshjani and Beigi Herchgani (2012) showed that the concentration of nitrate and phosphate in the southern parts of the plain is maximum by examining the patterns of spatial changes and geological zoning of nitrate and phosphate statistics in groundwater of Shahrekord plain; The nitrate concentration of some wells in the southern parts was higher than the permissible limit of 45 mg/l. Perhaps the main reason for the high nitrate concentration in this section is the location of the Shahrekord refinery and the shallow water level and the movement of water flow in this direction. The average nitrate concentration fluctuated between 21 and 24 mg/l. The results showed that the middle parts of the plain had lower nitrate concentrations compared to the north and south and showed less changes during different seasons of the year. The most important factors in increasing nitrate pollution are agricultural drainage and consumption of nitrogen fertilizers from agricultural operations. The upper parts of the plain due to more agricultural lands, low aquifer thickness, high groundwater level and the high volume of nitrogen fertilizers in the spring and with irrigation is transferred to groundwater (Lalehzari and Tabatabaei, 2010). The classification map of the nitrate concentration layer is shown in Fig. 8.

Electrical conductivity (EC)

Moradi et al. (2011) in the study of salinity zonation of groundwater in Shahrekord plain using conventional kriging method concluded that the salinity of groundwater increases from northwest to southeast of the plain in the direction of groundwater flow. In fact, the salinity of groundwater has decreased with increasing the number of wells from northwest to southeast and uncontrolled abstraction of groundwater, the thickness of the saturation layer has decreased (Lalehzari et al., 2009) and this has increased the water solutes and especially its salinity (Fig. 9).

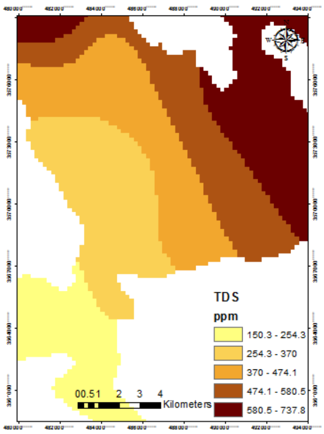

Fig. 9. EC interpolated map

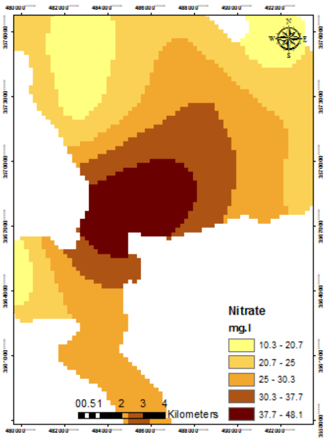

Fig. 9. Nitrate interpolated map

After forming the AHP matrix and binary comparison of the main and sub-criteria, weighting was performed in Expert Choice 11 software. The final weights and incompatibility rates are shown in Fig. 10.

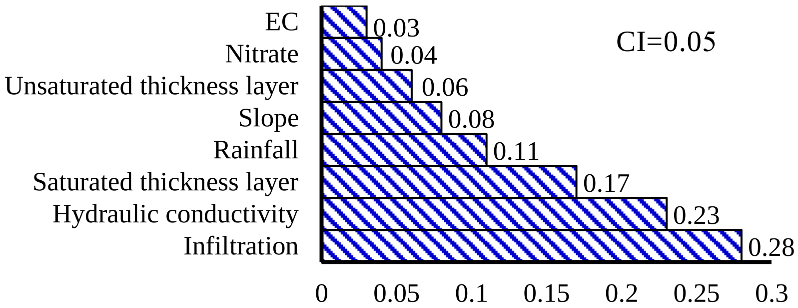

Fig. 10. The weight of the different layers

Using the obtained weights, each layer was weighed in GIS software. Then, the final map was identified using the combined weighting method and areas with high potential for the construction of artificial recharge system (Fig. 11).

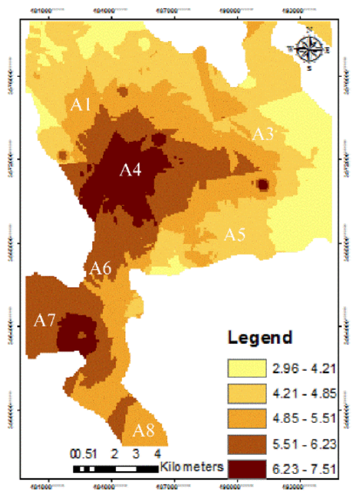

Fig. 11. Classification map for selecting the suitable site

The substrate weighs from 2.96 to 4.21 with a score of 1, which is in a very bad area in terms of the construction of artificial recharge system, covers 0.14% of the area. The highest percentage of area belongs to the substrate with a weight of 4.21 to 4.85, which is located in the bad area. The middle class of the final map with a weight of 4.85 to 5.51, includes 0.246% of the area of the study area. Substrate with a weight of 5.51 to 6.23 and a score of 4, which indicates good areas for the construction of artificial recharge system, includes 0.225 percent of the area. Very good areas for the construction of artificial recharge system, which are located in the substrate with a weight of 6.23 to 7.51, cover 0.089% of the area (Table 3).

