



A NOVEL HYBRID MCDM MODEL TO SELECT A SUITABLE LOCATION FOR IMPLEMENT GROUNDWATER RECHARGE

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Abstract

The management of the groundwater resources is a challenging task worldwide against the backdrop of the growing water. The Sarkhoon plain in the Hormozgan Province has experienced a water table fall due to the recent years' drought and the growth of water withdrawal of the ground water. Artificial recharge plays an important role in the sustainable management of groundwater resources. This goal of this study is to use a novel methodology to delineate the artificial recharge zones as well as to identify favorable artificial recharge sites. The data used are slope, geomorphology, water table, thickness of alluvium, hydraulic transmissivity, land use, water quality, drainage density, and infiltration coefficient. The importance of each criterion and its classes was obtained using the ANP and AHP methods. The layer overlaying was performed using the TOPSIS method. After the elimination of the limitations, the final zonation map is presented in four classes. The results show that about 5 percent of the region is in the excellent class with high drainage density and high transmissivity that is primarily located in the quaternary deposits with slopes of less than 3 percent. Also, The results are then checked against the existing sites to estimate their accuracy and show which excellent class is indicative of 73 percent overlapping with the successful artificial recharge plan groups, which denotes the model's high accuracy. The results of this study could be used to formulate an efficient groundwater management plan for the study area to ensure the sustainable utilization of scarce groundwater resources.

Keywords: Groundwater, Artificial Recharge, Analytic Network Process, TOPSIS, Sarkhoon Plain, Iran

Introduction

Groundwater is a vital natural resource for the reliable and economic provision of potable water supply in both urban and rural environment (Magesh *et al.*, 2012). As water demand will likely increase in the short and long term, there will be increasing pressures on groundwater resources (Sethi *et al.*, 2010). Furthermore, climate change has a significant impact on the quantity and quality of groundwater resources (Adamowski & Chan, 2011). The sustainability of groundwater resources is a critical issue (Gleeson *et al.*, 2012). The sustainable management of groundwater resources in conjunction with surface waters in a watershed is very important to ensure the sustainability of a watershed's surface and groundwater resources (Mohanty *et al.*, 2010). By constructing suitable types of artificial recharge structures, groundwater resources can be augmented (Basagaoglu & Marino., 1999). The artificial recharge is a process consisting of introducing water in a permeable formation, as to be reused in different conditions (Ketata, Gueddari, & Bouhlila, 2014). Therefore it is a temporary storage of the surface waters in an underground reservoir (Bize *et al.*, 1972). Artificial recharge is one method of modifying the hydrological cycle and thereby providing groundwater in excess of that available by process (Ketata *et al.*, 2014). In the field of water resources planning and management, managed aquifer recharge (MAR) is becoming an important solution for mitigating water scarcity related problems in arid and semi-arid areas (Rahman *et al.*, 2012). Complex regional characteristics, heterogeneities in surface and/or subsurface characteristics, and variable groundwater qualities make site selection for MAR difficult (Anbazhagan *et al.*, 2005). Surface and sub-surface hydrological features

such as lithology, geological structure, drainage density, groundwater flow and boundary conditions of the aquifer system play an important role in groundwater replenishment (Chenini & Ben Mammou, 2010). According to the environmental and human conditions in every regional it is of great importance to choose the suitable areas in order to perform artificial recharge campaigns. The old methods for selecting the region are costly, time-consuming and replete with faults. Multi criteria design making (MCDM) is helpful in identifying priorities for a given MAR project (Gomes & Lins, 2002). The integration of MCDA techniques with GIS has considerably advanced the traditional map overlay approaches for site suitability analysis (Malczewski, 1996). MCDA integrated into GIS (SMCDA) provide adequate solution procedures to this problem because the analysis of potential MAR projects may be done more comprehensively and at a lower cost (Rahman *et al.*, 2012). The technique for order preference by similarity to ideal solution (TOPSIS), which is one of the well-known classical MCDM methods (Pazand *et al.*, 2012). that can be implemented in GIS. This technique is based on the concept that the ideal alternative has the best level for all attributes, whereas the negative ideal is the one with all the worst attribute values (Önüt & Soner, 2008). But till now it's not integrated with analytical network process that can make network connection between important criteria in determining suitable areas for artificial recharge. In the field of zonation of the regions suitable for ground water artificial recharge by taking advantage of supporting systems, the decision-making process has been performed in combination with investigational geographical information system every one of which has taken different standards into consideration (Krishnamurthy & Srinivas, 1995; Anbazhagan *et al.*, 2005; Ghayoumian *et al.*, 2007; Alesheikh *et al.*, 2008; Chenini & Ben Mammou, 2010; Magesh *et al.*, 2012;

Rahman *et al.*, 2013) The explanation for some of them in the next section:

Krishnamurthy and Srinivas (1995) believe that geological and geomorphologic factors play a significant role in the ground water behavior at different levels. Therefore, in one of their studies entitled "The role of the geological and geomorphologic factors in ground water withdrawal," they studied these factors in three fields with different characteristics. The results suggest that valleys and faults as well as their contact surfaces and large pediplains are the appropriate locations for recharging campaigns, and the hills, ridges, and high lands are locations that lead to runoffs. This study has shown that in each region, one characteristic type of relief is suitable to recharge the ground water. Krishnamurthy *et al.* (1996) used remote sensing and GIS to determine the suitable regions for feeding the ground water. They studied the geological and topographical factors, faults, fractures, surface waters, drains, streams, stream density, and slope, and they divided each of the above-mentioned maps into excellent, very good, good, medium, and poor categories based on the ground water importance. They assigned a value to each of the factors based on their importance, and they blended the factors step-wisely and obtained the recharge proportion map. The study results indicate that the suitable regions in this respect are the quaternary domains (weathered faults) and slopes less than 5%. Saraf & Choudhury (1998) determined the suitable locations for artificial recharge programs in the Indian central regions with the characteristic of 1040 mm precipitation. In order to localize the localities suitable for ground water recharge, they used remote sensing technology for extracting land use, vegetation cover, geomorphology, and geology of maps and combined them with slope map. By comparing the obtained feed map with the data collected from the field measurements, they determined that the results were satisfactory. Ale Sheikh *et al.* (2008) identified the spreading site selection in the Samal district in the Boushehr province of Iran by Using Layers geological strata, slope, land use, infiltration speed, runoff, and the underground aquifers' depth and using three methods, which were the Boolean blending method, index skewing, and fuzzy skewing. They performed their evaluations using the extant sites, and the results show that 0.1 and 0.2 fuzzy Gama operators produce the best results. In a study of the Gorbayegan area in Fasa county of Iran, Faraji Sabokbar *et al.* (2012) determined the suitable areas for artificial ground water recharge by utilizing GIS and MCDM. In their study of ground water artificial recharge, they used the following seven parameters: slope, water quality, geology, alluvial thickness, land use, transmissivity potential, geomorphology, and drainage density. Their results show that the most suitable areas for aquifer recharge are often located in quaternary deposits, Q_b , Q_{gsc} , Q_g and morphologic pediment units and alluvial fans with a slope of less than 3 percent. Rahman *et al.* (2013) performed a study to identify flood prone regions using mathematical modeling and multi-standards decision-making systems in the north of Gaza. They weighted their standards using hierarchical weighting and then blended their layers using the WLC and OWA methods, and about 25 percent of the lands were determined

to be suitable for a recharge campaign. By land surveys, they proved that the combination of mathematical models and OWA is an appropriate method to determine the areas prone to flooding. The Sarkhoon plain is one of the plains near the province center of Hormozgan in Iran. The ground water resources have supplied the water needed for the region and its neighbors for many years. The study of the recent years' statistics is indicative of the plain's negative groundwater Levels. The objective of the current study is to determine the factors that are effective for the identification of the suitable areas for artificial recharge in the Sarkhoon plain using the ANP process and the determination of suitable areas for performing the artificial recharge operations using the TOPSIS method and inserting it into the geographical information system. By determining the suitable areas for artificial recharge and proposing to utilize it, the waste of water resources in the area can be prevented, and the long-term development planning of the region's water resources can move one step forward.

