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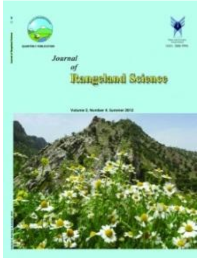

Full Length Article:

Site Selection for Groundwater Artificial Recharge in Silakhor Rangelands Using GIS Technique

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Abstract. Groundwater is among the most important resources of drinking water supply of the worldwide population. Use of recharge area is one of the methods for artificially recharging groundwater. Selection of suitable sites for artificial recharge is very important and must be carried out accurately. There are different types of land use, only rangelands are appropriate for artificial recharge because of their topographical situations. In this study, the groundwater artificial recharge suitable area of Silakhor, Borujerd of Iran rangelands was investigated and extracted using Geographic Information System (GIS) and Analytic Hierarchy Process (AHP) method. The layer information of rainfall, soil, lithology, slope, land use and fault components were prepared and weighed by applying AHP method and were used for artificial recharge site selection. Aquifer artificial recharge maps showed that in Silakhor catchment 14%, 64.8% and 21.2% of the area of the catchment had high, moderate and low capability for artificial recharge, respectively. The most suitable areas were located in the low land areas.

Key words: Silakhor, Borujerd, Catchment, Groundwater, Artificial recharge, AHP.

Introduction

Groundwater is a natural drinking water resource often subjected to severe human impact. Strategies are required to preserve optimum groundwater quality, so management of this vital natural resource has become a worldwide priority. In recent years, international scientific communities have shown great interest on this topic and thus, many works have focused on the environmental management for the groundwater protection (Gerth and Forstner, 2004; Ebrahimi *et al.,* 2011). Similarly, environmental impact of various point and non-point source pollutants to groundwater resources is equally important for both scientific communities and regulating organizations. Groundwater pollution resulting from leachates created from garbage dumps or uncontrolled industrial effluents at ground surface can create significant deterioration in the water quality of many aquifers (Fatta *et al*., 2002). Groundwater quality has been deteriorated in many countries both in urban landscapes where a high level of contamination is expected and also in rural areas with predominantly agricultural landscapes.

Use of recharge area is one of the methods for artificially recharging groundwater. Selection of suitable sites for artificial recharge is very important and needs to be carried out accurately. GIS is a useful system to be employed for spatial data management (Mahdavi *et al.*, 2011), due to the presence of various effective spatial parameters in selection of suitable sites for artificial recharge and a need to review the evaluated factors of their interrealtionships as well as their changes. Flood management is important to recharge ground water tables in dry land regions where the agricultural lands and rangelands are vulnerable to soil erosion. Remote sensing and GIS systems are effective techniques in watershed management and flood distribution over rangelands (Amiri *et al.*, 2006).

Selection of appropriate artificial recharge locations of groundwater is an inevitable important necessity and is one of the main principles of creating this system. Thus, it needs to be done with great care. There are several characteristics for recharge locating which should be integrated and analyzed together since the quantity of these parameters is constantly changing. So, GIS is a very useful tool in this regard (Mahdavi *et al.*, 2004 and Ghayoumian *et al.*, 2007; Mahdavi *et al.*, 2011).

Vulnerability assessment of groundwater studies have also been undertaken under different socioeconomic and hydroecological settings (Tesoriero *et al.*, 1998; Lake *et al.*, 2003; Al-Adamat *et al.*, 2003; Dixon, 2005). Howover, a standardized method has not yet been developed. Selecting optimal sites for floodwater spreading involves integrating several complicated parameters, which necessitates the use of GIS in combination with MCDM (multi criteria decision making). Groundwater contamination risk assessment methods are amply documented in non-karst and karst environments (Sinkevich *et al.*, 2005; Breytenbach, 2005; Bonacci *et al.*, 2009; Parise *et al.*, 2008). Preparation of various hazard maps is a very important endpoint of these studies (Breytenbach, 2005).

