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Assessment of Groundwater Vulnerability Using Lulc Map and DRASTIC Technique in Bahr AL-Najaf Area, Middle of Iraq

Ali H. Al-Aboodi
Zaid N. Hashim*

Civil Engineering Dept., College of Engineering, University of Basrah. Iraq

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ABSTRACT

Groundwater is the greatest significant source of water in the Bahr Al-Najaf area. In this research the DRASTIC technique has been utilized, to produce a map of ground water vulnerability for the area. Because of the relation between LULC (Land Use and Land Cover) and groundwater pollution, the LULC map was applied with the standard DRASTIC technique to confirm accuracy of vulnerability for pollution. A LULC map is extracted from Enhanced Thematic Mapper (TM) satellite imagery utilizing several methods in GIS. The LULC map shows that three portions of LULC can be recognized (Agricultural land, Wet land and Barren land). The LULC map was weighted and rated then changed to LULC index map. That index map is a supplementary factor that was combined to the standard DRASTIC technique to modify DRASTIC vulnerability in study area. The final vulnerability was obtained by the DRASTIC technique that varies from (70 to 140). The LULC index map as a modified DRASTIC with ranging of (95-175). The modified LULC of DRASTIC technique has a higher correlation (Pearson's factor) 0.87 per concentration of nitrate values and is suggested as the best suitable technique to be utilized for the area of study.

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تقدير حساسية المياه الجوفية باستخدام خرائط LULC وتقنية DRASTIC في منطقة بحر النجف وسط العراق

أ.م.د. علي حسن العبودي / القسم المدني كلية الهندسة جامعة البصرة
م.م. زيد نوري هاشم / طالب دكتوراه في القسم المدني كلية الهندسة جامعة البصرة

الخلاصــة

تعتبر المياه الجوفية اكبر مصدر للمياه في منطقة بحر النجف. في هذا البحث تم تطبيق تقنية DRASTIC لرسم خارطة لحساسية المياه الجوفية اتجاه الملوثات في المنطقة. وبسبب العلاقة بين (استخدام الاراضي والغطاء النباتي) مع تلوث المياه الجوفية ، تم اضافته كعامل مهم لتقنية DRASTIC ، تم استخراج خارطة LULC من صور الاقمار الصناعية باستخدام تقنيات مختلفة في نظم المعلومات الجغرافية. توضح خارطة LULC وجود ثلاث فئات من الاراضي في منطقة الدراسة (الاراضي الزراعية ،الاراضي الرطبة والاراضي القاحلة). تم اعطاء وزن و رتبة للخارطة ودمجها مع تقنية DRASTIC كمعلمة اضافية لتحسين النتائج . تراوحت قيم الحساسية باستخدام التقنية القياسية بين (70-140) بينما التعديل المستند على اضافة عامل LULC تراوح بين (95-175). حيث معامل الارتباط مع قيم تركيز النترات في منطقة الدراسة كان 0.87.

الكلمات الدالة: بحر النجف ، المياه الجوفية، حساسية التلوث، استخدام الاراضي، تلوث.

* Corresponding Author: Zaid N. Hashim, E-mail: mzaid.nori.hashim@gmail.com

1.Introduction

In dry regions of the world, groundwater is an invaluable provenance for water. If groundwater is contaminated, may cause an environmental degradation and health risk. Groundwater can be exposed for a wide range of activities or human actions that may lead to the leaching of pesticides and fertilizers, disposal of sewage, and waste materials. Prohibition of groundwater pollution is the best way to effective and efficient environmental administration, as the groundwater treatment is slow and costly. In order to conserve groundwater resources and areas exposed to pollution, as a result of human activities, must be identified, which can be best achieved by estimating the vulnerability of groundwater [1]. Bahr Al-Najaf area considers as one of dry regions, and it is part from western desert which lack of surface water except in the north east section of the studied area. Therefore, the area depends on groundwater (which consider the main source of water) to use it in different activities. This study will be an important step for assessing exposure to pollution, and results will be merged with existing data to enable stakeholders and decision-makers to take the right decision regarding pollution prevention.

