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Evaluation of Vulnerability of Groundwater Aquifers to Risks Pollution Using GIS in Shewasoor Sub basin, Iraq

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ABSTRACT

The importance of water is life, so groundwater is one of the most important water sources, especially at present, due to the scarcity of surface water. Because of the expansion of the agricultural area, the advancement of the industry, and the potential population growth, it becomes necessary to turn to the groundwater, its investment, and its suitable utilization. The study area, the Shewasoor Basin, is located in the northeastern part of Iraq, about 40 kilometers northeast of Kirkuk City, between latitudes (35° 45' 28.9" N - 35° 48' 59.1" N) and longitudes (44° 31' 23.9" E - 44° 37' 07.5" E). The study area covers about 160 km2. Elevations of the Shewasoor region range between (329-1186) m.a.s.l. The Shewasoor region is bordered at the north and northeastern sides by the Taqtaq anticline, and the northern Chamchamal anticline at the southwest and west sides. The geological formations in the area extend from the youngest Quaternary sediments to the older middle Miocene. It is important in this research to clarify the waters affected by groundwater pollutants within the study area using several models based on geographic information systems (GIS) to determine the extent of the risk and pollution of groundwater in the study area. These calculated factors are water depth (D), net recharge (R), aquifer media (A), soil media (S), topography (T), vadose effect zone (I), and aquifer conductivity (C). Groundwater, through which the water flow is controlled inside and outside the area. Where VI represents the vulnerability index, and (D, R, A, S, T, I, and C) represent the parameters used in groundwater vulnerability assessment. Multiple criteria decision analysis shows that the vulnerability in the area is divided into five zones. The northern and northwestern regions have high vulnerability, while areas of low vulnerability are in the center and parts of the south of the study area, and areas of medium vulnerability are found in the remaining areas.

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تقييم قابلية تعرض الطبقات الحاملة للمياه لمخاطر التلوث باستخدام نظم المعلومات الجغرافية في حوض شيواسور، العراق

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الملخص

أهم ما في الحياة هو الماء، لذا تعتبر المياه الجوفية من أهم مصادر المياه، خاصة في الوقت الحاضر بسبب شح المياه السطحية. وبسبب توسع الرقعة الزراعية وتقدم الصناعة وزيادة النمو السكاني، أصبح من الضروري التوجه إلى الاهتمام بالمياه الجوفية واستثمارها والاستغلال الأمثل لها. تقع منطقة الدراسة التي تمثل حوض شيواسور في الجزء الشمالي الشرقي من العراق، على بعد حوالي 40 كيلومتراً شمال شرقي مدينة كركوك، بين خطي عرض (35° 45' 28.9" شمالاً – 35° 48' 59.1" شمالاً) وخطي الطول (44° 31' 23.9" شرقاً – 44° 37' 07.5" شرقاً). تغطي منطقة الدراسة حوالي 160 كم2 – وتتراوح ارتفاعات منطقة شيواسور بين (329 – 1186) م فوق مستوى سطح البحر ويحد منطقة شيواسور من الجهتين الشمالية والشمالية الشرقية طية طقطق المحدبة، وطية جمجمال الشمالي من الجهتين الجنوبية الغربية والغربية. تمتد مساحة التكوينات الجيولوجية من الأحدث (رواسب العصر الرباعي) إلى الأقدم (الميوسين الأوسط). وتكمن أهمية البحث في توضيح المناطق المتأثرة بملوثات المياه الجوفية ضمن منطقة الدراسة باستخدام عدة نماذج تعتمد على نظم المعلومات الجغرافية (GIS) لتحديد مدى خطورة وتلوث المياه الجوفية في منطقة الدراسة. هذه العوامل المحسوبة هي عمق المياه (D)، صافي التغذية (R)، نوع الطبقة الحاملة للمياه (A)، نوع التربة (S)، التضاريس (T)، منطقة تأثير نطاق غير مشبع (فوق منسوب الماء الجوفي) (I)، والتوصيلة الهيدروليكية للطبقات الحاملة للمياه (C). يتم التحكم في تدفق المياه الجوفية من خلال حركة المياه إلى المنطقة وعبرها وخارجها. حيث يمثل VI مؤشر الضعف، وتمثل D و R و A و S و T و I و C العوامل المستخدمة في تقييم مدى تعرض المياه الجوفية للتلوث. أظهر تحليل القرار بمعايير متعددة أن درجة التعرض للتلوث في المنطقة تم تقسيمها إلى خمس مناطق، المناطق الشمالية والشمالية الغربية ذات قابلية عالية للتعرض للتلوث، بينما المناطق ذات التعرض القليل للتلوث تقع في وسط منطقة الدراسة وأجزاء في جنوب منطقة الدراسة، بينما توجد مناطق ذات خطورة متوسطة للتعرض للتلوث في باقي المناطق.