The determination of potential sites for groundwater artificial recharge requires a basic knowledge of the rainfall regime characteristics and a detailed evaluation of surface topography, surface soil properties, land use and lithology in space and time. Integration of remote sensing and GIS techniques provides reliable, accurate and up-to-date information on land and water resources, which is a prerequisite for the purpose of multi-criteria decision-making for site suitability analysis for ground water recharge. GIS capabilities for supporting spatial decisions can be analyzed in context of decision-making process

(Jacek, 1999; Andrade-Rolland and Rangarajan, 2012) dealt with Analytic Hierarchy Process (AHP) which is a structured technique for dealing with complex decisions. This process is most useful where teams of people are working on complex problems, especially those with high stakes involving human perceptions and judgments whose resolutions have long-term repercussions. From the earlier studies, different possible constraints were identified for selecting suitable sites for flood water spreading (Andrade-Rolland and Rangarajan, 2012).

The aim of this study was to select suitable sites for groundwater recharge Silakhor floodplain, Broujerd using GIS technology.

Materials and Methods

Site

The study was conducted in Silakhor plain in Lorestan province, in southwest of Iran (33°33' to 34°4' N and 48°30' to49°0' E) (Fig.1). Silakhor is a mountainous catchment with the area of 1973 km^2 that 69.06% of it is mountains and hills. Mean annual precipitation and temperature in this area is about 530 mm, 14.6 °C, respectively. Average altitude of this catchment is 2500 meters above sea level, having moderate semi-arid climate.

Fig. 1. Geographical location of Silakhor in Lorestan province, and in Iran

Methodology

In order to find the suitable areas of the catchment for groundwater artificial recharge, some attributes including soil type, slope, rainfall, land use faults, infiltration rate, groundwater table, quality of alluvial sediments, and land use of the Quaternary regions were used. The thematic layers of these parameters were prepared, classified, weighted and integrated in a GIS environment by means of AHP method.

Two points were considered. First, the drought threatens the people and ecosystem in the catchment particularly in areas receiving low precipitation and second, there should be enough high quality water available in the catchment to manage and use it as the source of aquifer recharge. Hence, in this research, the critical regions in terms of groundwater level were recognized, and then the evaluation indices for artificial site selection based on the area priority were selected. Digital topographic, lithology (Fig. 2), soil (Fig. 3), faults (Fig. 4), land use maps and climatologically data series including precipitation (Fig. 5), temperature, evapotranspiration, hydrologic and water resources data including the number of wells, springs and water level from the authorized organizations were collected and used. Moreover, ArcGIS, Excel and Autocad softwares were used for analyzing the maps and data. Slope is an important factor in determining the most suitable areas for recharge purposes. Water velocity is directly related to land slope and its depth. On steep slopes, runoff is more erosive. It can remove loose sediments down slope more. Topographic maps of the region were used to develop a slope map by the Digital Elevation Model. The slope map was classified into three classes (Fig. 6).

The AHP is a Multi-Criteria Decision-Making (MCDM) method that appeared to be one of the most promising techniques for the development of weights (Eastman *et al.*, 1995; Breytenbach, 2005). Because computing time becomes the core in such complex problem situations, the need for powerful computing platforms to digest and analyze this spatial information arises. This brings the researchers to the advantages of GIS when used in combination with MCDM models (Breytenbach, 2005). In this research for site selection, the information items, slope, surface infiltration, alluvial thickness and quality of sediments were investigated and integrated in GIS. Satellite images were used to prepare the prevailing streams coastal conditions create limitations for artificial groundwater recharge plans. The more geomorphologic and land use maps. Then, the layer information of these parameters were prepared and weighed by applying AHP method. Finally, artificial recharge suitable map was derived by integrating and overlapping of the parameters. The resulted map is shown in (Fig. 7).

Results and discussion

According to the different types of land-use, only rangelands are always appropriate for artificial recharge. Therefore, the rangelands and non-rangelands regions are determined on the land-use (Saravi *et al.*, 2006). This classification and some agricultural lands are applied to the map of recharge satisfactory areas as a filter. The resulted digital layers of the catchment and weights in AHP models are given in (Table 1). Also, the result of overlaying the maps of the geomorphology and suitability areas for groundwater artificial recharge using use is shown in (Table 2).