As can be seen in Fig. 11, 8 options have been considered for the construction of an artificial recharge system in the Shahrekord plain. In the first stage, areas with the potential to build an artificial recharge system are identified. At this stage, the areas with more weight were selected and as a result, points A1, A3 and A5 were removed. In the second stage, suitable options were identified in areas with potential for the construction of an artificial recharge system. Locations A2, A4, A6, A7 and A8 were selected in this stage and in the third stage, suitable options were evaluated and prioritized for the construction of an artificial recharge system.

Point A6 with high rainfall, high soil permeability, good hydraulic conductivity, suitable slope for the construction of artificial recharge system, minimum thickness of unsaturated section and low salinity is the first priority. , Is in the second priority. The weight of each parameter in the appropriate places was calculated using Expert Choice 11 software. Suitable locations for the construction of an artificial recharge system are identified in order of priority in Table 4.

Table 3. Map classification

Weight	Status	Score	Area (%)
296 – 4.21	Very bad	1	14
4.21 – 4.85	Bad	2	30
4.85 – 5.51	Middle	3	24.6
5.51 – 6.23	Good	4	22.5
6.23 7.51	Very good	5	8.9

Table 4. Selecting the suitable locations for artificial recharge

Locations	Infiltration m/h	Hyd. con. m/d	Sat. layer (m)	Rainfall mm	Slope	Unsat. layer (m)	Nitrate mg/l	EC	Scope
A2	0.09	0.05	0.21	0.11	0.06	0.06	0.15	0.05	5
A4	0.09	0.21	0.33	0.22	0.05	0.13	0.09	0.1	3
A6	0.19	0.13	0.08	0.28	0.28	0.25	0.04	0.17	1
A7	0.19	0.07	0.12	0.17	0.08	0.08	0.24	0.27	4
A8	0.19	0.3	0.05	0.09	0.23	0.06	0.07	0.27	2

Conclusion

The present study was conducted to study the appropriate locations for the construction of an artificial recharge system using Arc GIS10.3 software and the AHP method in the Shahrekord plain wastewater treatment plant. Factors influencing the location of the artificial recharge system in this study are permeability, hydraulic conductivity, saturation section thickness, rainfall, slope, unsaturation section thickness, nitrate concentration and salinity. For this purpose, ArcGIS10.3 and Expert Choice 11 software were used for hierarchical analysis and prioritization of the proposed areas. The weight of different layers was calculated using hierarchical analysis and Expert Choice 11 software. Permeability with a weight of 0.28 in the first priority, hydraulic conductivity with a weight of 0.23 in the second priority and the thickness of the saturation layer with a weight of 0.17 were in the third priority. Also, the weight of the precipitation parameter was 0.11, the slope was 0.08 and the thickness of the unsaturated layer was 0.06. Nitrate and salinity concentrations with weights of 0.04 and 0.03 were among the last priorities. These information layers were then classified and weighted in GIS software and the final map was obtained by weighting method. The location map of the artificial recharge system in Shahrekord plain has been prioritized from very good to very bad. In this map, the southern areas of the plain are suitable for the construction of artificial recharge system and the northern areas of the plain are in poor condition for the construction of artificial recharge system due to various reasons such as low rainfall, low soil permeability, low hydraulic conductivity and high salinity. Location A6 is the best option among the 5 suitable options due to its location in the area with more rainfall, high soil permeability in this location, good hydraulic conductivity of the aquifer, suitable slope for the construction of artificial recharge system, with the least thickness of unsaturated part and low salinity. The direction of groundwater flow is due to the difference in height from north to south of the plain. The placement of the artificial recharge system at the outlet of the water flow causes more water storage in the structure. As a result, location A8 was placed in the second priority of the construction of artificial recharge system due to its location at the exit of the plain and also being located in the area of good permeability and hydraulic conductivity. The results showed that about 0.089% of the study area is very good in terms of construction of artificial recharge system in the area and 0.23% is in the good range.

References

ALIZADEH, A. 2011. Principles of Applied Hydrology. Thirty-second edition, Astan Quds Razavi Printing and Publishing Institute, Mashhad.

AMINIZADEH, M., GHASEMI, M. 2015. Locating Suitable Sites for Construction of Underground Dams. Cumhuriyet Üniversitesi Fen FakültesiFen Bilimleri Dergisi (CFD), 36. ISSN: 1300-1949.