Material and Methods

Study Area

The Sarkhoon Plain is located approximately 25 km from Bandar Abbas, the city center of the Hormozgan Province, with an area of 114 Km², and it is situated at 27° 9'-27°, 35' northern latitude and 56°, 7'-56°, 33' eastern longitude Fig. 1. The annual precipitation average in the high lands and the plains are 234 and 219 mm, respectively, the climate is arid and semiarid, and the evaporation average is estimated to be about 3080 mm. The study area from structural geology is located in the folded Zagros, and there are formations from the Precambrian to the quaternary (Agha nabati, 2004). Because of the prominent attributes of the area, it can be referred to as having a simple and gentle texture accompanied with a series of closely-located and compressed domes with the usually perpendicular axis level and the approximate orientation of northwest-southeast. Most of the formation constituents in the Sarkhoon Plain belong to the quaternary units, which comprise approximately 53 percent of the area. The survey of the vegetation cover is indicative that 70 percent of the area is covered with pastures, and 20 percent is comprised of dry land farming and irrigated agriculture. The surface streams in the study area include surface streams produced in the highlands and surface runoffs produced in the plains, some of which exits the study area after being used in the agriculture sector or from evaporation, perspiration, and infiltration. The exiting stream volume leaving the study area is estimated to be 98.5 million cubic meters (Hormozgan Regional Water Company, 2013). The aquifer reference hydrograph was used to show the ground water depth variations during various years, and it is indicative of the aquifer reaction to recharge and discharge factors. From the hydrograph, the average length variations can be determined for a certain time period. According to figure 2, the amount of the ground water variations in the Sarkhon Plain during a 25-year period from 1989-1990 to 2012-2013 has decreased 0.44 meter annually on average Fig. 2.