Based on the fault map (Fig. 5) of the catchment, most faults are located in the southern mountainous area of the catchment, so these areas are not in priority order for the recharge. Based on the distributed precipitation map of the catchment (Fig. 6) annual precipitation ranges between 400 and 700 mm which in the most suitable areas for groundwater recharge locates on areas with 500 mm precipitation per year.

Suitability maps showed that 14 and 21.2% of the Silakhor aquifer have high and low suitability for artificial recharge, respectively. Other parts were mid range as shown in (Table 2 and Fig. 8).

The main limitation factor is the catchment slope and as one can see the slope between 0 to 2% shown in Fig. 4 is compatible with Fig. 7 that shows suitable areas for groundwater artificial recharge. The results indicate that evolved streams, the more suitable for groundwater artificial recharge; so, streams having higher orders are more opt for recharge and as shown in the suitability maps, the most suitable areas are in the low land areas that have higher stream orders.

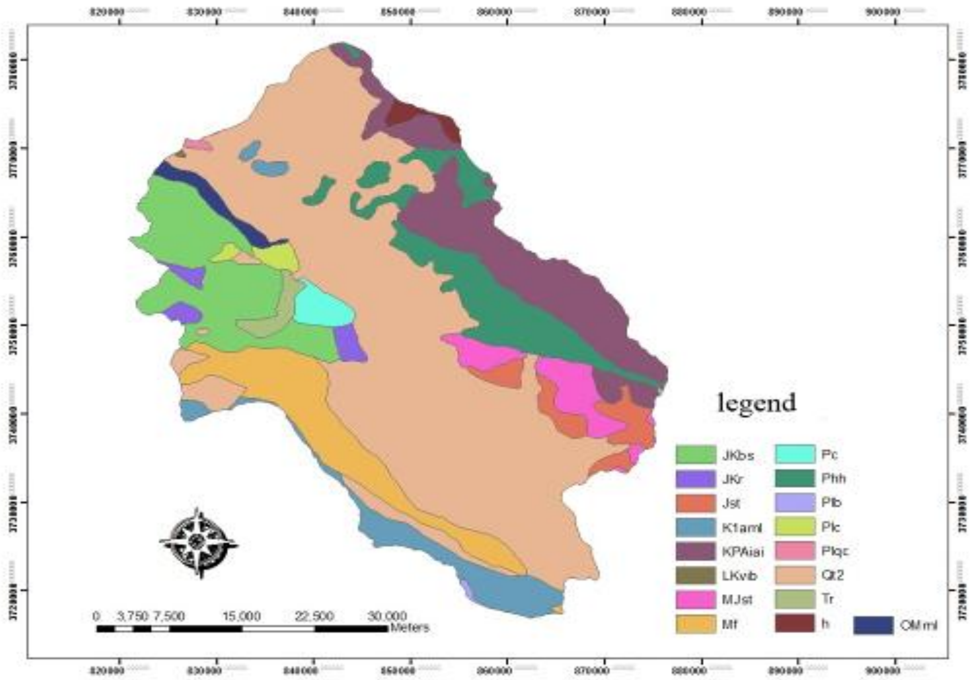

Fig. 2. Lithology map of Silakhor

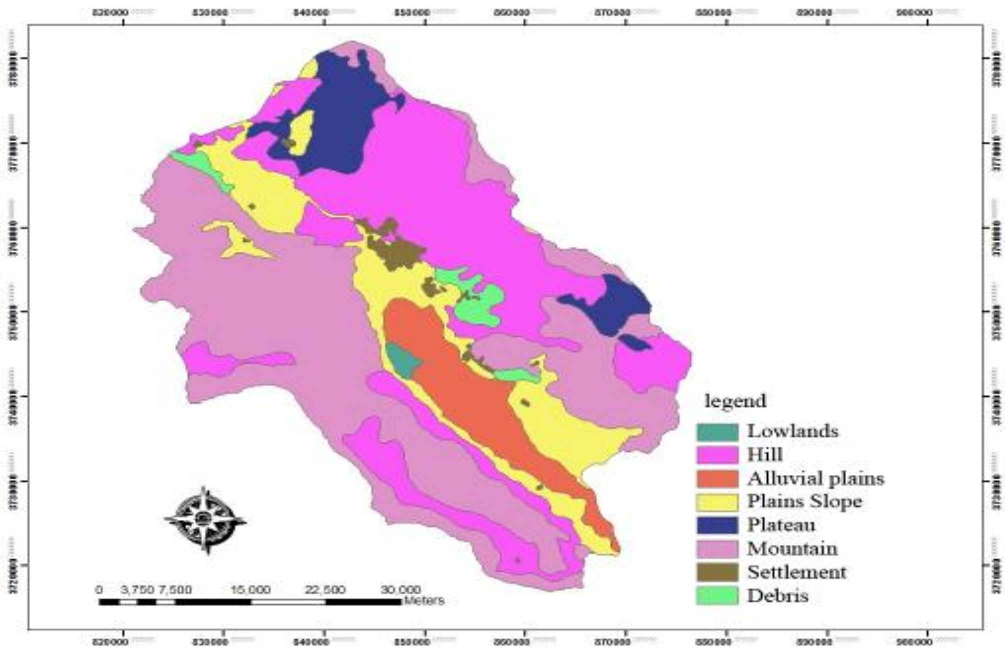

Fig. 3. Soil map of Silakhor

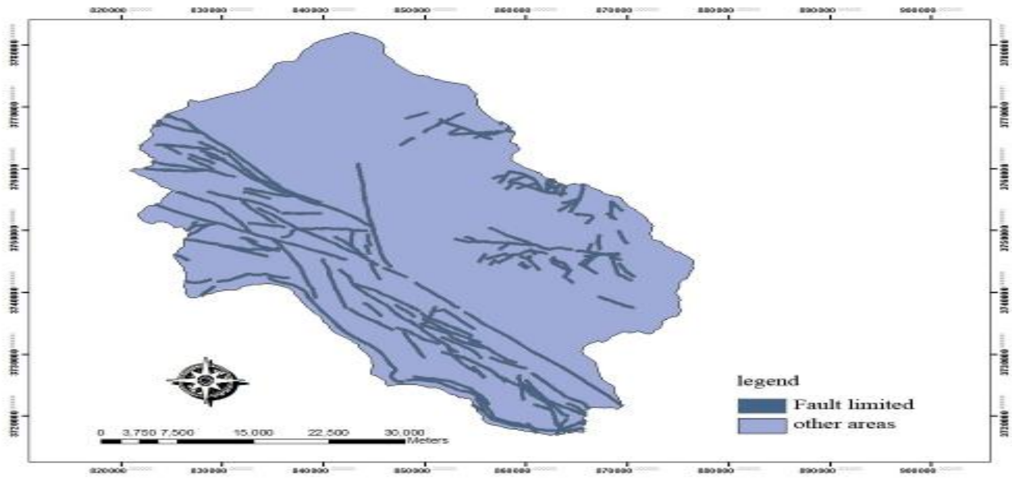

Fig. 4. Faults map of Silakhor

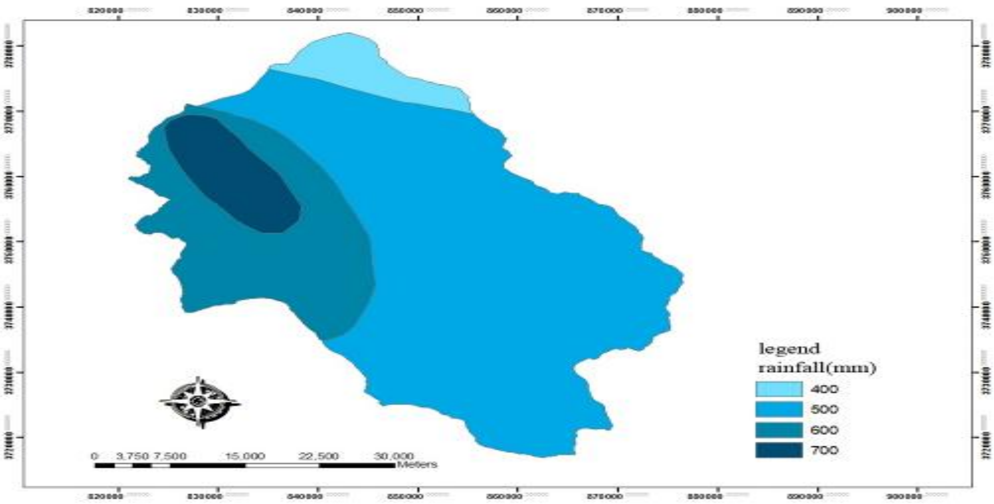

Fig. 5. Rainfall map of Silakhor

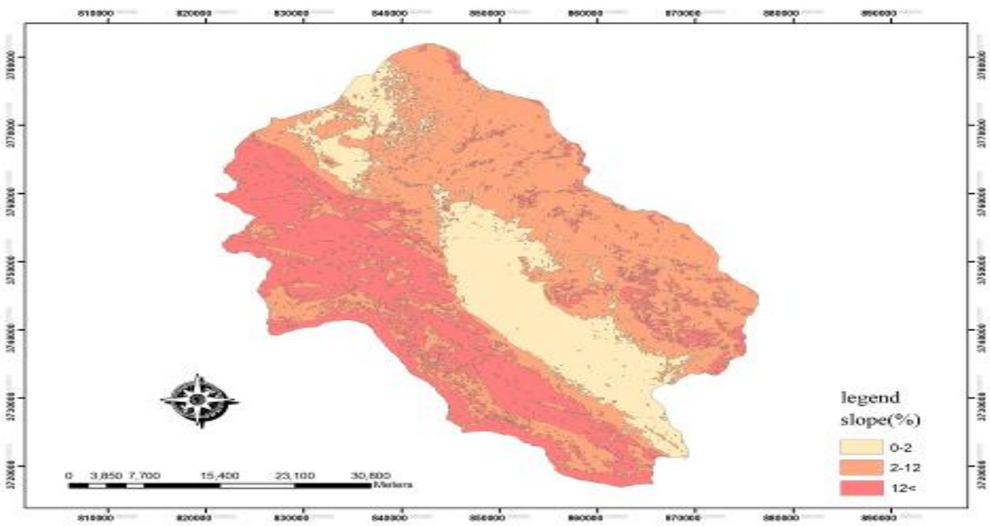

Fig. 6. Classified slope map of Silakhor

Table 1. Layers and Weights in AHP models

Layer	Weight	Groups Name	Weight in AHP
		0-2 %	0.105
Slope	0.162	2-12 %	0.045
		12< %	0.012
		Qt2	0.083
		JKbs, Mf, OMml, Pc, Tr	0.042
Lithology	0.162	h, K1aml, Plqc,	0.021
		JKr, MJst, Phh, Plb, Plc	0.010
		Jst, KPAiai, LKvib	0.005
Rainfall	0.057	400-600	0.042
		600-700	0.014
		Hilly plains Plateau and upper terraces	0.263
		Land by alluvial plains and river debris fan	0.134
Soil	0.030	Barrow	0.066
		Mountain	0.033
		Settlement and industrial site	0.017
Fault	0.019	Buffer :200 m	0.016
		Other area	0.003

Table 2. Classification and percentages of area suitability for artificial recharge in Silakhor catchment using AHP model

Suitability Class	Area (km^2)	Area Percentage
High suitable	227	14.05
Suitable	368	18.66
Average	366	18.55
Rather unsuitable	543	27.54
Low suitable	418	21.2