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Introduction

Water is the basis of life on Earth. It is considered an essential element for the survival of living organisms because water is involved in forming the cells of various living organisms, including animals and plants. Water is considered an important and influential factor in the economic development of humans through its impact on industrial and agricultural activities. Water also plays an important role in generating electrical energy (Al-Najmawi, 2010). Therefore, groundwater is considered one of the important sources at present due to the lack of surface water, the expansion and development of humankind in agriculture and industry, and population growth. It has become necessary to resort to groundwater, benefit, and exploit it (Al-Sudani,2019). The community of this region depends on groundwater, which is extracted through several dug wells to benefit agriculture, industry, and other uses (Agha,2021). The study area, from a hydrogeological standpoint, is in the aquifer of the district Altun Kopri- in the Koysanjaq system (Jasim and Goff, 2006). In general, the DRASTIC system has two main parts: (1) The first represents the designation of, also called, hydrogeological settings; (2) The second represents an application numerical diagram of the relative ranking of hydrogeological factors. DRASTIC is an abbreviation for hydrological and geological factors (Jesiya 2019). The factors are water depth (D), net recharge (R), aquifer media (A), soil media (S), topography (T), vadose effect zone (I).

Location of the study area

The study area, which represents the Shewasoor basin, is located in the northeastern part of Iraq, about 40 kilometers northeast of the city of Kirkuk, between latitudes (35° 45' 28.9" N - 35° 48' 59.1" N) and longitudes (44° 31' 23.9" E - 44° 37' 07.5" E). The study area covers about 160 km^2, and the elevations of the Shewasoor range between (329 - 1186) m.a.s.l., and is bounded from the north and northeastern sides by the Taqtaq anticline and the northern Chamchamal anticline, and from the southwest and west sides, while the southeast boundary is a surface water divided by the Al-Khassah River sub-basin. (Sultan,2022)

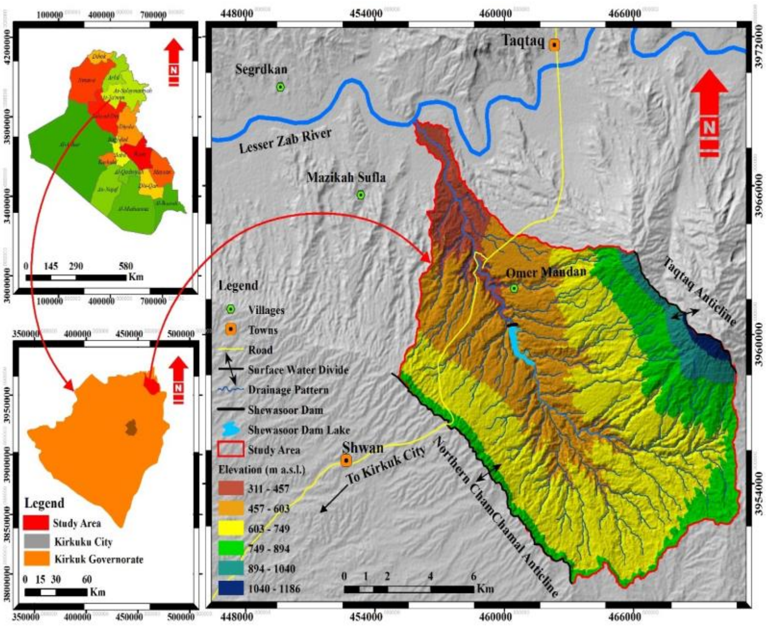

Fig. 1. Location Map of the Study area (Ali, 2018).

Geological and hydrogeological setting

Generally, the study area consists of sedimentary rock units and sediments belonging to the Cenozoic era, and their ages range from the Tertiary (Middle-Upper Miocene) to the Quaternary (Pleistocene-Holocene). Many geological formations (Fatha, Injana, Muqdadiyia, Bai Hassan) and Quaternary sediments crop out within the study area (Sisakian, 1992; Jassim and Goff, 2006) (Fig. 2). Fatha Formation consists of limestone, gypsum, anhydrite, marl, and refined grains. The Injana Formation is a basin formed in central deposits (Al-Naqib, 1960). It consists of brown mudstone, brown and gray siltstone, and brown sandstone. The Muqdadiyia Formation consists of coarse-grained gray sandstone with brown mudstone, gray-brown siltstone, and cobblestone sandstone. The geological age of the formation is Pliocene, and the thickness of the formation is more than 2000 meters (Al-Naqib, 1960). The Quaternary deposits consist of river terraces, polygenic deposits, and sloping deposits. Iraq's climate is generally continental, with cold and rainy winters. The weather is hot and dry in the summer (Jaradat, 2002). Mediterranean climate affects the study area, which has hot, dry summers and cold, humid winters. Due to the lack of rain in recent years, drought periods have become longer than rainy periods (Mohammed, 2017).

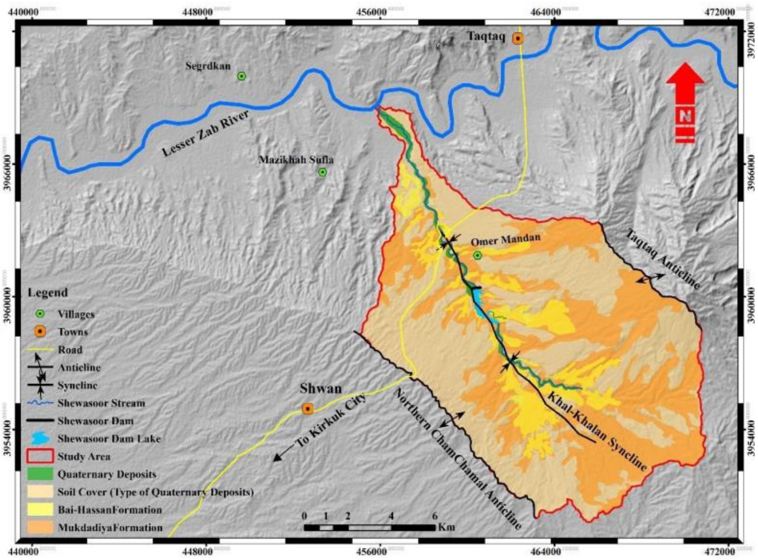

Fig. 2. Geological map of the study area (Ali, 2018).