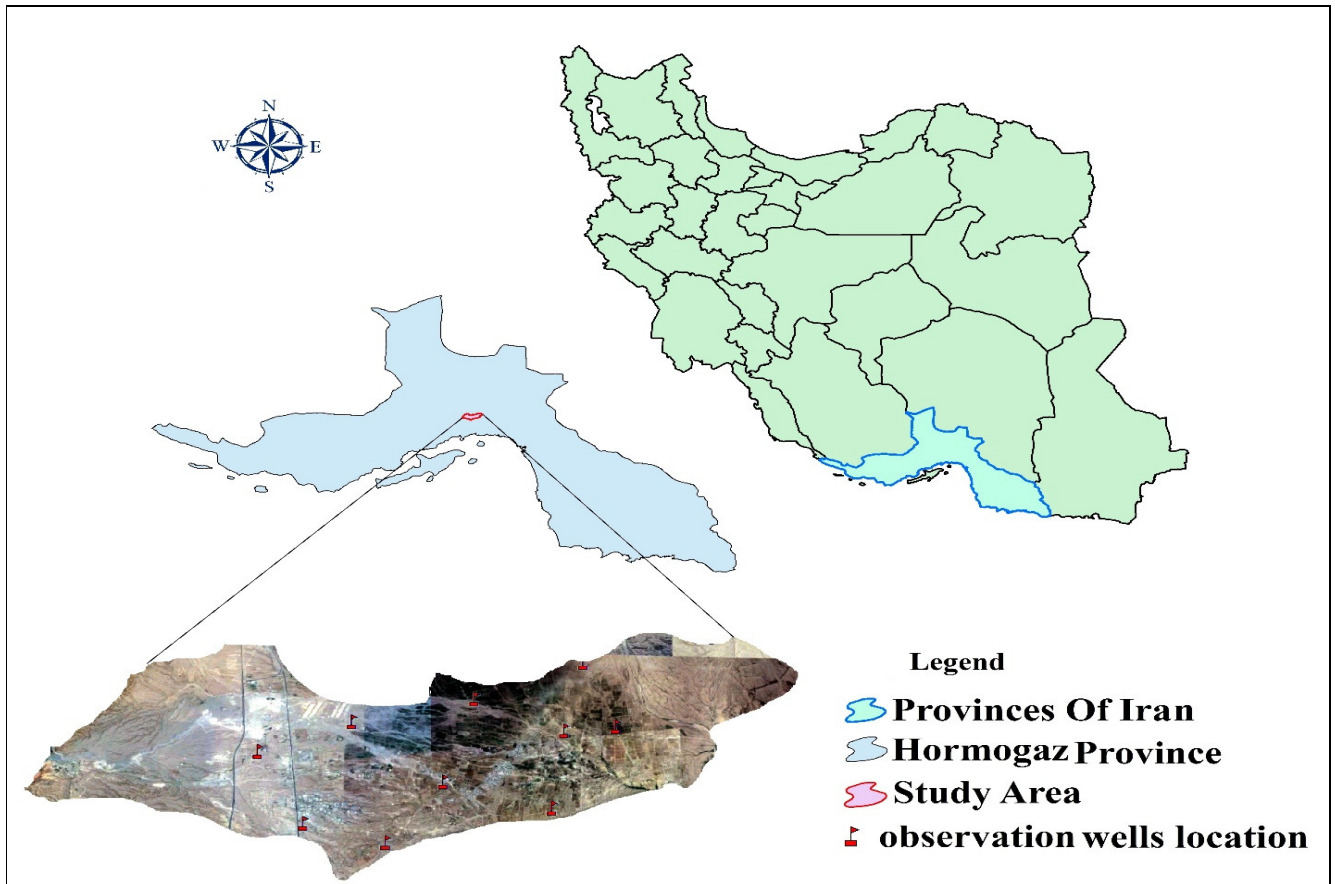


Fig. 1 : The studied area’s position in Iran and in the Hormozgan Province

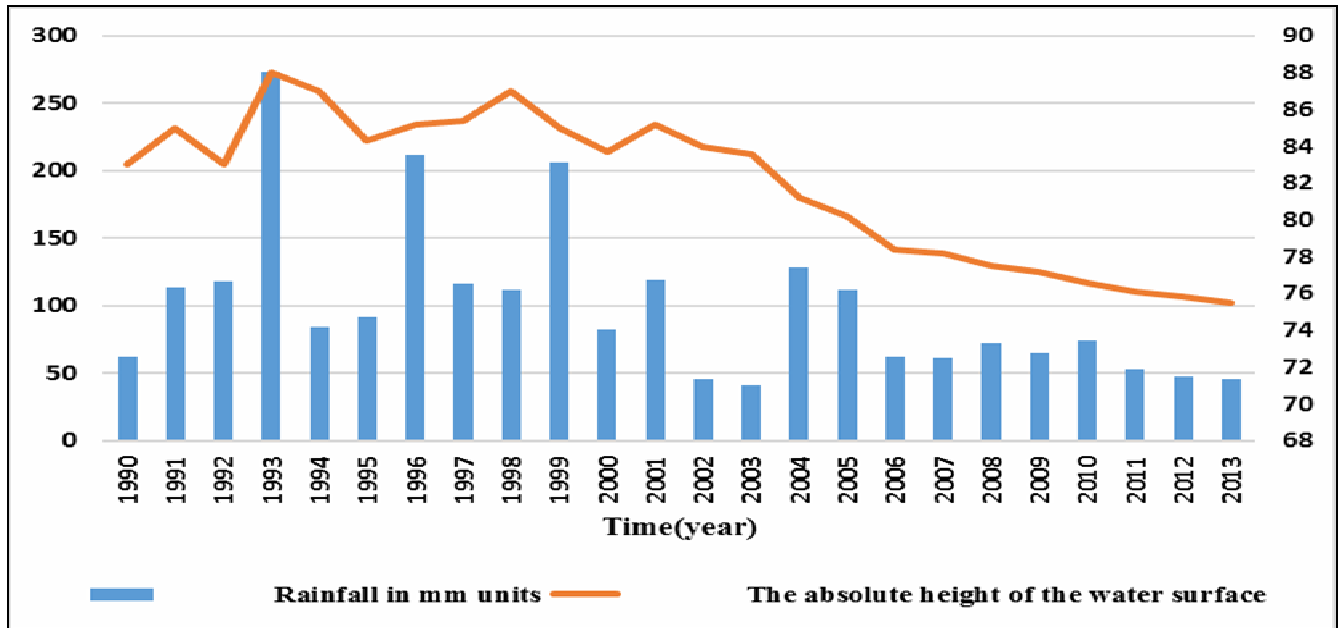


Fig. 2 : Chart rainfall-water table level charts of the Sarkhoon Plain
 Ref. (Hormozgan Regional Water Company, 2013)

Data

The determination of the areas suitable for artificial recharge is based on points such as work scale, and the expected precision and the region conditions depend on many parameters. Using all of the parameters to perform a study is very difficult and sometimes impossible. Therefore, in the current research, which is based on the studies previously conducted on artificial recharge, concepts from four groups of experts of ecology, hydrology, geology, and GIS

specialists were used, and the local conditions of the area, slope parameters, geomorphology, water quality, water depth, infiltration coefficient, alluvial thickness, land use, transmissivity potential, and drainage density were determined and analyzed. The reason for choosing these standards is summarized in the following section. In the current study, the information from ten observatory wells during a 25-year period from 1989-1990 to 2012-2013 was used, and the characteristics are presented in (Table 1).

Table 1 : Characteristics of observation wells

Y	X	Level	Status	Depth(M)	Year of construction	Observation well
3027445	437148	180.12	Active	81	1989	1
3028107	434755	165.41	Active	63	1989	2
3028641	441975	144.83	Active	37.29	1989	3
3029555	438824	94.72	Active	44.5	1989	4
3030622	433399	132.02	Active	61	1989	5
3031353	442369	91.85	Active	50	1989	6
303150	442981	86.69	Active	41	1989	7
3031679	446139	74.4	Active	30.5	1989	8
3032484	439748	86.52	Active	47	1989	9
3033793	442971	71.42	Active	30.2	1989	10

Slope: Slope is one efficient factor in locating the areas prone to ground water recharge, and it plays a significant role in controlling factors, such as flood and transmissivity. The experience from 36 flood spreading stations in Iran have shown that the most suitable area for flood spreading must have a slope less than 5 percent (Alesheikh *et al.*, 2008). The digital elevation model (DEM) with the pixel size of 30 meters extracted from the ASTER remote sensing data was used in order to determine slope layer. After the layer determination, the slope scale was divided into four classes. Most areas in the region have a 0-3 percent slope, and, in the western and southern areas, the slope is sporadically scattered to around 18 percent Fig. 3.

Geomorphology: In the previous studies, the vast plains with a gentle slope, pediments, and alluvial fans (depending on their area and position) were considered to be the optimum spots for performing the artificial recharge plans. Based on the province morphology plans, the study area was separated and categorized into four classes as shown in Fig. 3.

Water depth: Ground water depth indicates the dry layer thickness; the less thickness the layer has, the less it has a recharge potential. The water depth map was obtained with the least amount of error possible using the 15-year average of the water surface data relative to the observatory wells as well as using the interpolation (Table 2). Finally, using the Simple Kriging model, it was generalized to include the entire plain to whole the plain. The water depth of the study area varied to about 15 to 68 meters from the ground surface. The maximum depth was observed in the western area, and the minimum depth was observed in the northeast area. The related layer was reclassified into 5 classes as shown in Fig. 3.

Table 2 : Spatial Interpolation methods and their RMSE

Averaging methods	RMSE
Inverse distance weighting with powe1	29.53
Inverse distance weighting with powe2	21.045
Inverse distance weighting with powe4	14.93
Local polynomial interpolation	11.84
Radial Basis function	12.41
Simple Kiriging	0.6586
Universal Kiriging	1.44
Probability Kiriging	2.9883

Infiltration coefficient: Infiltration rate restricts the entrance of water into the soil or porous material (Liu *et al.*, 2001). The effect from this factor is significant in environments with high evaporation. The experimental results performed by the Agricultural Research Center of the Hormozgan Province in 2012 were used to determine the study area permeability, and the permeability layer was produced using interpolation in GIS and classified into 5 classes, which is shown in Fig. 3.

Thickness of Alluvium: Theoretically, the greater the alluvial thickness, the higher the amount of the water reserved in it (Faraji sabokbar *et al.*, 2012). The above-mentioned layer was reclassified into four classes as shown in Fig. 3.

Hydraulic transmissivity: One of the other factors that is valuable in determining the groundwater Recharge prone and recharge prone areas is the water transmissivity potential in the alluvium. The aquifer transmissivity is defined as the groundwater discharge through the unit width of the aquifer for the fully saturated depth under a unit hydraulic gradient (Chowdhury, Jha, and Chowdary, 2010). The aquifer transmissivity for the Sarkhoon plain was designed according to the 10 piezometer pump age experimental results of the plain (Hormozgan Regional Water, 2013) and by interpolating using the Simple Kriging model in the ArcGIS 10 environment, and it was reclassified into four classes as shown in Fig. 3.

Land cover: Having the correct information regarding land use is necessary for any sort of activity and planning, including artificial recharge. Inappropriate lands are irrigated agriculture and orchards, residential areas, roads, and deep slopes. Among the various land uses, pastures with vegetation cover contribute to the water infiltration of the soil and prevent soil degradation, and they are deemed suitable for artificial recharge plans. The land use layer for the study area was obtained from the 1/25000 maps and was synchronized using ASTER sensed images with the band combination of 1,2, and 3 as well as Google earth images. It was then classified into four classes as shown in Fig. 3.