2.Study area

Bahr Al-Najaf area is located in the south western part of Najaf City between the latitude 31º 27' 57" & 32º 08' 29" N and longitudes 43º 47' 02" to 44º 32' 08" E Fig.1. The whole area of study basin is about (2500) km_2. It is bordered to the north by Karbala, the western edge of sedimentary plain (west of the Euphrates River) on the north-eastern side, Al-Muthanna Province on the eastern and south-east side, Anbar Province on the western and the south-west, and its extends to the Al-Shabakah township. The climate of study area is arid with the average annual precipitation (105.3) mm. Study area contains a lake with approximately area (48) km^2.

3.Drastic technique

Such paper requires a prior research which could serves as a solid foundation about urban problems in the city coming in question

DRASTIC technique applied in a GIS environment has been utilized to estimate the vulnerability of the study region. This technique was depended by Environmental Protection Agency in the United State [2]. Seven parameters are utilized in the technique to appear the idea of the hydrogeological setting that includes the major geologic and hydrologic agents controlling the groundwater movement through an area. Each parameter has a specific rate and weight value in order so that the vulnerability index can be evaluated. Each parameter has a rating on a scale of 1 to 10. This rating is then scaled by a weighting factor from 1 to 5; according to their relative susceptibility to pollutants. The DRASTIC index is based on the linear integration of all factors as explained by the following equation:

$$DI = DW.Dr + RW.Rr + AW.Ar + SW.Sr + TW.Tr + IW.Ir + CW.Cr \quad (1)$$

where: DI is the DRASTIC Index, (D, R, A, S, T, I and C) are the depth to water table, recharge, aquifer media, soil media, topography, vadose zone, and conductivity, w is the weight factors and r is the rate of the factors.

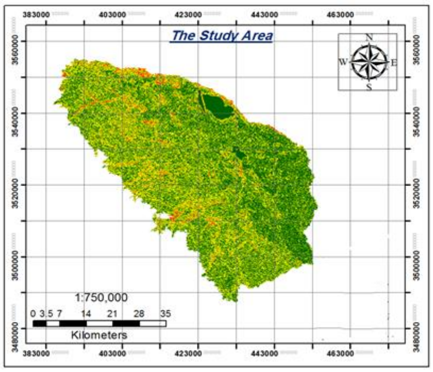

Fig. 1. Location of study area

4.Material and source of data

The required data to use in mapping groundwater vulnerability are presented in Table 1. The availability of input data is the corner stone of how to choose the appropriate technique as the absence or insufficient input information into the technique is applied difficult [3]. In the study area, information which are essential for calculation of DRASTIC ratings are acquired from wells logs, pumping test results, geological maps and hydro-geologic reports of MWR (Ministry of Water Resource) archives of groundwater directorate in Al-Najaf government, Najaf meteorological station, and soil survey). Data in the present study are of two kinds: spatial information and non-spatial information. Spatial information was taken from maps, satellite imageries, etc. They could be directly digitized into GIS environment. Non-spatial information was the tabular information taken from tables, points, lists, etc. and this data could be stored in the database.

Table 1
Parameters and their Data Sources of DRASTIC Technique

No.	Data Type	Data Source
1	Depth to Groundwater	Wells logs of MWR Archives of Groundwater Directorate in Al-Najaf Government.
2	Net Recharge	Najaf Meteorological Station and CMB technique
3	Aquifer Media	Geological Maps and Hydro-geologic reports of MWR Archives of Groundwater Directorate in Al-Najaf Government.
4	Soil Media	Soil Survey
5	Topography	DEM with 30 m pixel size Maps
6	Impact of Vadose Zone	Geologic reports of MWR Archives of Groundwater Directorate in Al-Najaf Government.
7	Hydraulic Conductivity	Pumping Test Results of MWR Archives of Groundwater Directorate in Al-Najaf Government.