Materials and Methods

The DRASTIC model, which assesses the vulnerability of aquifers to malware, has been widely used around the world (Aller et al., 1985). It is the most famous and probably the most widely applied vulnerability assessment scheme, developed by the US Environmental Protection USEPA (Aller et al., 1987). In general, the DRASTIC system has two main parts: (1) The first represents the designation of playable units, also called hydrogeological settings; (2) The second represents an application numerical diagram of the relative ranking of hydrogeological factors. The factors are water depth (D), net recharge (R), aquifer media (A), soil media (S), topography (T), vadose effect zone (I), and aquifer conductivity (C), through which it controls the flow of groundwater into, through, and out of the area (Sener, 2015). Recently, the GIS technique has been widely used in the aquifer through vulnerability mapping. The data are collected through the parameters hall and from these sources: previous studies from the Groundwater Department in Kirkuk and the US Geological Survey, arranging the previous studies sequent. Satellite images and the DEM (30 X 30) m resolution are downloaded. The next table (1) shows the depth of water in the wells of the study area, as well as the map shows the location of these wells. Figure 1 shows the location of these wells. The calculated factors are water depth (D), net recharge (R), aquifer media (A), soil media (S), topography (T), vadose effect zone (I), and aquifer conductivity (C). Each parameter is divided into ranges and set differently. Evaluations are ranked on a scale from (1) least likely to be contaminated to (10) most likely to be contaminated (Dara, 2004). Table 3 shows the parameter weight and classification. (Aller et al., 1987) It shows working methods in a simplified way, which explains this method exclusively by collecting data and displaying the results on the final map. Depth data are collected from the field in addition to previous studies. After the data collection, they entered it into the GIS software, through which the map is generated, and these data are displayed in a simple and intuitive map created by the inverse distance weighting (IDW) method. In the researcher's study area, there are also no permanent lakes or rivers to recharge groundwater, except for the precipitation that falls after parts of it are lost, either through evaporation or surface runoff. The precipitation is limited to large valleys such as the Shewasoor Valley and major rivers. Its thickness ranges between (0.5 -3) m. It consists of sand, silt, and clay, part of rock, and conglomerate. The soil in the study area, whose large part is of the loam type, extends from the northwest to the southeast. The map and classification table explain the slope classification in the study area later in this article. This area is part of the tributaries of the Great Zab River, which represents one of the feeding areas. The researcher continues that this data are used to map the spatial distribution of rocks and sediments in the area, which is measured using the inverse distance weighted (IDW) method, five zones in the region that differ in location and the degree of their ability to pass water through them (Goumehei et al., 2016). This study relies on four selected wells covering the entire study area. The data are obtained through previous studies. (Agha, 2021). A radical model based on these seven criteria indicates the layout of this map that shows the locations of vulnerable areas. After processing these criteria, a final map is produced that simulates the sum of these criteria and their impact on each. Groundwater vulnerability maps adopt a radical model based on these seven criteria, indicating the production of this map, which shows the weak locations in the study area. After processing these criteria, a final map is produced that simulates the sum of these criteria and their impact on each other. The following figures show drastic parameters, weighting, and rating of the aquifer media (Figs. 3, 4, 5, 6, 7, 8, 9, 10, and 11)

Table 1: Groundwater level (Agha, 2021).

Well no.	Longitude	Latitude	SWL
W1	44° 35' 55"	35˚ 45˙ 50"	586.9
W2	44° 33' 04"	35˚ 45˙ 58"	590.45
W3	44° 33' 36"	35˚ 46˙ 53"	476.8
W4	44° 33' 47"	35˚ 45˙ 51"	547.95
W5	44° 31' 54"	35˚ 46˙ 45"	549.4
W6	44° 31' 23"	35˚ 46˙ 42"	550.5
W7	44° 31' 41"	35˚ 47˙ 08"	535.3
W8	44° 33' 05"	35˚ 47˙ 51"	435.45
W9	44° 34' 31"	35˚ 47˙ 43"	561.45
W10	44° 35' 57"	35˚ 47˙ 56"	589.85
W11	44° 36' 27"	35˚ 47˙ 12"	657
W12	44° 37' 05"	35˚ 47˙ 13"	687.35
W13	44° 36' 27"	35˚ 45˙ 45"	604
W14	44° 39' 40"	35˚ 45˙ 54"	871.75
W15	44° 35' 41"	35˚ 45˙ 39"	562.7
W16	44° 36' 08"	35˚ 45˙ 39"	624.35
W17	44° 37' 07"	35˚ 45˙ 52"	642
W18	44° 33' 48"	35˚ 48˙ 56"	486.7
W19	44° 33' 31"	35˚ 48˙ 55"	473.6
W20	44° 32' 56"	35˚ 48˙ 59˙˙	448.75

Figure 3 represents the depths of groundwater in the study area, which are distributed across parts of the region, and through it, some hydrogeological characteristics are identified in terms of water quality and quantity, and their effect on pollutants. Through well water in the area, the concentrations of some compounds and chemical elements can be determined and compared to the results of the study to confirm them.