Water quality: Since the electrical conductivity is indicative of the amount of water minerals, it can be used for the water quality index. In a present study, the observatory well information was used to determine the electrical conductivity layer in the Sarkhoon plain. First, the registered log of the observatory well's EC parameter was entered layer by layer into the ArcGIS software, and then it was obtained using the Simple Kriging of the EC scatter map. The electrical

conductivity parameter ranged from 682 to 6250 $\mu\text{mho/cm}$, and it was classified into four classes as shown in Fig. 3.

Drainage Density: Drainage density is the proportion of all of the streams in one catchment to its area, and it has a direct relationship with the maximum discharge. Using the digital

elevation model (DEM), the collective stream layer was extracted, and then the stream density layer was obtained, which was classified into the six classes that are shown in Fig. 3.

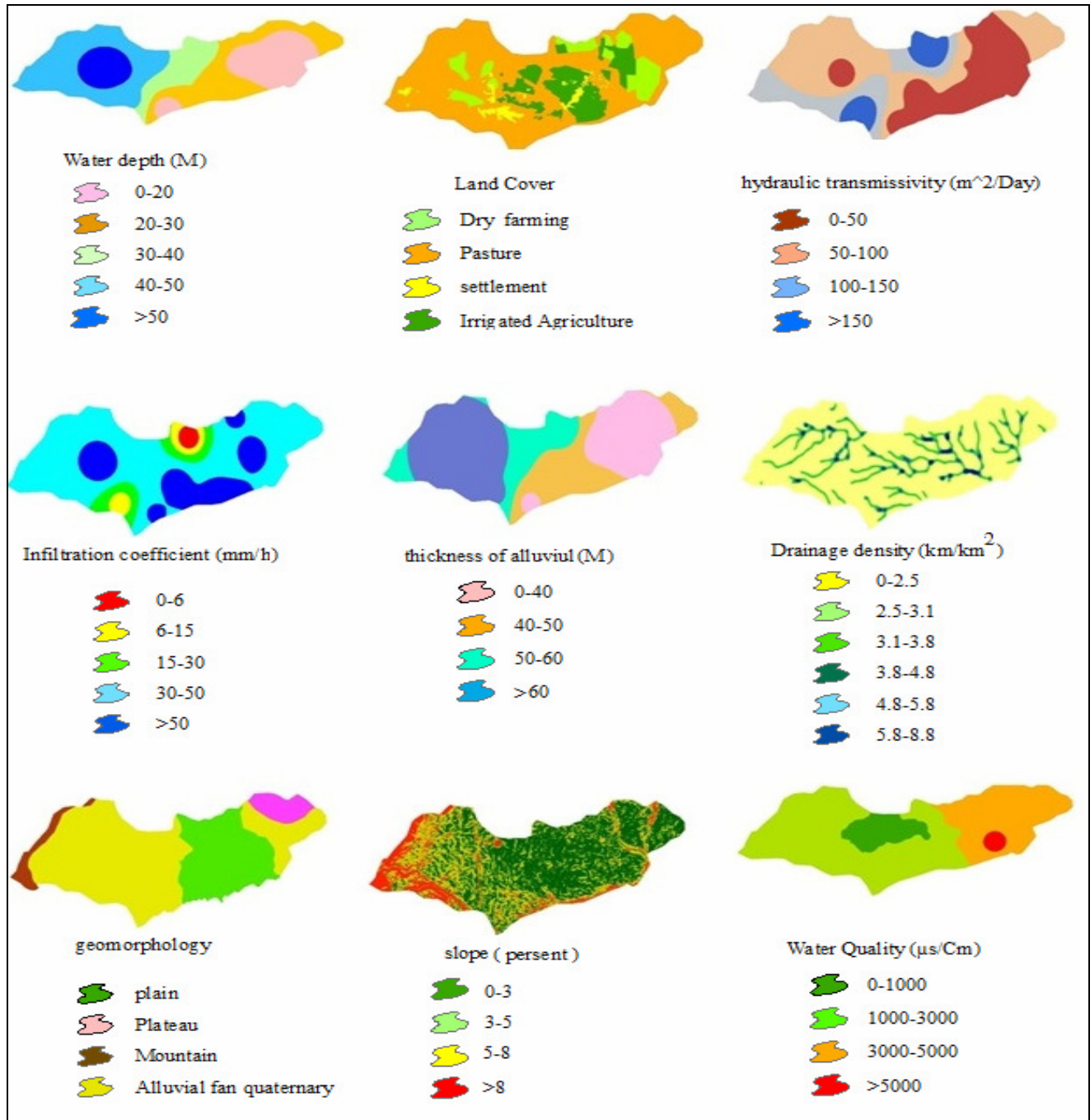


Fig. 3 : Reclassification layers

Methods

In the current study to determine the importance of each criterion used ANP method. This model is one of the Multi-Criteria Decision Making techniques which is grouped as compensational models. The ANP feedback approach replaces hierarchies with networks in which the relationships between levels are not easily represented as higher or lower,

dominant or subordinate, direct or indirect (Meade & Sarkis, 1999). The method provides a tool to evaluate all the relationships systematically by adding all interactions, interdependences, and feedbacks in Decision Making (DM) system (Zaim *et al.*, 2014). There are four basic steps when using ANP: (1) deconstructing a problem into a complete set of hierarchical or network model; (2) generating pairwise

comparisons to estimate the relative importance of various elements at each level; (3) building a super matrix to represent the influence priority of elements; and, (4) making decisions based on the super matrix (Yang, Wang, Dulaimi, & Low, 2003). Also, in order to determine the importance of each class weights used the Analytical Hierarchy process. The AHP, first introduced by Saaty (1977, 1980) by creating a hierarchy in which the decision-making problem is structured into smaller parts at different levels (Rezaei *et al.*, 2014) AHP divides the decision-making process into the following three main steps (Saaty, 1977): (1) Problem structuring; (2) Assessment of local priorities; and; (3) Calculation of global priorities. To determine the weight firstly the pairwise comparison matrix was constructed and the comparison was performed pairwise in scales from 1-9. In case of consistency, the weight computation matrix is obtained through simplifying and normalizing the components of each of the columns. Besides calculating the weight, the calculation of the inconsistency amount is of great value. Generally, it can be said that the acceptable amount of inconsistency of a matrix depends on the decision maker but Saaty (1980) suggests 0.1 as the acceptable extent and believes that if the inconsistency is higher than 0.1 it is better to give the judgments a second thought.

The most significant stage in selecting the appropriate areas for artificial recharge is the skewing of the standard maps, and, in the current study, the TOPSIS method was used. In this method, the m factor, or the option, is evaluated. This technique is based on the concept that every chosen factor should be at the least distance from the positive ideal factor (the most important) and at the maximum distance from the negative ideal factor (the least important). In other words, for this method, the amount of distance between one factor and the positive and negative ideal factor is evaluated, which is the factor's rating scale.

First step: The creation of a decision-making matrix: At this stage, a matrix is drawn at the first line in which the options are presented. In the columns, the indices are presented. In the ending line, the weight of each of the indices is presented. At the interception of the line and the column, the amount of importance given by the respondents for each of the options is presented. r_{ij} is the score of the option i_{th} in the index i_{th} , and w_j is the weight of the index i_{th} .