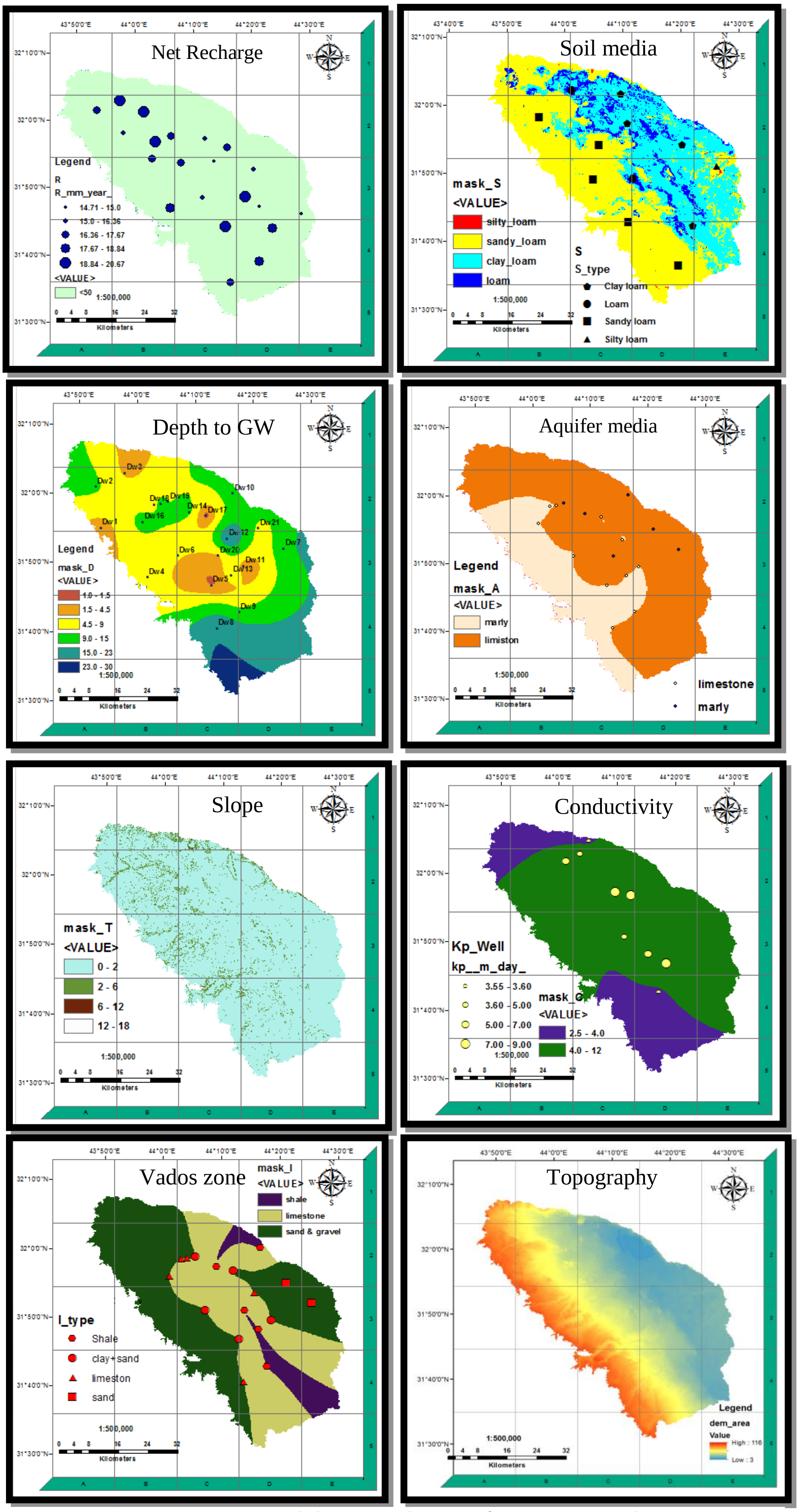

Fig. 2. Parameters and their Distribution of DRASTIC Technique

The groundwater depth differs from 1 to more than 21m. The average annual recharge computed using chloride mass balance is equaled to 19.27 mm/year. Four different soil media was founded in the area based on soil survey, soil media was classified into (clay loam, silty loam, loam, and sandy loam). In the study area vadose zone was classified into (shale, limestone, sand and clay). The hydraulic conductivity varies between 2.5- 9 m/day. Table 2 shows the summary of parameters, range, rating, percentage, and relative weight for parameters used. Fig. 2 shows parameters and their distribution of DRASTIC Technique.