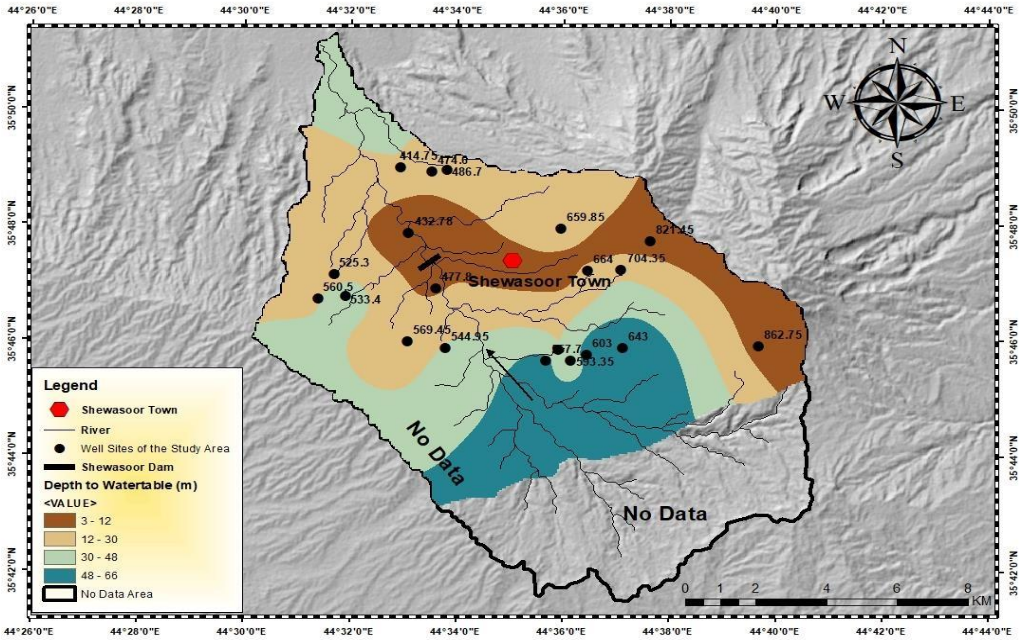

Fig. 3. Depths to groundwater (Agha, 2021).

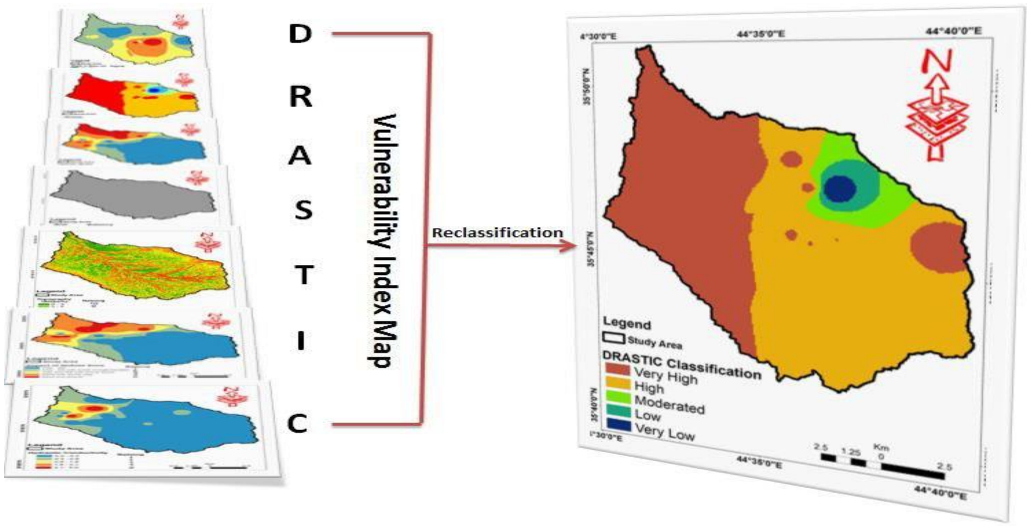

Fig. 4. Evaluation layer of the seven parameters and groundwater vulnerability.

Results and discussion

A drastic map is created through the depths of groundwater in wells distributed in the study area. Groundwater depths range from (450 - 870) m (a.s.l.) as shown in Table 1. The data have been mapped. The recharge map of the study area indicates that water recharge moves from the northwest and northeast of the sub-basin, similar to the topography of the study area (Fig. 4). Table 2, Figures 5, 6, 7, 8, 9, 10, 11, respectively. Adopting a radical model based on these seven criteria indicates the production of this map, which shows the weak locations in the study area. After processing these criteria, a final map is produced that simulates the sum of these criteria and their impact on each other. Figure 12 displays a groundwater vulnerability map.

