The vulnerabitiy assessment of ARDABIL PLAIN by using DRASTIC and GIS

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ABSTRACT
The contamination of groundwater from point and non-point sources of pollution is one of the sensations of development countries such as Iran. This study presents the application and estimation of aquifer vulnerability by applying the DRASTIC model using GIS.
Result show north of the Arabil aquifer was dominated by very high vulnerability classes while the center and south east part was characterized by low vulnerability classes. The central area toward east part of the study area displayed moderate aquifer vulnerability.

RÉSUMÉ
La contamination des eaux souterraines du point et non des sources ponctuelles de pollution est une des sensations de pays en développement comme l'Iran. Cette étude présente la demande et l'estimation de la vulnérabilité des aquifères par l'application DRASTIC modèle en utilisant système d'information géographique (GIS).
Sur la base des résultats de modèle de DRASTIC pour la zone d'étude nord de l'aquifère d'Ardabil était dominé par de très grande vulnérabilité des classes tandis que le centre et la partie sud-est se caractérise par une faible vulnérabilité classes. La zone centrale vers l'est partie de la zone d'étude affichés aquifère vulnérabilité modérée.

1 INTRODUCTION

Recently groundwater pollution and contamination has become one of the most serious environmental problems especially in arid and semi-arid regions such as Iran. As contamination reaches the groundwater, remediation of aquifers would be necessary which is very difficult and costly. Protecting and preventing groundwater system from contamination therefore has significant importance for groundwater resource management. Groundwater vulnerability assessment is one of the major measures of groundwater protection. Vulnerability assessment has been recognized for its ability to delineate areas that are more likely than others to become contaminated as a result of human activities near the earth's surface. Once hot spot of contamination identified, these areas can be targeted by careful land-use planning, intensive monitoring, and by contamination prevention of the underlying groundwater.

The Ardabil aquifer, which is located in the North part of Iran, provides a source of water for domestic, industrial and mostly for agricultural use. To ensure that this aquifer can remain as a source of water for the Ardabil area, it is necessary to estimate whether certain locations in this groundwater aquifer are more susceptible to receive and transmit contamination

A very important tool for groundwater management consists of vulnerability mapping. The vulnerability concept is implemented by classifying a geographic area with regard to its susceptibility to groundwater contamination because groundwater models often have data requirements that cannot be satisfied in many parts of the world (Knox et al. 1993).

One of the most widely used models to assess groundwater vulnerability for a wide range of potential contaminants is DRASTIC (Aller et al. 1987). The DRASTIC model under GIS techniques is the most widely used for vulnerability assessment studies at regional scales (USEPA, 1993) and is an effective method for groundwater pollution risk assessment and water resource management. The acronym DRASTIC model, which incorporates the most important hydrogeologic factors that affect the potential for groundwater pollution, stands for the seven parameters used in the model which are:

Depth to water (D), net Recharge (R), Aquifer media (A), Soil media (S), Topography (T), Impact of vadose zone (I) and hydraulic Conductivity (C) (Aller et al. 1987). Refer to the Table 1 for more information.

DRASTIC methodology uses four major assumptions: the contaminant is introduced at the ground surface, the contaminant is flushed into the groundwater by precipitation, the contaminant has the mobility of water and the area evaluated is 0.4 km2 or larger (Aller et al. 1987).

The aim of this study was to assess the groundwater vulnerability of Ardabil Aquifer. The GIS technique was used to integrate hydrogeological data obtained in the field. The first objective of this study is to evaluate the Ardabil aquifer vulnerability by DRASTIC. The second objective is to locate and identify the relative importance of area which is under the risk of contamination or vulnerability in Ardabil aquifer.

2 LOCATION OF STUDY AREA

The study area is located in the eastern of Ardabil in North West of Iran, between longitude 47 and 48 Eastern and latitude 37 to 38 Northern (Figure 1). It represents a mountain and plain area with a mild slope from south–east to north-west. The drainage area has minimum elevation 1170 from the sea level. The area is characterized by a cold and dry climate with an annual temperature between 7.9 C to 15.2 C and an annual average precipitation of 380 mm.