CHEZGI, J., POURGHASEMI, H.R., NAGHIBI, S.A., MORADI, H.R. AND KHEIRKHAH ZARKESH, M. 2015. Assessment of a spatial multi-criteria evaluation to site selection underground dams in the Alborz Province, Iran, Geoca International. DOI: 10.1080/10106049.2015.1073366.

FAKHARINIA, M., LALEHZARI, R. AND YAGHOOBZADEH, M. 2012. The Use of Subsurface Barriers in the Sustainable Management of Groundwater Resources. World Applied Sciences Journal. 19 (11): 1585-1590.

FATHI HAFSHJANI, A. AND BEIGI HARCHEGANI, H. 2012. Patterns of spatial changes and geological zoning of nitrate and phosphate in groundwater of Shahrekord plain, Irrigation Science and Engineering (Agricultural Scientific Journal), 36 (1), 103-112.

GHAFFARI, A., MONTAZER, A.A. AND RAHIMI JAMNANI, A. 2010. "Development and evaluation of a model for determining the optimal cultivation pattern of irrigation networks using hierarchical analysis process (Case study: Irrigation network of Varamin plain)". Journal of Water and Soil, 24 (6), 1119-1128.

GHODRATI, M. 2014. "Arc GIS10.2 Applied Training with Emphasis on Water Engineering and Environmental Issues", First Edition, Simaye Danesh Publications.

JAMALI, I.A. OLOFSSON, B. AND MORTBERG, U. 2013. Locating suitable sites for the construction of subsurface dams using GIS. Environmental Earth Sciences. 70(6): 2511-2525.

JAMALI, I.A., MORTBERG, U., OLOFSSON, B. AND SHAFIQUE, M. 2014. A Spatial Multi-Criteria Analysis Approach for Locating Suitable Sites for Construction of Subsurface Dams in Northern Pakistan. Water Resources Management. 28:5157-5174.

JANAT ROSTAMI, S ., KHALQI, M., MOHAMMADI, K. AND MALMIR, M. 2011. Management of groundwater aquifer exploitation in Shahrekord plain. Sixth National Congress of Civil Engineering, Semnan University, Semnan, Iran.

LALEHZARI, R. AND TABATABAEI, S.H. 2015. Simulating the impact of subsurface dam construction on the change of nitrate distribution. Environmental Earth Sciences. 74(4): 3241-3249.

LALEHZARI, R., AND TABATABAEI, S.H. 2010. Chemical properties of groundwater in Shahrekord plain. Journal of Environmental Science, University of Tehran, 36 (53), 55-62.

LALEHZARI, R., TABATABAEI, S.H., AND YAR ALI, N. 2009.Study of monthly nitrate changes in groundwater of Shahrekord plain and zoning using GIS. Iranian Journal of Water Research, 3 (4), 9-17.

MAHAB GHODS CONSLUTING ENGINERS. 2000. Groundwater Studies Report imShahrekord Plain. Isfahan Water Company. PP: 285.

MAHAB GHODS CONSULTING ENGINEERING COMPANY. 2000. Groundwater Studies of Shahrekord Plain. Isfahan Regional Water Company.

MAHMOUD, S.H., ALAZBA, A.A. AND AMIN, M.T. 2014. Identification of Potential Sites for Groundwater Recharge Using a GIS-Based Decision Support System in Jazan Region-Saudi Arabia. Water Resour Manage (2014) 28:3319–3340.

MAIA, R., SCHUMANN, A. 2007. DSS Application to the Development of Water Management Strategies in Ribeiras Algarve River Basin. Journal of Water Resources Management. 21(5): 897-907.

MORADI, M., WAQARFARD, H., KHORANI, AA, MAHMOUDINEJAD. 2011 .Evaluation of different interpolation methods in groundwater salinity zoning, using Cross-Validation technique (Case study: Shahrekord plain). Iranian Journal of Remote Sensing and GIS. 3 (1), 44-35.

PINTO, D., SHRESTHA, S., BABEL, M.S. AND NINSAWAT, S. 2015. Delineation of groundwater potential zones in the Comoro watershed, Timor Leste using GIS, remote sensing and analytic hierarchy process (AHP) technique. Applied Water Science. 1-17.

SALAHALDIN, S. A., FOAD, A. A., SARKAWT, G., SALAR, N.A. AND SVEN, K. 2018. Evaluation of Selected Site Location for Subsurface Dam Construction within Isayi Watershed Using GIS and RS Garmiyan Area, Kurdistan Region. JWARP. 6(11): 972-987.

TAYARI, A. AND SHAMSAEI, A. 2006. Analysis of effective parameters on water head over the underground dams and an innovative methodology for estimation of it. J New Agric Sci 2(3):87–102.