Table 2: Hydraulic conductivity(K) values of the four wells in the study (Agha, 2021).

Pumping Test	
Well	K(m/day)
W8	5.1
W5	4.7
W12	0.67
W15	0.7

Table 3: DRASTIC parameter's weight and rating (Aller et al., 1987).

DRASTIC Parameter	Rating	DRASTIC Parameter	Rating
Depth to Water (m) (weight =5)		Soil (weight = 2)	
Less than 2.5-18.4	7	Loam	5
18.4-28.5	3	Topography (Slope %) (Weight =1)	
28.5-36.2	2	0-3	10
36.2-45.1	1	3-5	9
45.1-63.9	1	5-9	5
Recharge (mm) (Weight= 4)		9-17	3
0.00- 42.02	1	17-38	1
42.02 – 172.77	3	Impact vadose zone (weigh=5	
172.77 – 382.90	8	Clay, silt	1
382.90 – 691.09	10	Clay, silt with some conglomerates	2
691.09 -1,190.73	10	Clay, silt with some sand	3
Aquifer media (weight= 3)		Sand with some clay	4
Clay ,silt	2	Sand and Gravel	6
Clay ,silt with some Conglomerates	3	Hydraulic conductivity (weight = 3)	
Clay and Silt with Some Sand	4	0.0-0.3	1
Sand with some clay	6	0.3-0.9	1
Clay and Gravel	8	0.9-1.8	1
		1.8-3.1	1
		3.1-5.0	2