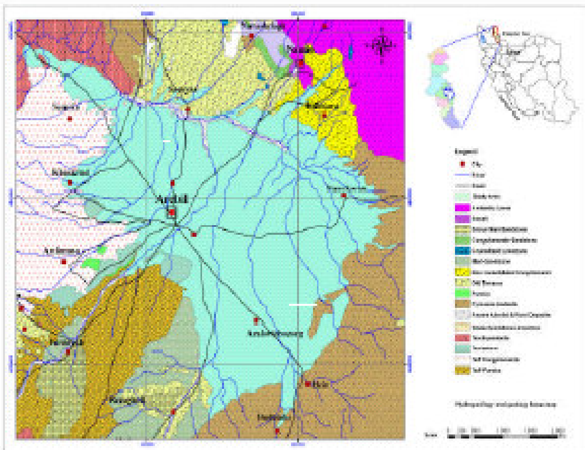

Figure 1: Location of study area (Ardabil Plain)

3 METHODS

A DRASTIC model in a GIS environment was used to evaluate the vulnerability of the Ardabil aquifer. The DRASTIC model was developed by the U.S. Environmental Protection Agency (EPA) to evaluate groundwater pollution potential for the entire United States. It was based on the concept of the hydrogeological setting that is defined as a composite description of all the major geologic and hydrologic factors that affect and control the groundwater movement into, through and out of an area (Aller et al., 1987). The description and relative weight of the DRASTIC model's parameters presented in (Table 1) based on (Aller et al., 1987).

DRASTIC uses a relatively large number of parameters (seven parameters) to compute the vulnerability index, which ensures the best representation of the hydrogeological setting. The numerical ratings and weights, which were suggested by Aller et al., 1987, are well defined and are used worldwide. This makes the model suitable for producing comparable vulnerability maps on a regional scale.

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Based on the value for each parameter in DRASTIC, the model yields a numerical index that is derived from

Table 1. DRASTIC Model Parameters.

Factor	Description	Relative weight
Depth to water	Represents the depth from the ground surface to the water table, deeper water table levels imply lesser chance for contamination to occur.	5
Net Recharge	Represents the amount of water which penetrates the ground surface and reaches the water table, recharge water represents the vehicle for transporting pollutants.	4
Aquifer media	Refers to the saturated zone material properties, which controls the pollutant attenuation processes.	3
Soil media	Represents the uppermost weathered portion of the unsaturated zone and controls the amount of recharge that can infiltrate downward.	2
Topography	Refers to the slope of the land surface, it dictates whether the runoff will remain on the surface to allow contaminant percolation to the saturated zone.	1
Impact of vadose zone	Is defined as the unsaturated zone material, it controls the passage and attenuation of the contaminated material to the saturated zone.	5
Hydraulic Conductivity	Indicates the ability of the aquifer to transmit water, hence determines the rate of flow of contaminant material within the groundwater system.	3

ratings and weights assigned to the seven model parameters. The significant media types or classes of each parameter represent the ranges, which are rated from 1 to 10 based on their relative effect on the aquifer vulnerability. The seven parameters are then assigned weights ranging from 1 to 5 reflecting their relative importance. The DRASTIC Index is then computed applying a linear combination of all factors according to the following equation:

DRASTIC Index = $D_rD_w + R_rR_w + A_rA_w + S_rS_w + T_rT_w + I_rI_w + C_rC_w$

Where: D, R, A, S, T, I, and C are the seven DRASTIC model parameters and the subscripts r and w are the representing rating and weights, respectively.

3-1 Depth to Water Table

Depth to water (D) is an important factor since it determines the depth of material through which a contaminant must travel before reaching the water table in an aquifer. Data was obtained from measurement in the field. Based on geostatistical analysis depth to groundwater is decrease from south east toward north. The ratings for study area for depth to water assigned according to Aller et al. (1987), are presented in Table 2.

The depth to water table map was then classified into ranges defined by the DRASTIC model and assigned rates ranging from 1 (minimum impact on vulnerability) to 10 (maximum impact on vulnerability). The deeper the groundwater, the smaller the rating value (Table 2).