5.Effect of land use and land cover parameter

As observing definitive signals about the influence of land use on the soil and groundwater quality, the parameter “land use” appeared an important bearing on the status of aquifer vulnerability along with other parameters proposed earlier. "The effect of human and natural process as a fundamental environmental erratic can be identified from land use/ land cover map" [4]. "Land use / land cover is normally marked by a short term of (LULC). Land cover (LC) defines the cover of the earth surface that naturally occurs such as bare land, forest, grassland, vegetation, snow and water. Land uses (LU) illustrate the modification of land cover due to human processes or man-made modification" [5]. As mentioned by Mas [6], "remotely sensed satellite images are the most widespread source of data onto mapping LULC, because of its availability and repetitive data acquisition, improved quality of multi-spatial and multi-temporal remote sensing data at different (spatial, spectral, and digital) format suitable for computer processing and new analytical techniques. Remote sensing technique and field survey can be used to supervise LULC". LULC map prepared from image of land sat (8) Thematic Mapper (TM). Images consist of nine spectral bands of cell size (30x30m). The Operational Land Imager (OLI) spectral band of gray scale was used. Scene date back to (11-02-2017). Fig.3 illustrates the TM land sat image of the study area for extracted LULC map.

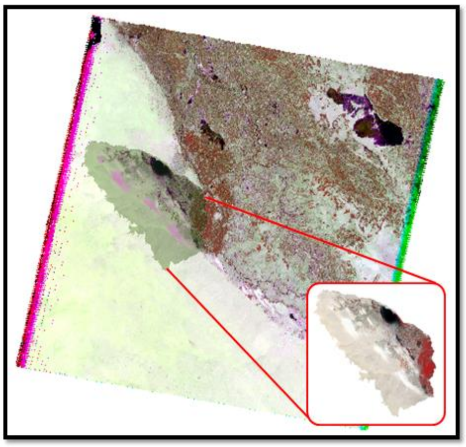

Fig. 3. The TM landsat image of the study basin.

6.LULC Classification processes

"The most important steps in LULC preparation are classification processes because it gives you the degree of accuracy. There are several proposed methods of LULC classification in the world, but the USGS (United States Geological Survey) system that developed by Anderson" [7], was applied in this study. The factors that support the selection of this method are the availability of remote sensing data and it’s suitability for application to the study basin. "The USGS system of classification consists of four levels, from I to IV; the difference between them depends on the resolution of remote sensing data used for classification" [8]. Arc Map 10.3 software was used to prepare the digital image classification of the study basin. Supervise classification for level I of USGS was done with band combination RGB / 753 for image that covered the basins. The analyses were also supported by field work. Many points were taken with GPS and several photos were taken as well to check the accuracy and validity of the final map of classification.

7.LULC Rating and index map

LULC maps were rated and weighted as supplemental factor and added to DRASTIC technique. The LULC rating map was rated based on the values given in Table 3. Moreover, it was changed to a raster grid and multiplied by the weight of the factors (Lw=5) to institute LULC index map.

Table 3 Rate and Weight for LULC Classes [9]

Level I Classes	Rating
Built-up Land	**10**
Agricultural Land	**8**
Wetland	**7**
Barren Land	**5**
Weight=5	

The LULC map of the study basin is shown in Fig. 4.The map demonstrates that only three classes can be recognized as explained on Table 2 with percent and the area of land covering in each. The map illustrates that barren land covered most of the studied basin land with an area of (1577.5) km^2 or (63.1%) of total studied area. In addition, agriculture lands cover an area of (560) km^2 or (22.4%) occupy mostly the central and northeastern parts of studied basin. The remaining classes of (water and wet land) were covering an area of 362.5 Km^2 or (14.5%) of the whole studied area respectively.