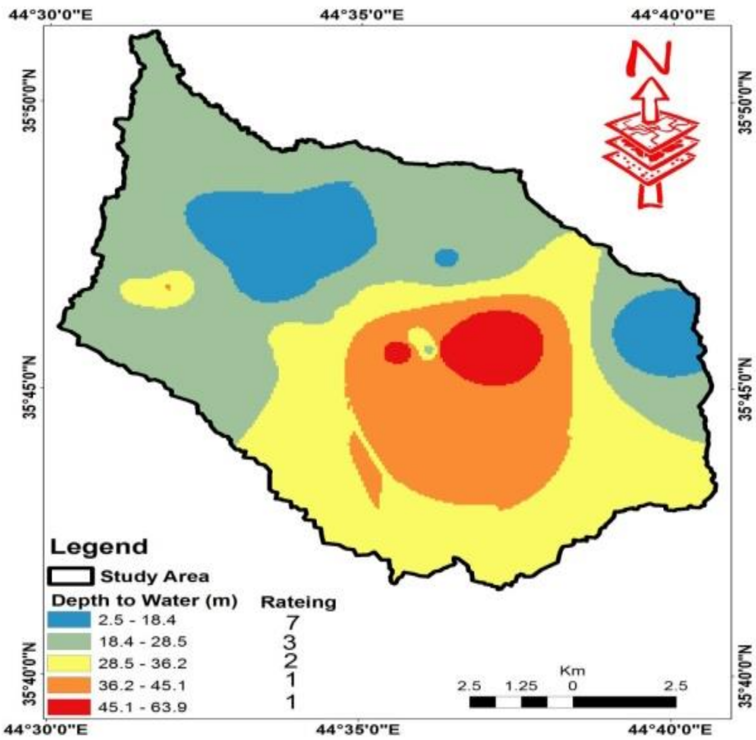

Fig. 5. Groundwater depth map of the study area

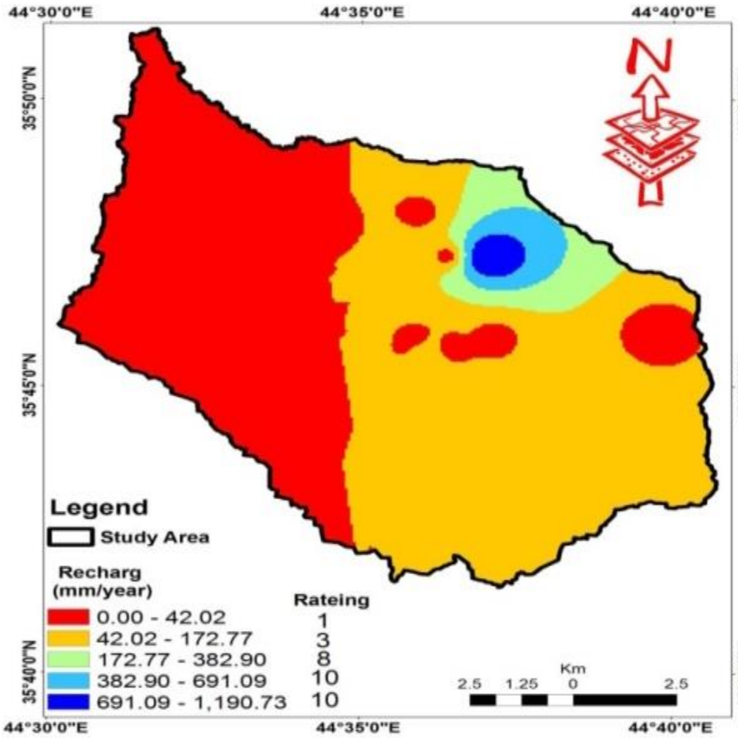

Fig. 6. The groundwater recharge of the study area

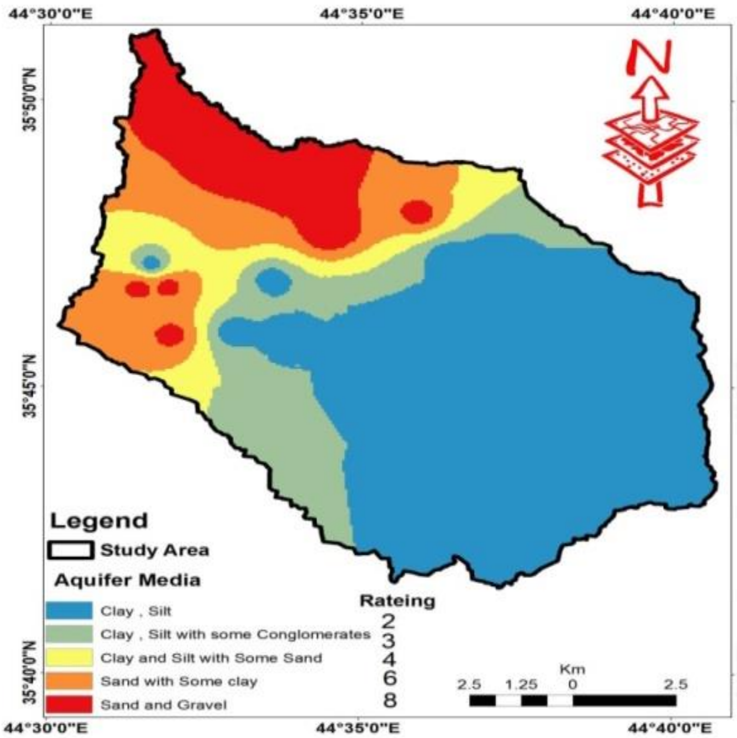

Fig. 7. Aquifer media of the study area

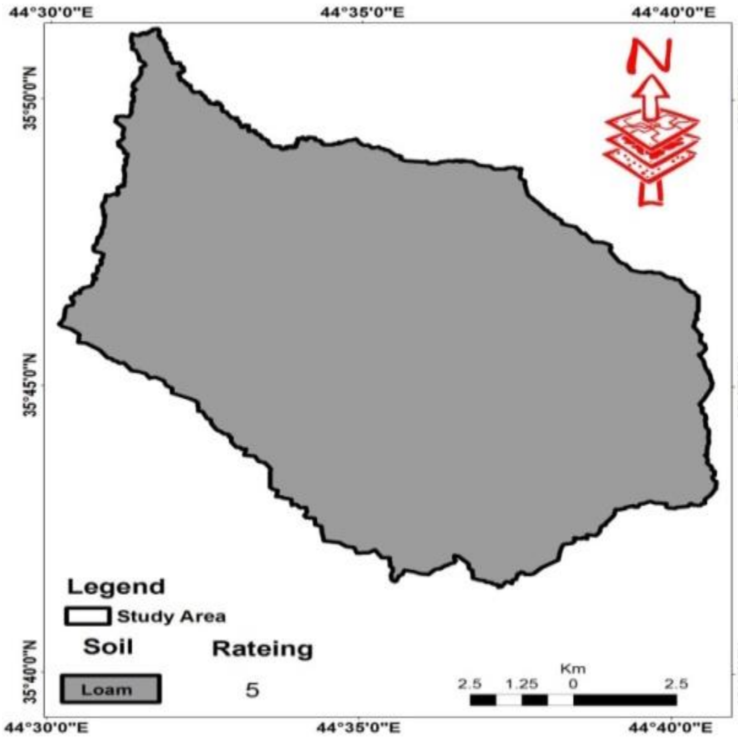

Fig. 8. Soil map classification of the study area, modified on HWSD version 1.2

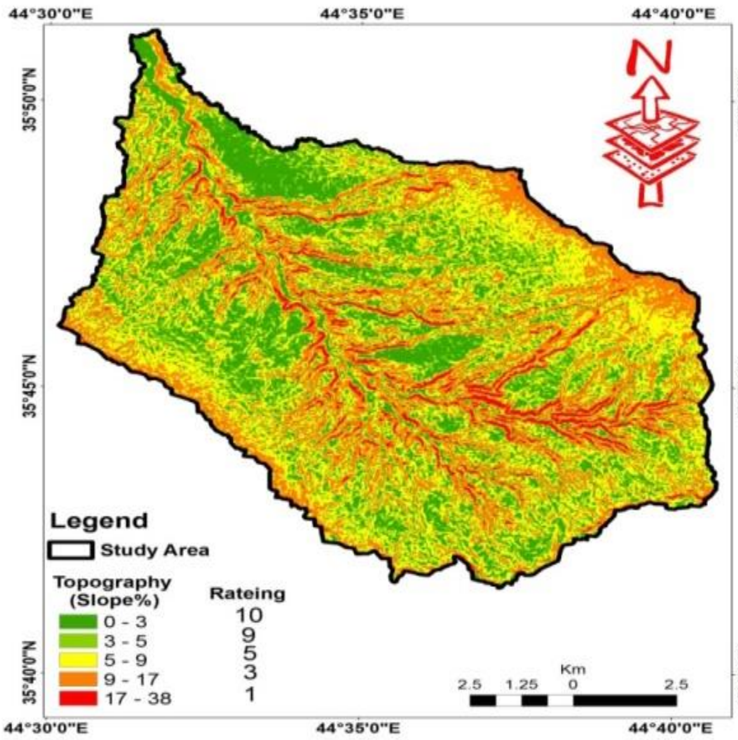

Fig. 9. The slope map extracted from the DEM 30m resolution.