Figure 2 shows the rated parameter maps used to obtain the DRASTIC aquifer vulnerability index regarding the depth to groundwater. The depth to water table in Ardabil is shallow in north and deep in toward south east. This makes the north part of the aquifer more susceptible to contamination according to DRASTIC assumptions. The rating scores ranges between 1 and 9 where the highest scores were assigned to the far north part of the area.

Figure 2 represent the vulnerability map regarding of depth to groundwater.

Table 2: Ranges and ratings for (D) Depth to water (Aller et al. 1987)

Depth to Water Table	
Range(m)	Rating
1.6 – 3	9
3 – 10	7
10 – 15	5
15 – 23	3
23 – 30	2
30 - 44.8	1

3-2 Net Recharge

The primary source of groundwater is typically precipitation and leakage along the rivers, which infiltrates through the surface and reaches the water table. This recharge water is thus available to transport a contaminant vertically to the water table and horizontally within the aquifer. The recharge map was constructed based on the relative recharge potential from a combination of slope, soil permeability and rainfall using following formula which suggested by Piscopo 2001.

Recharge value = Slope + Rainfall + Soil Permeability

The recharge map was then classified into ranges defined by the DRASTIC model and assigned rates ranging from

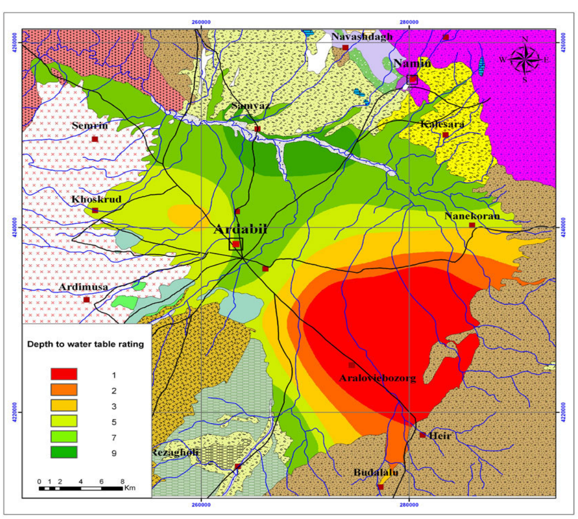

Figure 2: Depth to Groundwater Table Map

3 to 8. The higher the recharge the higher the rate assigned to the vulnerability index (Table 3). Figure 3 shows the rated parameter maps used to obtain the DRASTIC aquifer vulnerability index regarding the net recharge.

Table 3: Ranges and ratings for (R) net Recharge (Aller et al. 1987)

Recharge (R)	
Range	Rating
11 - 9	8
9 - 7	5
7 - 5	3

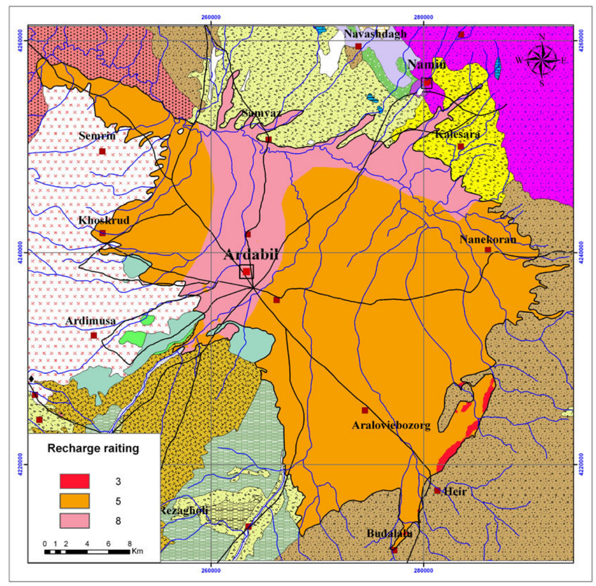

Figure 3: Net Recharge vulnerability map

3-3 Aquifer Media

Aquifer media refers to sediment of unsaturated zone. The aquifer media parameter was prepared from the geology map of the study area and consists primarily of sand, gravel, clay, and loam aquifer made up of alluvial aquifer in the study area.