Fig. 5 illustrates rating values of LULC which ranging from 5 to 8. "Urban areas and agricultural land were assigned a probability rating of 8, because chemical contaminant concentrations such as nitrogen in groundwater from human activities in urban and agriculture areas were higher than in all other land use areas. Vegetation and barren land areas were combined and assigned to probability rating of 5, as they contain low nitrogen of nearly similar concentrations. Water body and wet land area was rated 7 as water act as a good transporter for contaminant" [10].

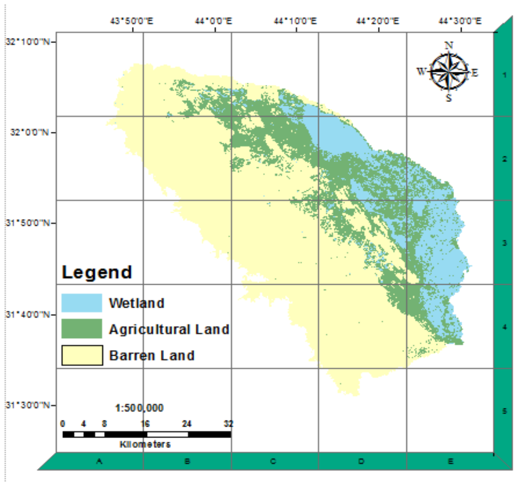

Fig. 4. LULC map of the study area.

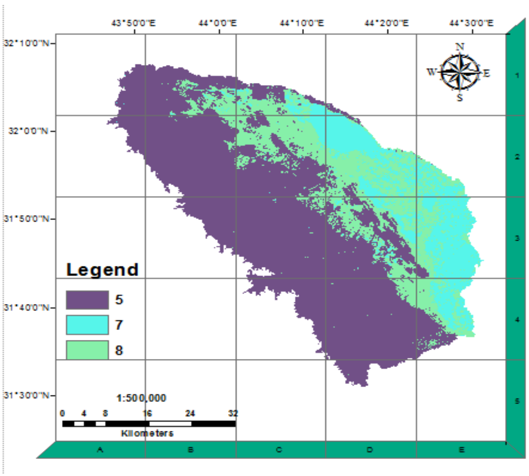

Fig. 5. Rating values of LULC map.

8.Modify DRASTIC Technique using LULC index map

To modify the original DRASTIC indexes map, it was results demonstrate the effect of specific land uses type on the vulnerability system.

$$MD(i) = DI + (LULC\ Index) \quad (2)$$

Where: MDi: is the modified DRASTIC technique, DI: is the standard DRASTIC index, and The LULC index (ratings × weights).

9.Results and discussion

The definitive vulnerability was acquired by implementation the technique in the environment of GIS by utilizing the seven data layers. The DRASTIC scores acquired from the technique ranged from 70 to 140. The mean value of DRASTIC index for all study area is 109. Fig. 6 delineates spatial vulnerability of groundwater in the study area. The map marks out areas with varying sensitivity (very low, low, and moderate). The demarcated area is relative indication of susceptibility of groundwater to pollution from diffuse sources. About 65.6% of study area is classified under low vulnerability; the remaining 28.16% and 6.24% are under very low and moderate vulnerability respectively. It seems that southern part, the surrounding of the lake east of study area, and small strips of middle area are very low vulnerable areas. The majority of study areas are of low vulnerability. The remaining area is moderately vulnerable. Fig. 7 demonstrates the modified DRASTIC index map based on LULC index map with ranging of (95-175). The range of index values was divided into four classes including very low to high vulnerability classes Table 4.

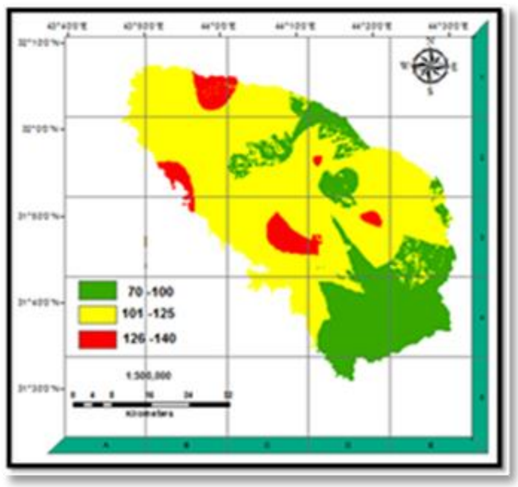

Fig. 6. DRASTIC technique

The modified vulnerability map shows that about (65.3%) of the study basin has moderate vulnerability to contamination with index values ranging between 125 to 150. Low vulnerability measured as a second effective class of the studied area with (18.9%). while, high and very low areas comprise (14.7%), and (1.1%) respectively.