Second step: Regularizing the decision-making matrix (normalizing): In order to be comparable, the decision-making matrix should be converted into a normalized matrix N_1 using the relation 1:

$$n_{ij} = \frac{r_{ij}}{\sqrt{\sum_{i=1}^m r_{ij}^2}} \quad (1)$$

Third step: obtaining the weighted normalized matrix: To obtain the weighted normalized matrix (V), normalized matrix (fetched from the second step) is multiplied by the square matrix ($W_{n \times n}$) which the components of its main diagonal are the indices measurements and its other components are zero.

$$V = N_1 \times W_{n \times n} \quad (2)$$

Fourth step: The determination of positive ideal factor and the negative ideal factor: In this stage, the options should be identified that are described by the respondents as the most important and the least important factors. In other words, for the positive indices, the positive ideal is the maximum amount of v , and the negative ideal is the minimum amount of v . For the negative indices, the positive ideal is the minimum amount of v , and the negative ideal is the maximum amount of v . Relations 3 and 4 express this idea.

$$A^+ = \left\{ \left(\max_i V_{ij} \mid j \in J \right), \left(\min_i V_{ij} \mid j \in J' \right) \mid i = 1, 2, \dots, m \right\} = \{V_1^+, V_2^+, \dots, V_n^+\} \quad (3)$$

$$A^- = \left\{ \left(\min_i V_{ij} \mid j \in J \right), \left(\max_i V_{ij} \mid j \in J' \right) \mid i = 1, 2, \dots, m \right\} = \{V_1^-, V_2^-, \dots, V_n^-\} \quad (4)$$

In these relations, J represents the positive indices, and J' represents the negative indices.

Fifth step: Calculation of the distance to the positive and the negative ideals: In this stage, the amount of distance of each of the options from the positive ideal and the negative ideal is determined via relations 5 and 6.

The distance of option i_{th} from the positive ideal:

$$d_i^+ = \sqrt{\sum_{j=1}^n (V_{ij} - V_j^+)^2} ; i = 1, 2, \dots, m \quad (5)$$

The distance of option i_{th} from the negative ideal:

$$d_i^- = \sqrt{\sum_{j=1}^n (V_{ij} - V_j^-)^2} ; i = 1, 2, \dots, m \quad (6)$$

Sixth step: The proximity amount calculation for each of the factors to the positive and the negative ideal factors: In this stage, the amount of the proximity of each of the options to the positive and the negative ideals is obtained according to:

$$CL_i = \frac{d_i^-}{d_i^- + d_i^+} \quad (7)$$

Since $d_i^+ \geq 0$ and $d_i^- \geq 0$ then $CL_i \in [0, 1]$. The larger the index value the performance of the alternatives (Pazand *et al.*, 2012).

A flowchart of the study steps and the stages is provided in Fig. 4.

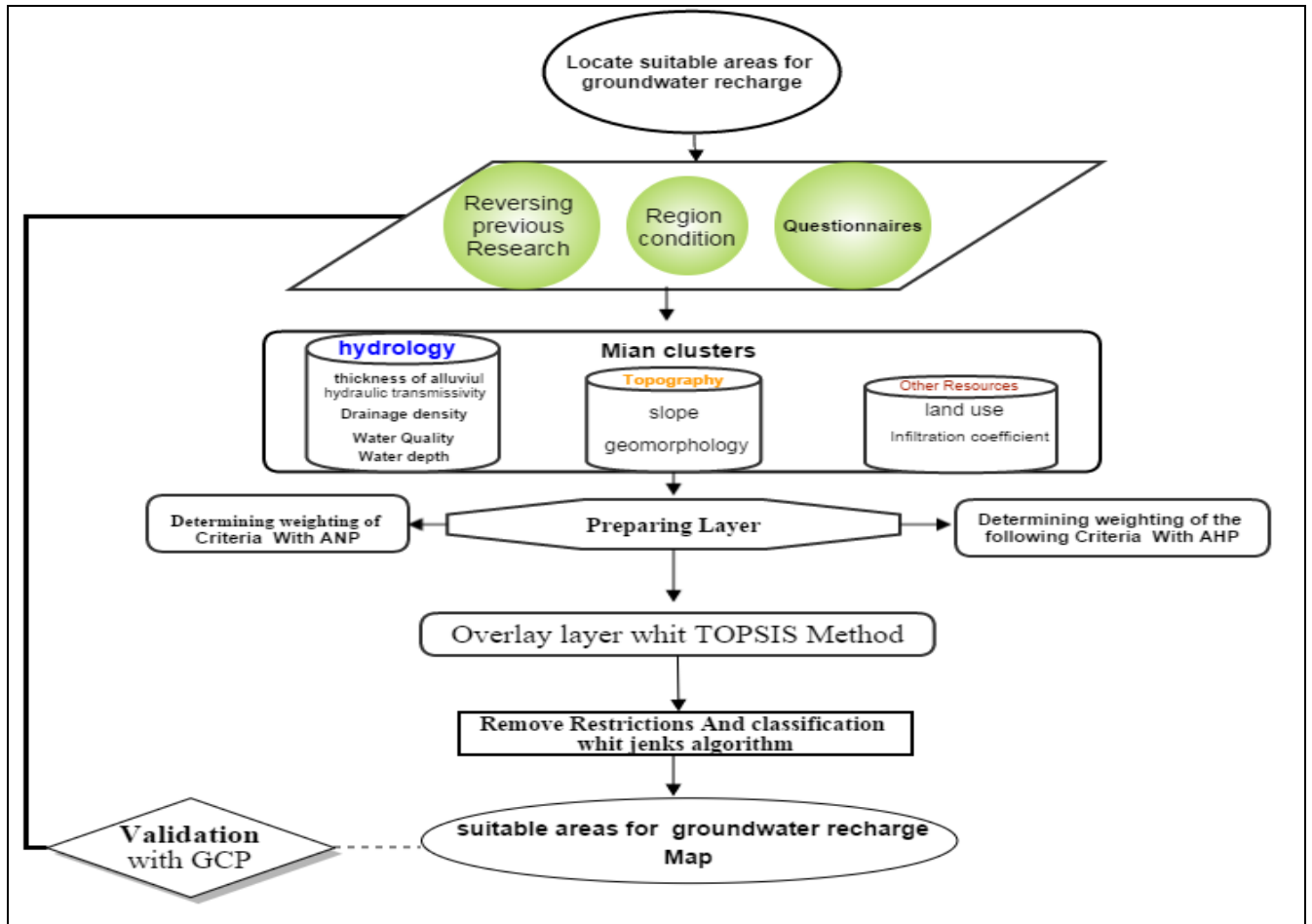


Fig. 4 : Flowchart of the Methodology Adopted.

Results

After creating the location database according to the existing data and the analytical requirements, the space modeling process was performed on the data. First, the questionnaires were prepared and were given to 12 experts in the economy, bioenvironmental, and social-cultural fields. After the briefings, they were asked to assign a value from one to nine to each of the standards based on their priorities. Then, based on the geometric averaging of the experts' opinions and the AHP method, the weight for each standard class was obtained (Table 3).