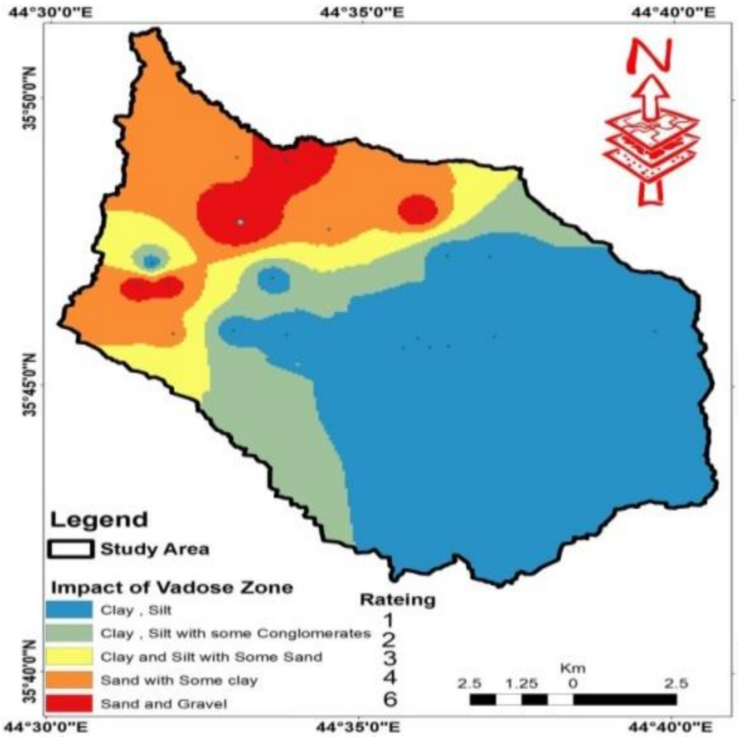

Fig. 10. The Impact of the vadose zone of the study area.

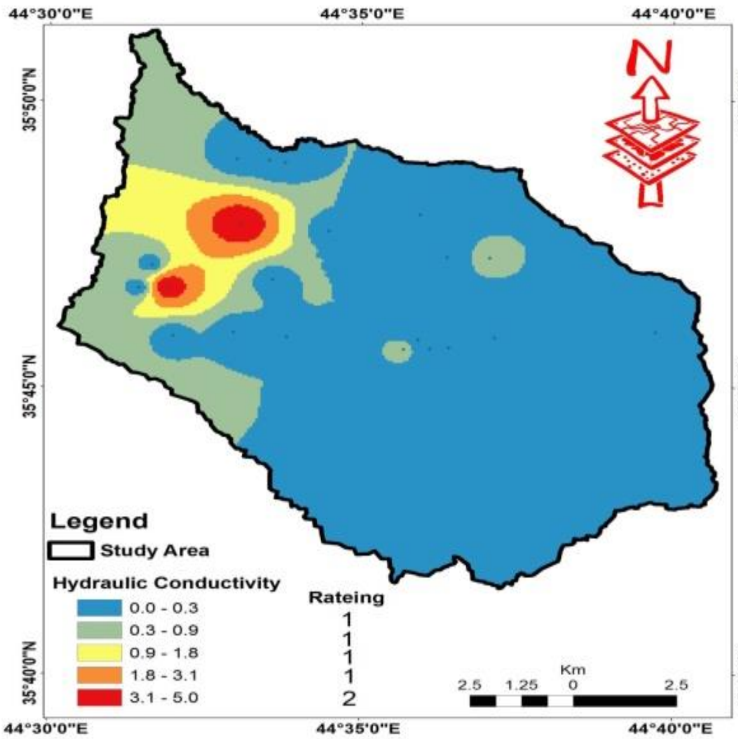

Fig. 11. Hydraulic conductivity map of the study area.

Vulnerability Map

Adopting a radical model based on these seven criteria indicates the production of this map, which shows us the weak locations in the study area. After processing these criteria, a final map is produced that simulates the sum of these criteria and their impact on each other. Groundwater vulnerability maps represent valuable groundwater, an administrative tool that is at the regional level. That is produced for many purposes, such as helping us to select engineering safeguards and provide a measure of probability of pollution, helping us to ensure that protection plans are not unnecessarily restrictive of economic activity, and enabling significant developments of excellent importance and contaminant potential (Warren et al., 1998).