The route and path length which a contaminant must follow are governed by the flow system within the aquifer. The path length is an important control in determining the time available for attenuation processes. The aquifer media was determined from the wells logs of study area. These data indicated that the aquifer made up from sand, gravel, clay and loam. The rate which assign to sand and gravel is higher than the rate of sandy loam as indicated in Table 4. According to Aller et al. (1987), these aquifer types receive range 8 and 6. Figure 4 also shows the vulnerability of aquifer based on Aquifer media.

Table 4. Ranges and ratings for (A) Aquifer media (Aller et al. 1987)

Aquifer media	
Media	Rating
Sand and gravel	8
Sandy clay loam	6

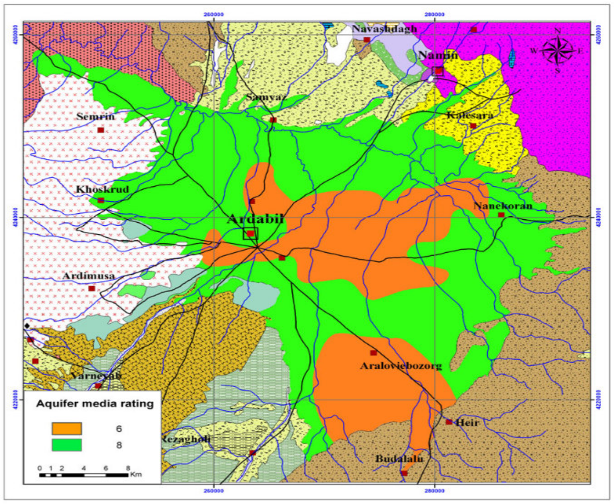

Figure 4: Aquifer Media vulnerability map

3-4 Soil Media

Soil media refers to that uppermost portion of the vadose zone characterized by significant biological activity. Soil has a significant impact on the amount of recharge that will infiltrate into the ground and hence on the ability of a contaminant to move vertically into the vadose zone. The soil media parameter refers to the top 1 m of the unsaturated zone referred to as top soil and was prepared using the soil map of the area.

Five soils type were described in the study area: gravelly loamy sand, sandy loam, loam, sandy clay loam, and clay loam. Table 5 shows the ratings for soils, according Aller et al. (1987). Figure 5 present the vulnerability map regarding the soil media.

Table 5: Ranges and ratings for (S) Soil media (Aller et al. 1987)

Soil media	
Media	Rating
Gravelly loamy sand	9
Sandy loam	7
Loam	5
Sandy clay loam	4
Clay loam	2

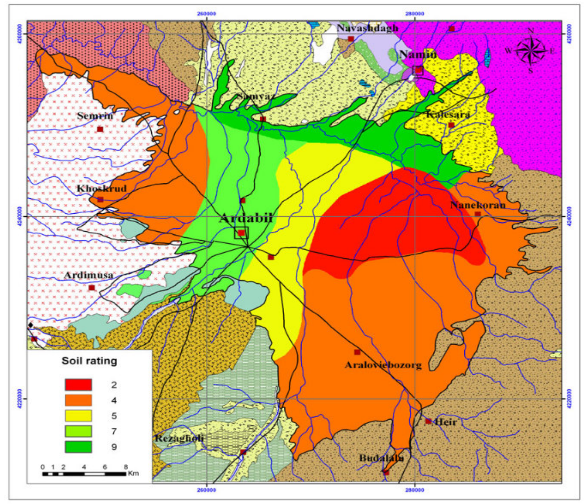

Figure 5: Soil Media vulnerability map

3-5 Topography

Topography refers to the slope variability of land surface. Topography helps control the likelihood that a pollutant will run off or remain on the surface in one area long enough to infiltrate. The slope map was generated from digital elevation model (DEM) of the study. An extensive plain was observed with slope less than 2 in the DEM at the study area. Lower the slope assigned for higher the rate, since contamination move slowly at low slope. The ratings of slope intervals are presented in Table 6, according to Aller et al. (1987). Also figure 6 present the vulnerability map regarding the topography.

