GROUNDWATER VULNERABILITY MAPPING USING A MODIFIED-DRASTIC MODEL IN AJABSHIR PLAIN, SOUTHEAST COAST OF URMIA LAKE, IRAN

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ABSTRACT:

Groundwater resources play an important role not only in providing drinking water but also in irrigation, industry and power generation. In general, groundwater is a part of the water cycle in nature that can be collected by wells, qanats, drains, or natural springs. In this research, the potential of groundwater vulnerability in Ajabshir plain, located in the Southwest of East Azerbaijan Province and Southeast of the Urmia Lake, Iran, is investigated using 7 hydrogeological parameters as well as land-use criterion. Depth to water map is provided using 26 boreholes. Twenty-seven drilling points are also used in generating aquifer media and impact of vadose zone maps. After providing and ranking all layers, they are multiplied by appropriate weights and overlaid to produce vulnerability map. Modified-DRASTIC model is applied to achieve the aim. According to the results, an approximately large part of the aquifer (29 percent), mostly located in the west of the plain, is covered with moderate vulnerability class. Spearman correlation coefficient is calculated 0.63 between the vulnerability and land use maps.

1. INTRODUCTION

Nowadays, supplying freshwater is one of the greatest concerns all over the world. This problem is considered more serious in arid and semiarid countries than others. Due to the location of Iran in arid and semiarid latitude, the importance of groundwater has doubled in this country. Groundwater is defined as a part of the rainfall that penetrates into the ground. It is one of the most valuable sources of fresh water due to its less exposure to contamination and evaporation than surface water. Therefore, the importance of the groundwater in the areas without or with low surface water is much more noticeable (Zhou et al, 2010; Jia et al, 2019). On the other hand, freshwater extraction from natural glaciers and saline sea water is a difficult and costly process. One of the best ways to prevent groundwater contamination is to identify vulnerable aquifers and land use management (Yu et al, 2010). Groundwater quality can also be protected through the development of vulnerability maps. According to related studies, groundwater vulnerability is often assessed applying the DRASTIC and modified versions of this model (Wu et al, 2016; Kong et al, 2019). Groundwater vulnerability can be evaluated considering two different aspects, including intrinsic vulnerability and specific vulnerability. Intrinsic vulnerability uses only the geologic factors of hydrogeology without considering human activities while the special vulnerability is used to define the vulnerability of groundwater to particular contaminants or group of contaminants (Vrba and Zaporozec, 1994; Aller et al. 1987).

Up to now, many studies have done worldwide to evaluate aquifer vulnerability using DRASTIC and geographic information system (GIS) (Shirazi et al. 2013; Yin et al. 2013; Kaliraj et al. 2015).

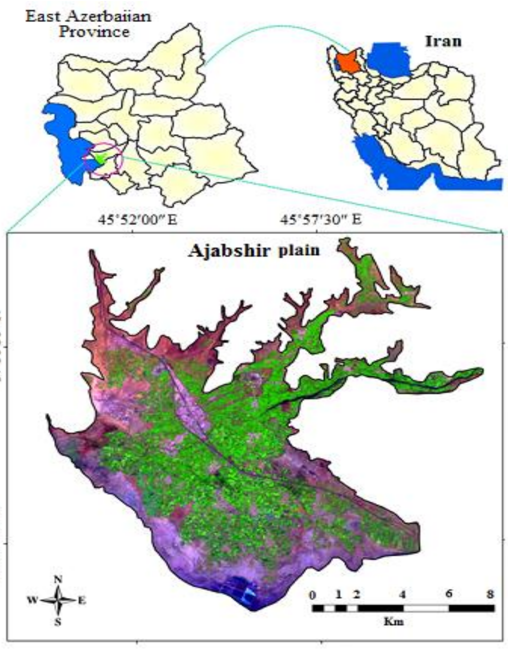

Figure 1. Study Area

The main aim of the present study is to map the groundwater vulnerability in Ajabshir plain using a modified-DRASTIC model.