Table 3 : The importance of each class of criteria and CR

criteria	Class	Wight	CR
slope	0-3	.727	.02
	3-6	.118	
	6-10	.093	
	>10	.062	
geomorphology	plain	0.25	0.07
	Plateau	0.133	
	Mountain	0.042	
	Alluvial Fan Quaternary	0.501	
Drainage density	0-2.5	.019	.0004
	2.5-3.1	.048	
	3.1-3.8	.085	
	3.8-4.8	.151	

thickness of alluvial	4.8-5.8	.228	0.01
	5.8-8.8	.469	
	0-40	.077	
	40-50	.141	
	50-60	.186	
Water depth	>60	.596	0.0091
	0-20	.053	
	20-30	.084	
	30-40	.163	
	40-50	.233	
hydraulic transmissivity	>50	.467	0.0057
	0-500	.074	
	500-1000	.183	
	1000-1500	.324	
land cover	>1500	.419	.00001
	Dry Farming	.282	
	Pasture	.618	
	Settlement	.030	
Infiltration coefficient	Irrigated Agriculture	.070	0.02
	0-6	.048	
	6-12	.101	
	12-18	.117	
	18-24	.353	
>24	.381		

To obtain the standards' weights, they were first classified in hydrology, topography, and other standards clusters using the Analytical Network Process, and then a procedural grid based on Fig. 5. was created to show the relationship between the clusters and the standards. According to this method, the standards inside the cluster possessed an affinity to one another in addition to the existence of a relationship between the clusters Figure 5.

Although the grid analysis process also uses a relative measurement standard based on pairwise comparisons, it does not impose the sole hierarchical structure. It evaluates the problem using a systemic viewpoint accompanied with feedback. Then, the weight for each of the standards is obtained by considering the geometric average of the experts' ideas and by using Super Decision software (Table 4).

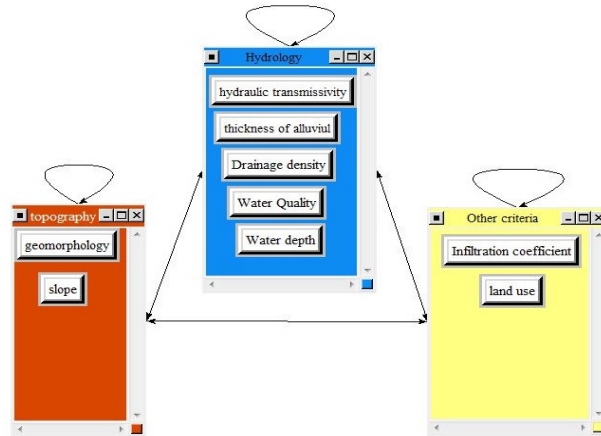


Fig. 5 : Network model for the case study

Table 4 : The importance of each criteria

Cluster	Cluster Weight	Criteria	Criteria Weight	Final Weight
Topography	0.27529	slope	0.5855	0.16119
		geomorphology	0.4144	0.11410
Hydrology	0.573732	Drainage density	0.4785	0.27454
		thickness of alluvial	0.2085	0.11996
		Water depth	0.0011	0.00063
		Water Quality	0.0164	0.00941
		hydraulic transmissivity	0.2953	0.169474
Other criteria	0.15097	land use	0.5292	0.0798948
		Infiltration coefficient	0.4707	0.071075

Using this method, the final weight table of the standards was deemed sufficient, and using the weight super-matrices and limiting the super-matrix tables was avoided. different layers were created in the ArcGIS environment and the TOPSIS method was used for the overling. At first, the negative and the positive layers of each layer Created and then the sum of them then obtained Fig. 6 by using the using the relation 7.

In order to identify the districts with limitations in the present study, the layer with a slope of larger than 8 percent in the mountainous geomorphology layer and the land use layer of residential areas and streambeds are considered to be limitations based on the research performed on the subject and the local conditions. The grounds that were inappropriate for Groundwater Recharge were eliminated. To obtain more precise results by natural division, the entire region was classified into four classes, and then polygons of less than one hectare were merged into larger neighboring polygons. The final map was then classified Fig. 7.

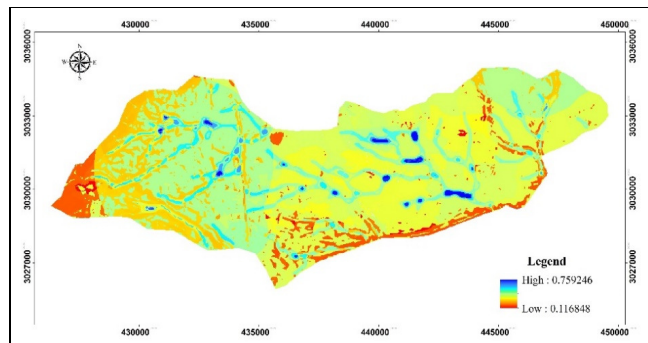


Fig. 6 : Potential mapping for Groundwater Recharge

Of the total area of the Sarkhoon plain, about 5.25 square kilometers are considered to be suitable for artificial recharge, and about 24.91 square kilometers are considered to be unsuitable for the artificial recharge operations (Table 5). is the total area of the classes based on the square kilometer and percentage.

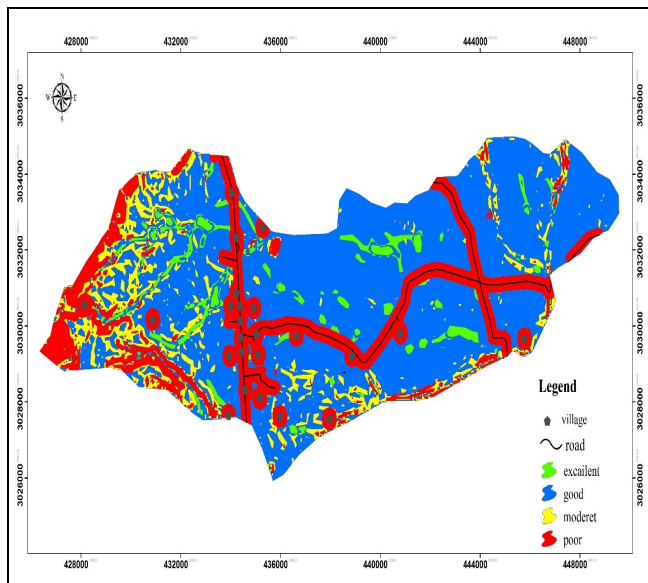


Fig. 7 : Overall suitability map for Groundwater Recharge

Table 5 : The area of the zonation map classes

Excellent	Good	Moderate	poor	Class
5.2599	71.6875	12.4127	24.9193	Area(km ²)
4.60	62.72	10.86	21.80	Area (percent)

The combinational method was used in order to validate the data. In this research, the flood scattering plans and the artificial recharge programs from the Organization of Forests, Pastures, and the watershed of the Hormozgan Province were used. Therefore, all of the 32 areas in which the recharge operations were performed in the previous years were surveyed in order to determine if their performance was successful or unsuccessful. The success scale was based on the current status at the time of study in which all of the projects left unfulfilled or abandoned after the program began due to un-profitability or suffering from large damages during the passage of time were classified as unsuccessful, and other cases were considered to be successful Fig. 8. Then, the most suitable class from the zonation map was compared with the control sites from the successful group, and the overlapping percentage was obtained Fig. 9.