Table 6: Ranges and ratings for (T) Topography (Aller et al. 1987)

Slop	
Range(%)	Rating
0 - 2	10
2 - 6	9
6 - 12	5
12 - 18	3
18 - 26	1

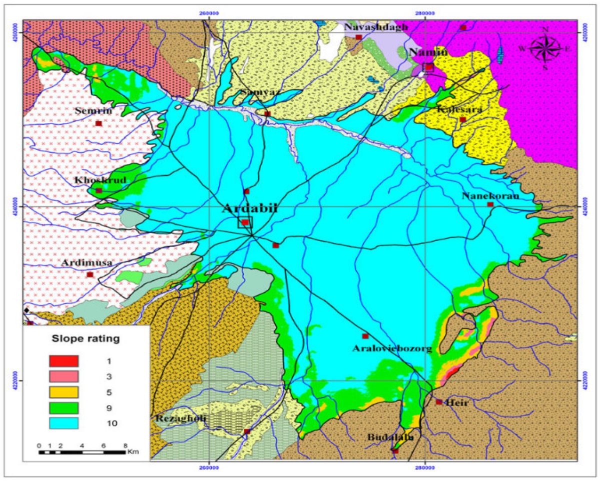

Figure 6: Topography vulnerability map

3-5 Impact of vadose zone media

The vadose zone is defined as that zone above the water table which is unsaturated or discontinuously saturated. The type of vadose zone media determines the attenuation characteristics of the material below the typical soil horizon and above the water table.

The vadose zone media was defined from geophysics exploration and exploration wells and local hydrological information. In the plain, the texture of the vadose zone was defined as sand and gravel, sandy clay loam and silt and clay. In Ardabil plain deposits the vadose zone is formed mainly by sand and gravel. The ratings for vadose zone media are shown in Table 7, according to Aller et al. (1987). Vulnerability map with regard the impact of vadose zone media represent in figure 7.

Table 7: Ranges and ratings for (I) the impact of vadose zone media (Aller et al. 1987)

Vadose media	
Media	Rating
Sand and gravel	8
Sandy clay loam	6
Silt and Clay	3

3-7 Hydraulic conductivity

Hydraulic conductivity refers to the ability of the aquifer materials to transmit water, which in turn controls the rate at which groundwater will flow under a given hydraulic gradient. Contamination moves away from the point and enters to the aquifer based on the amount and direction of groundwater flow. The hydraulic conductivity was defined from field tests and pumping wells data. Table 8 shows the weights and rate of the studied values, according to Aller et al. (1987). Figure 8 shows the vulnerability with regard to hydraulic conductivity.

4 RESULTS

In this paper, the groundwater vulnerability of a Ardabil plain located in north of Iran was assessed applying the DRASTIC method. Seven parameters were used to represent the natural hydrogeological setting: Depth to

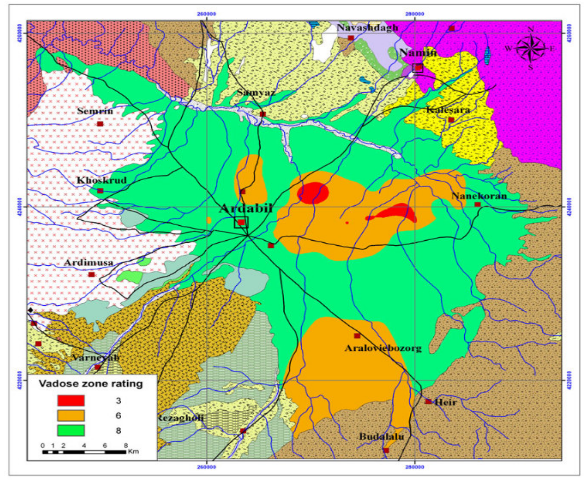

Figure 7: Impact vadose zone media vulnerability map

Table 8: Ranges and ratings for (C hydraulics conductivity (Aller et al. 1987)