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2. PROPOSED METHOD

2.1 Study Area

The region studied in this research is Ajabshir plain with an area of 144.69 km2 and a perimeter of 165.75 km situated in the southwest of East Azerbaijan Province and southeast of Urmia Lake. The study area is located at longitude 45° 49′–46° 02′ E and latitude 37° 23′–37° 33′ N. The minimum and maximum altitudes of the plain are 1280 and 1641 meters above the sea level, respectively. The average annual rainfall reaches about 329 mm per year. Ajabshir Plain is considered as a part of the Urmia Lake basin (Fig 1).

2.2 Data Used

•Quantitative data
Transferability data obtained from the results of pumping experiments in 15 wells; Water surface data in 26 piezometers; Depth of 27 drilling profiles; Soil permeability at 10 points.
•Qualitative data
• Soil type in 27 drilling profiles
•Remote sensing data
• Landsat 8 satellite image of the 168th pass and 34th row recorded on May 26, 2014

2.3 Method

2.3.1 DRASTIC method

DRASTIC method is an overlay and index method. It is the most commonly used indicator to assess the potential of groundwater intrinsic vulnerability. This approach was developed by Aller et al in 1987 aiming at systematically assessing the potential of groundwater to contamination based on hydrogeological characteristics in the United States. The term DRASTIC refers to 7 hydrogeological parameters including depth to water level, net recharge, aquifer media, soil media, topography, impact of the Vadose zone, and hydraulic conductivity (Stigter et al., 2006). After extracting the maps of the 7 parameters required, a DRASTIC map is obtained using Boolean logic and index overlay. DRASTIC equation is written like following:
Equation (1):

$$DI = \sum_{j=1}^{7} r_j\, w_j = D_r D_w + R_r R_w + A_r A_w + S_r S_w + T_r T_w + I_r I_w + C_r C_w$$

DI: The DRASTIC Indicator; Capital letters: First letters of the layers' name; r: layer ranking Indicator; w: Layer's weight

2.3.2. The single-parameter sensitivity analysis

This analysis presents an effective or real weight for each parameter. After comparing effective weights with theoretical weights, each parameter's real effect is computed, and finally the most effective parameters on the DRASTIC index are recognized. Effective weights are calculated using the following equation (Rahman 2008):

$$W = (P_r P_w / V) \times 100$$

Where W is the effective weight of each parameter, Pr and Pw are the rating and weight of parameters, and V is the vulnerability index.

2.3.3 Modified-DRASTIC method

In this method, the final criteria weights are calculated based on the results of the single-parameter sensitivity analysis of DRASTIC model. Moreover, land-use criterion is added to 7 DRASTIC parameters to improve it. AHP model is also used to produce the weights for sub-criteria and criteria.

3. RESULTS

3.1 Results of single parameter sensitivity analysis

Based on the results obtained from single parameter analysis (table 1), depth to water table and vadose zone are selected as the most efficient parameters in association with the vulnerability assessment. This is due to their higher efficient weights in comparison to theoretical weights. Moreover, the efficient weights of net recharge, soil media, and hydraulic conductivity are calculated less than theoretical ones. In fact, high importance of depth to water table, vadose zone, aquifer media, and topography in vulnerability assessment of the study area is demonstrated.

Table 1: Statistical results of single parameter analysis

Parameter	Theoretical weight	Theoretical weight(percent)	Mean of the efficient weight (percent)
D	5	21.7	24.21
R	4	17.4	13.12
A	3	13	15.31
S	2	8.7	8.3
T	1	4.3	7.46
I	5	21.7	23.62
C	3	13	7.95

The criteria and sub-criteria preferences are obtained using comparison matrices in AHP method. Both expert opinions and the results of single parameter analysis are used in this process. Because of the high importance of land use, the highest rank is assigned to this factor.