Validation

This must be done to validate the results obtained through the three models. In order to verify this, the majority of researchers who did this in this field I studied this matter. This is through the widespread use of fertilizers for agricultural purposes, as well as improper disposal of wastewater leads to nitrate contamination of groundwater (Jhariya et al., 2012; Guler et al., 2013; Rajasuriar et al., 2013; Hamza et al., 2014; Rodriguezgaliano et al., 2014; Viola et al., 2015). In different ways, all of which depend on its basic principle, which is to compare the pixel values in the maps with the results and obtain the correlation coefficient with various factors. NO_3 concentrations are obtained through well water samples and then analyzed in the Kirkuk Environment Directorate, obtaining results that differ from one well to another. The values of nitrate concentrations in the study area depend on the industrial, human, and natural activities in the area, so there are different values of concentrations depending on the activities. The highest value is in sample (7), which is about 82, because the area is residential and there is a lot of animal husbandry and agricultural activities. As for sample (1), it represents the lowest value (22) because the area is mountainous and there are no industrial activities.

Table 4: NO_3 concentrations in the study area.

Parameters in mg/l	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
NO_3	22	31	58	46	20	75	82	24

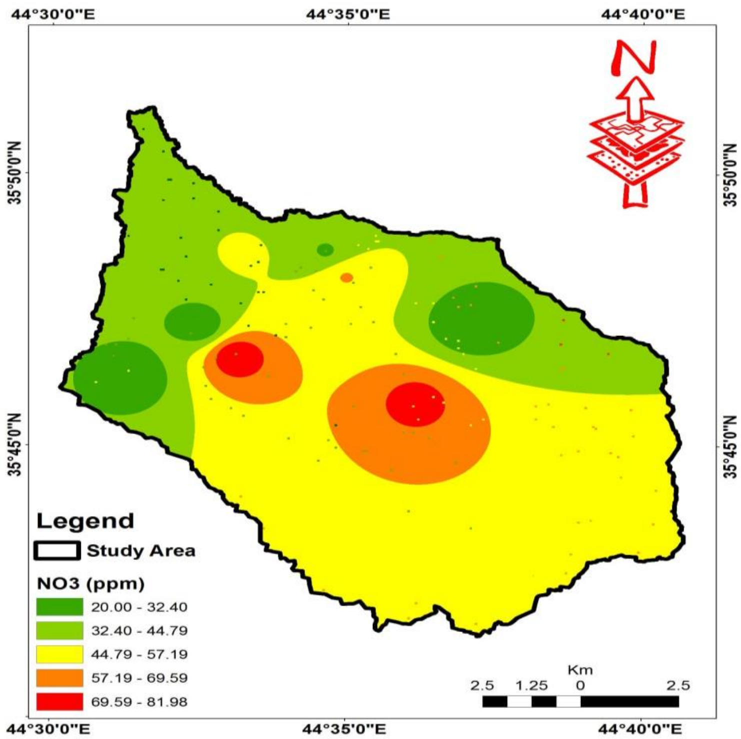

Fig. 11. Validation of the study area.

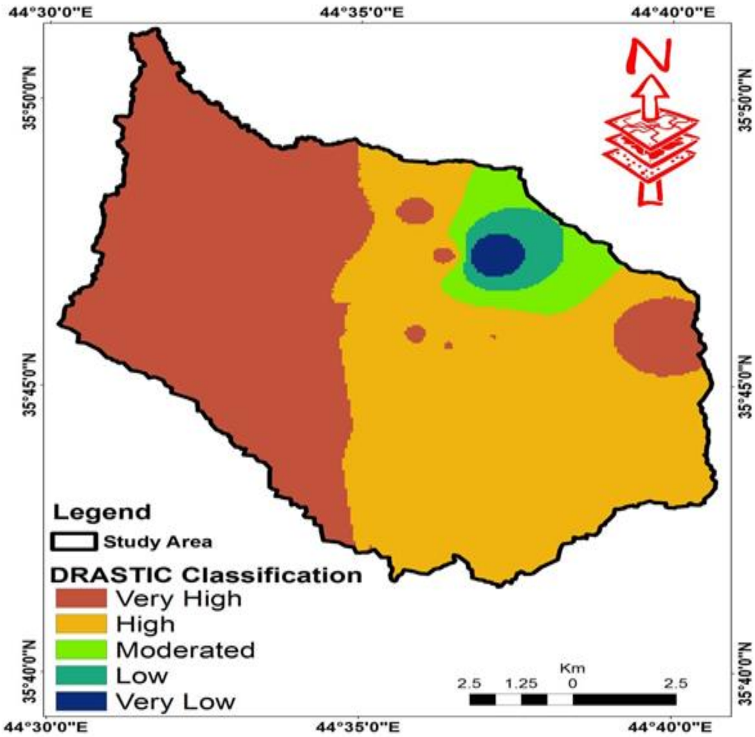

Fig. 12. DRASTIC map of the study area.

Conclusion

Based on the previous results, it is found that the study area consists of 5 vulnerable areas distributed over the study area, which range according to the degree of vulnerability gradually from the most vulnerable to the least.

The degree of vulnerability depends on several specific factors of the region that affect each other. All results reached through the models used show great convergence, which confirms the accuracy of the results. The study area is affected by vulnerability in the southern regions as well as in the northern regions. According to the maps, the reason for this depends on several factors, including porosity, permeability, which allow water to pass through the geological formations until it settles from the soil to the vadose zone and aqueous media.

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