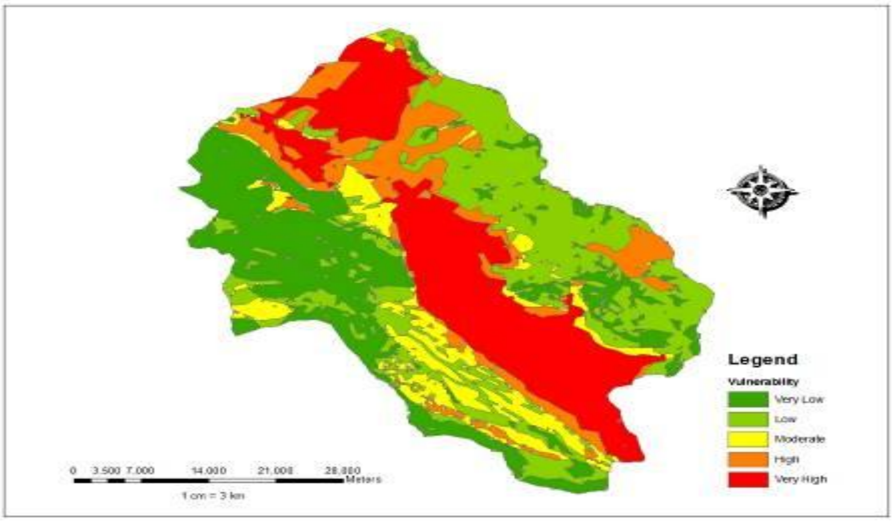

Fig. 7. Distribution of suitability areas for groundwater artificial recharge in Silakhor

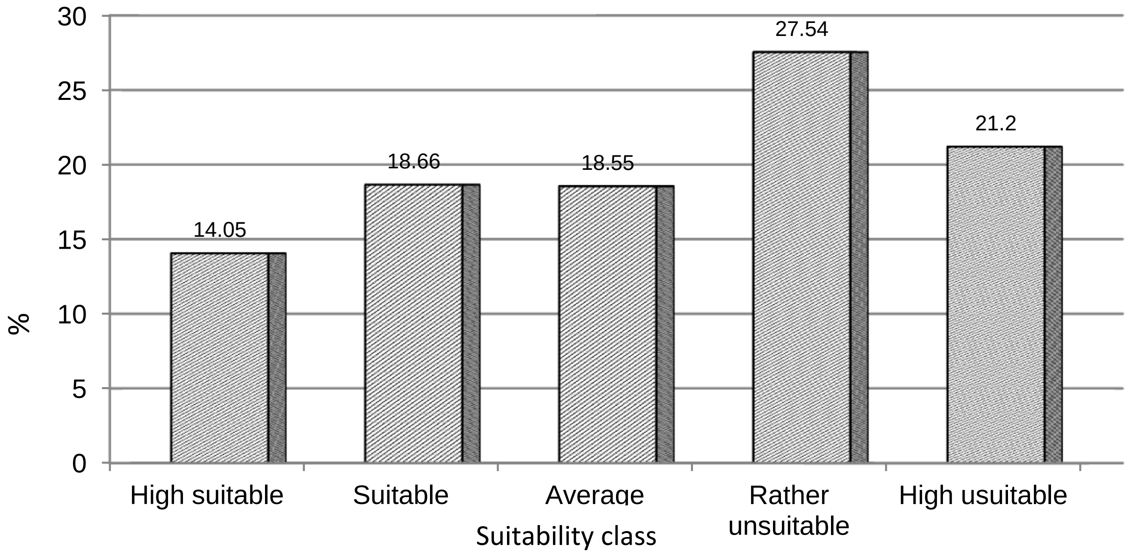

Fig. 8. Suitability area of Silakhor for groundwater artificial recharge

Conclusion

The feasibility of groundwater artificial recharge depends on availability of hydrogeologically suitable sites. Suitable areas for groundwater artificial recharge in Silakhor catchment located in Lorestan province in west of Iran are characterized as topographic, soil, lithology, fault and precipitation basic maps.

A set of specific criteria such as slope, rainfall amount, closeness or distance from the faults and stream order were involved to locate suitable sites for artificial recharging. Parameters considered in selection of groundwater artificial recharge locations are diverse and complex. Integrated assessment of thematic maps using AHP and GIS techniques was a suitable method for identifying preferred artificial recharge sites. The Geographic Information System (GIS) offers the tools to manage, manipulate the process, analyze, map, and spatially organize the data to facilitate the suitability analysis. Hence, application of GIS and AHP as a tool is very useful in integrating various data and deciphering suitable sites for artificial recharge to harvest the rainwater and enhance the aquifer performance. It can be suggested that this study's methodology is suitable to be applied for other basins and also to be compared to the similar approaches in order to find the best methodology.

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