3.2 Vulnerability map

The final weights of the criteria and sub-criteria and the ratio of compatibility of the pairwise comparisons are calculated using Expert Choice software designed for AHP (Table 3). As shown in the table, the compatibility ratio of all comparisons is less than 0.1, which indicates a high accuracy for comparisons. Based on the modified-DRASTIC method, the studied area is classified into 5 classes in terms of vulnerability potential from very low vulnerability to very high vulnerability (Fig. 2). There is a moderate vulnerability in an approximately large part of the study area (29.59%) in the West, Center, north and south. 23.21% of the study area is high-vulnerable in the central, northern, west and south-eastern zones. 23.02% of the area in the south, southeast, small parts of the north, center and northeast is distinguished as low vulnerable and 19.16% of the aquifer in the east, southeast, north, and northeast is displayed as very low vulnerable. Finally, only 4.99% of the aquifer in the east, west, and southeast is classified into very high vulnerability class. As a result, based on the modified version of DRASTIC model, moderate and high vulnerability classes overcome the other vulnerability classes (Table 2).

Table 2: The area of the vulnerability classes in the modified-DRASTIC map

Vulnerability	Area (percent)	Area (km^2)
Very low	19.16	27.67
Low	23.02	33.25
Medium	29.59	42.74
High	23.21	33.53
Very High	4.99	7.22

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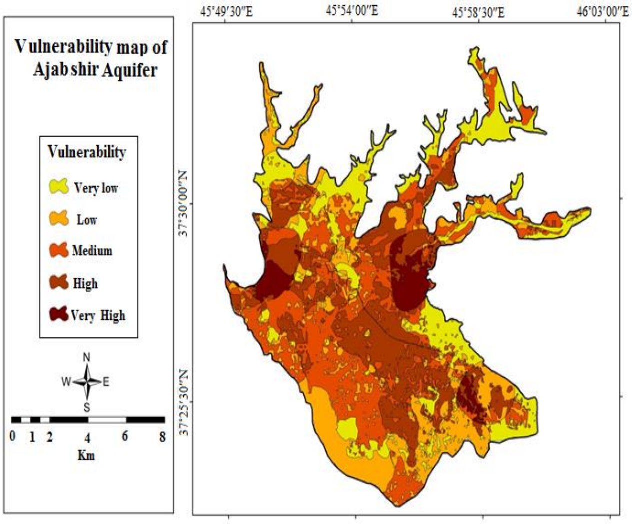

Figure 2: The map of Ajabshir vulnerability potential extracted from modified-DRASTIC model

Table 3: Paired comparisons of criteria

The final weight	Land use	Hydraulic conductivity	Impact of vadose …	topography	Soil media	Aquifer media	Net recharge	Depth to water table	Criterion
0.207								1	Depth to water table
0.052							1	1.4	Net recharge
0.108						1	3	1.3	Aquifer media
0.034					1	1.4	1.2	1.5	Soil media
0.073				1	3	1.2	2	1.4	topograp hy
0.160			1	3	5	2	4	1.2	Impact of vadose zone
0.022		1	1.7	1.4	1.2	1.5	1.3	1.7	Hydrauli c conduct
0.341	1	9	3	5	7	4	5	3	Land use
	CR = 0.034								

4. CONCLUSIONS

The main results are followed below:

- DRASTIC model can be corrected through different methods.
- In this research, land-use parameter, the results of single-parameter sensitivity analysis, and AHP model are used to produce a modified-DRASTIC model to assess the vulnerability potential of the aquifer.
- According to the vulnerability map, more area is covered by moderate vulnerability class (29.59%) than other classes.
- Only a very small region of the study area (4.9%) in the west, east, and southeast is covered with very high vulnerability potential to contamination.
- The high vulnerability class is more corresponded with the agricultural lands.
- Correlation coefficient between land-use map and vulnerability map is calculated 0.63.

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