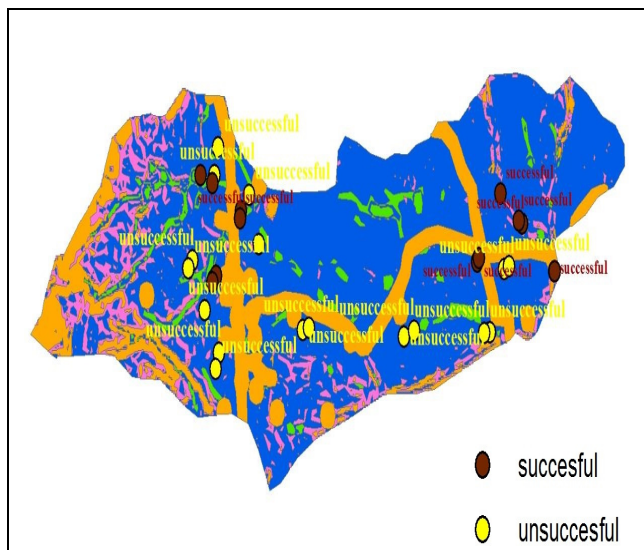


Fig. 8 : Successful and unsuccessful project areas

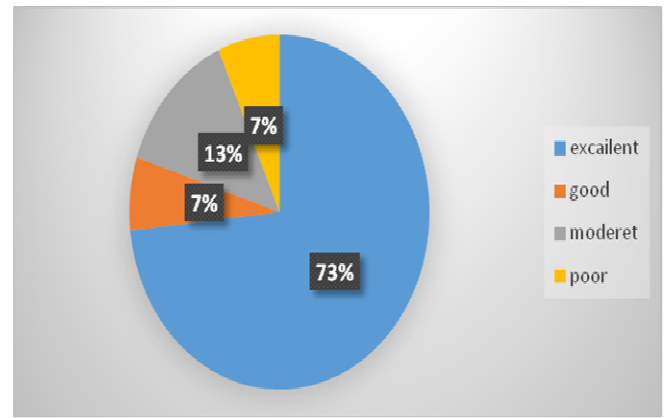


Fig. 9 : Percent compliance of the excellent class with a successful project

Discussion

Due to the declining procedure in the groundwater table, the runoffs from the intense and irregular precipitations, especially in the arid and semiarid areas, can be used as an opportunity to recharge the aquifers. The final prioritizing maps of the artificial recharge areas obtained from the modern combinational method in this study show that the most suitable areas for artificial recharge are mostly located in the north and the east of the Sarkhoon plain. In the current study, the highest importance was assigned to the drainage density scale. Based on the evaluation of the regional climate conditions, it was concluded that when the runoffs are flowing on the ground, they rapidly become unavailable due to the high evaporation rate if we do not make use of them. This result is not consistent with the results obtained by Chadhuri (2010) and Me gash (2012), who assigned a lesser importance to high densities. They considered the high density to be indicative of low infiltration, but, in the present study, the infiltration factor is given a separate weight. Regarding transmissivity, the most suitable class is located in the area above 150 meters. These areas are located in the sites with higher transmissivity, and some researchers, including Salami *et al.* (2012) and Chudri *et al.* (2010), have pointed this out. The results obtained from the current study show that most of the perfectly suitable and suitable regions are in the classes 3-0 and the classes 5-3 regarding the slope, which is consistent with the results obtained by Krishna Murthy *et al.* (1996), Alesheykh *et al.* (2008), Chadhuri (2010), Faraji (2012), and Muhammad Aziz Rahman (2012) who believed that the areas with slopes of less than 5% are suitable for flood scattering plans. Regarding the alluvium thickness, the areas with a thickness of more than 60 meters are suitable, which corresponds with the results obtained by AleSheykh *et al.* (2008) and Ghayoomyan *et al.* (2007). Regarding land use, the most suitable areas are located in the localities with pastures and rain-fed agriculture that are far from the residential areas. Regarding the transmissivity layer, the geology formation was mainly the topic of discussions in the previous studies, but, in the present study, the transmissivity itself without a

type of formation has been considered. The suitable areas from a geology and geomorphology perspective are located in the Quaternary units and the alluvial fans, respectively, and it can be asserted that due to the location around the runoff banks with a high density and a low slope, it leads to the formation of silt, sand, and gravel units, which eventually causes a good transmissivity in the Quaternary units and the alluvial fans. Unlike previous studies, in the current study, the ANP method has been used to determine the scales' weights. The ANP method deals systematically with the correlations (that is to say that it considers all of the internal and external correlations between the components and the clusters for the analyses). Therefore, according to the environmental problems correlations (including the topic of the present study), the ANP method provides the required support for the decision makers to solve the managerial problems in order to achieve a subtle understanding of the environmental problems. In addition, the weight summation method was used in the final blending of the layers in the previous studies, but, in the present study, the TOPSIS method was used. In addition to the closeness of the options to the positive ideal, the distantness from the negative ideal was considered, which enhanced the model's precision. The results obtained from the comparison of the most suitable classes overlaps more than 70 percent of the successful plans performed, which suggests the model's high output precision. In the present study, the data obtained from ten observatory wells was used to produce and according to the vastness of the plain their positional scattering for enhancing the interpolation model precision was low. Since the input layers were prepared using different resources at different times, there is some degree of indecisiveness in the determination of the data's exact boundaries, and there is a possibility that the zonation areas' boundaries differ from what they are in reality. This indecision could possibly be resolved using uncertainty determination methods, such as fuzzy models.

Conclusion

Groundwater is one of the most important natural resources which play an increasingly significant role for water supplies throughout the world (Nampak *et al.*, 2014). Because of the climate change as well as the method and the amount of water withdrawal from the aquifers, the ground waters have suffered from a descending process during the recent years, especially in arid and semiarid areas. Planning to use the flowing waters while decreasing their devastative effects provides a new water resource. Therefore, the construction of water structures to artificially recharge the aquifers could be an effective approach in durable resource management. The application of ground-related modern technologies, such as GIS and RS, can substantially influence the increase in location-finding plans' precision for artificially charging the aquifers. In the current study, the ANP modern blending method and a pairwise comparison in combination with TOPSIS were used in order to determine the suitable areas for artificial recharge in the Sarkhoon plain

in Hormozgan. To do so, the most effective and the most important factors for determining the suitable areas for flood scattering plans were applied according to the previous studies and the region's local conditions. About 5 percent of the region is in the most suitable class for artificial recharge, and the final map corresponded with more than 73 percent of the ground reality, which signifies the acceptable efficiency of the combination of ANP and TOPSIS for a region's evaluation in order to build artificial recharge structures. The model's output map can be used as a guide to determine the suitable sites for building the artificial recharge structures in the Sarkhoon plain. By implementing these designs, the durable and long-term use of ground water resources would be facilitated. Therefore, it is suggested that in order to locate the suitable areas for artificial recharge, a comprehensive geographical study of the entire area should be performed first, and then the different and efficient parameters should be chosen according to the region's conditions. To improve the location finding, artificial recharge plans accompanied by GIS is suggested. We used multi-target decision-making methods as well as more recent multi-scale methods, such as PROMETHEE 4 and GREY SYSTEM THEORY, and compared the results with the present study, which the authors will consider in their future studies. The use of the satellite images with a high location resolution can be useful in the production of parts of the applied layers in location findings, such as the extraction of the region morphology or land use. In addition, the creation of a multi-scaled decision-making backup system, which is capable of inputting various weight layers and performing various scenarios in the location-finding of artificial recharge, is suggested.