Hydraulic Conductivity	
Range(m/day)	Rating
40 - 28	6
28 - 12	4
12 - 4	2
4 - 0	1

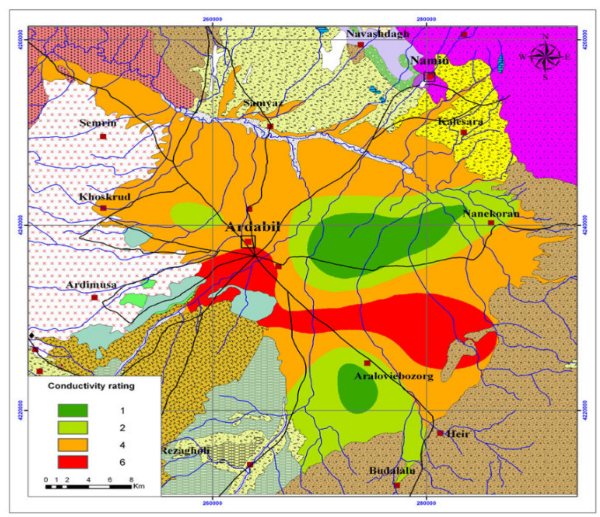

Figure 8: Hydraulic Conductivity vulnerability map

water table, net Recharge, Aquifer media, Soil media, Topography, Impact of vadose zone media, and hydraulic Conductivity. The groundwater vulnerability to pollution and contamination using the DRASTIC method indicated moderate values.

The minimum possible DRASTIC index using DRASTIC formula is 23 and the maximum is 230, this range was divided into seven equal classes as indicated in Table 9.

These classes are between no risks (23–53) to extreme risk (199-230).

Graph 9 shows that 12.75 % of the study area had a very high, 30.78 % had a high and 43.11 % had moderate and 13.34 % with low groundwater vulnerability to contamination.

Table 9: Risk of vulnerability based on DRASTIC index

DRASTIC index	
No risk	23-53
Very low	54-74
Low	75-105
Moderate	106-136
High	137-167
Very high	168-198
Extreme	199-230

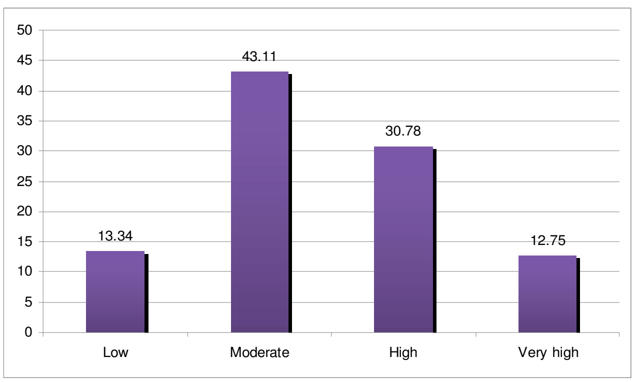

Figure 9: Risk of study area groundwater vulnerability

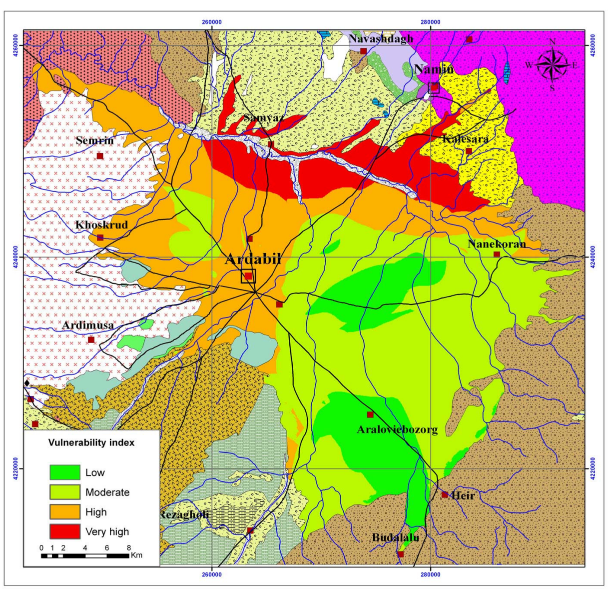

Figure 10: Map of the Vulnerability Index for Ardabil Plain

As Figure 10 indicates the DRASTIC aquifer vulnerability map clearly shows the dominance of moderate vulnerability classes in the centre towards eastern part of Ardabil, while the northern part is characterized by very high vulnerability, because of the sediment and soil type of this area. The south-east part of study area displays Low aquifer vulnerability. This is due to the deep of water table of this area.

The integrated vulnerability map shows that the northern part of the Ardabil aquifer is under a higher risk of contamination vulnerability (Figure 10).

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