References

- Adamowski, J. and Chan, H.F. (2011). A wavelet neural network conjunction model for groundwater level forecasting. *Journal of Hydrology*, 407(1-4): 28-40.
Retrieved from: <http://www.sciencedirect.com/science/article/pii/S0022169411004100>
- Agha Nabati, A. (2004). Geology of Iran. *Geological Survey of Iran*, 606.
Retrieved from: <http://geoiran91.blogfa.com/post/156>
- Alesheikh, A.A.; Soltani, M.J.; Nouri, N. and Khalilzadeh, M. (2008). Land assessment for flood spreading site selection using geospatial information system. *International Journal of Environmental Science & Technology*, 5(4): 455-462.
- Anbazhagan, S.; Ramasamy, S.M. and Gupta, S. D. (2005). Remote sensing and GIS for artificial recharge study, runoff estimation and planning in Ayyar basin, Tamil Nadu, India. *Environment Geology*, 48: 158-170.
Retrieved from: <http://link.springer.com/article/10.1007/s00254-005-1284-4>

- Basagaoglu, H. and Marino., M. A. (1999). Joint Management of Surface and Ground Water Supplies. *Ground Water*, 37(2): 214-222. Retrieved from <http://info.ngwa.org/gwol/pdf/990564792.PDF>
- Bize, J.; Bourguet, L. and Lemoine, J. (1972). *Alimentation artificielle des nappes souterraines*. Masson and Cie Editors, 199.
- Chenini, I., & Ben Mammou, A. (2010). Groundwater recharge study in arid region: An approach using GIS techniques and numerical modeling. *Computers & Geosciences*, 36(6), 801-817.
- Chowdhury, A.; Jha, M. and Chowdary, V.M. (2010). Delineation of groundwater recharge zones and identification of artificial recharge sites in West Medinipur district, West Bengal, using RS, GIS and MCDM techniques. *Environmental Earth Sciences*, 59(6): 1209-1222.
- Faraji, S.H.; Nasiri, H.; Hamze, M.; Talebi, S. and Rafiei, Y. (2012). Identification of suitable areas for artificial groundwater recharge using integrated ANP and pair wise comparison methods in GIS environment, (case study: Garbaygan Plain of Fasa). *Geography and Environmental Planning Journal*, 44(4): 143-166.
- Ghayoumian, J.; Mohseni, S.M.; Feiznia, S.; Nouri, B. and Malekian, A. (2007). Application of GIS techniques to determine areas most suitable for artificial groundwater recharge in a coastal aquifer in southern Iran. *Journal of Asian Earth Sciences*, 30(2): 364-374.
- Gleeson, T.; Alley, W.M.; Allen, D.M.; Sophocleous, M.A.; Zhou, Y.; Taniguchi, M. and VanderSteen, J. (2012). Towards Sustainable Groundwater Use: Setting Long-Term Goals, Backcasting, and Managing Adaptively. *Ground Water*, 50(1): 19-26.
- Gomes, E. and Lins, M. (2002). Integrating Geographical Information Systems and Multi-Criteria Methods: A Case Study. *Annals of Operations Research*, 116(1-4): 243-269.
- Ketata, M.; Gueddari, M. and Bouhlila, R. (2014). Hydrodynamic and salinity evolution of groundwaters during artificial recharge within semi-arid coastal aquifers: A case study of El Khairat aquifer system in Enfidha (Tunisian Sahel). *Journal of African Earth Sciences*, 97(0): 224-229.
- Krishnamurthy, J. and Srinivas, G. (1995). Role of geological and geomorphological factors in ground water exploration: a study using IRS LISS data. *International Journal of Remote Sensing*, 16(14): 2595-2618.
- Liu, C.W.; Chen, S.K.; Joe, S.W. and Kuo, S.F. (2001). Estimation of the infiltration rate of a paddy field in Yen-Lin, Taiwan. *Agricultural Systems*, 68(1): 41-54.
- Magesh, N.S.; Chandrasekar, N. and Soundranayagam, J.P. (2012). Delineation of groundwater potential zones in Theni district, Tamil Nadu, using remote sensing, GIS and MIF techniques. *Geoscience Frontiers*, 3(2): 189-196.
- Malczewski, J. (1996). A GIS-based approach to multiple criteria group decision Making. *International Journal of Geographical Information Systems*. 10: 955-971.
- Meade, L.M. and Sarkis, J. (1999). Analyzing organizational project alternatives for agile manufacturing processes: An analytical network approach. *International Journal of Production Research*, 37(2): 241-261.
- Mohanty, S.; Jha, M.; Kumar, A. and Sudheer, K.P. (2010). Artificial Neural Network Modeling for Groundwater Level Forecasting in a River Island of Eastern India. *Water Resources Management*, 24(9): 1845-1865.
- Nampak, H.; Pradhan, B. and Manap, M.A. (2014). Application of GIS based data driven evidential belief function model to predict groundwater potential zonation. *Journal of Hydrology*, 513(0): 283-300.
- Önüt, S. and Soner, S. (2008). Transshipment site selection using the AHP and TOPSIS approaches under fuzzy environment. *Waste Management*, 28(9), 1552-1559.
- Pazand, K.; Hezarkhani, A. and Ataei, M. (2012). Using TOPSIS approaches for predictive porphyry Cu potential mapping: A case study in Ahar-Arasbaran area (NW, Iran). *Computers & Geosciences*, 49(0): 62-71.
- Rahman, M.A.; Rusteberg, B.; Gogu, R.C.; Lobo Ferreira, J. P. and Sauter, M. (2012). A new spatial multi-criteria decision support tool for site selection for implementation of managed aquifer recharge. *Journal of Environmental Management*, 99(0): 61-75.
- Rahman, M.A.; Rusteberg, B.; Uddin, M.S.; Lutz, A.; Saada, M.A. and Sauter, M. (2013). An integrated study of spatial multicriteria analysis and mathematical modelling for managed aquifer recharge site suitability mapping and site ranking at Northern Gaza coastal aquifer. *Journal of Environmental Management*, 124(0): 25-39.
- Rezaei, J.; Fahim, P.B.M. and Tavasszy, L. (2014). Supplier selection in the airline retail industry using a funnel methodology: Conjunctive screening method and fuzzy AHP. *Expert Systems with Applications*, 41(18): 8165-8179.
- Saaty, T.L. (1977). A scaling method for priorities in hierarchical structures. *Journal of Mathematical Psychology*, 15(3): 234-281.
- Sethi, R.R.; Kumar, A.; Sharma, S.P. and Verma, H.C. (2010). Prediction of water table depth in a hard rock basin by using artificial neural network. *International Journal of Water Resources and Environmental Engineering*, 2(4): 95-102.

- Yang, Y.Q.; Wang, S.Q.; Dulaimi, M. and Low, S.P. (2003). A fuzzy quality function deployment system for buildable design decision-makings. *Automation in Construction*, 12(4), 381-393.
- Zaim, S.; Sevкли, M.; Camgöz-Akdağ, H.; Demirel, O.F.; Yesim Yayla, A. and Delen, D. (2014). Use of ANP weighted crisp and fuzzy QFD for product development. *Expert Systems with Applications*, 41(9): 4464-4474.