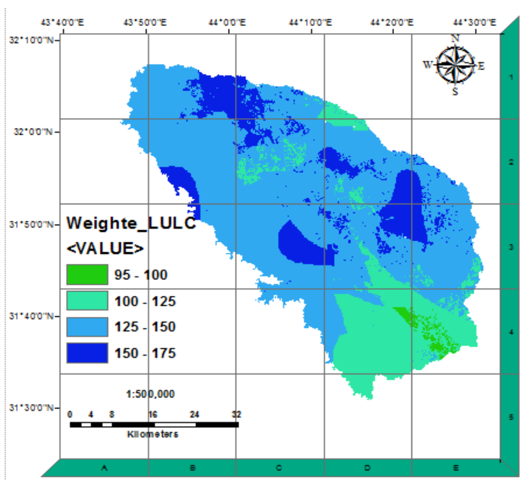

Fig. 7. Modified DRASTIC index map

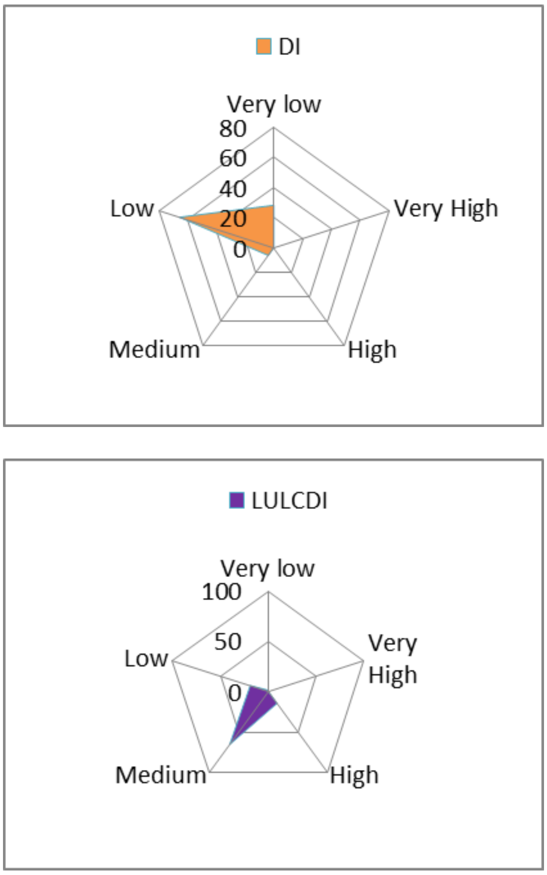

Fig. 8. Grid diagram for the vulnerability of study area.

In terms of land use class, agriculture and wetlands occupies a large area of studied basin with total area of 922.5 km_2 or 36.9% of the whole studied area. The effect of agriculture activity can be clearly noticed on the modified DRASTIC technique compared to standard one, as the agriculture land plays a significant role to convert the very low, and low vulnerability zones in the central and north eastern parts to moderate, and high vulnerability zones respectively. Fig. 8 clearly illustrates the dominance and tendency of the classes to be distributed in each model. Table 5 shows the minimum, maximum and mean values of vulnerability using different techniques.

Table 5 The Statistical Summary of the vulnerability values of Different Techniques.

	DI	LULC
Min.	70	95
Max.	140	175
Mean	109.9	139
SD	14.6	14.88
CV	13	11

"Each vulnerability map should be validated after its construction in order to estimate the validity of the theoretical sympathetic of current hydrogeological conditions" [11]. It was envisaged that comparison of the groundwater vulnerability to the actual groundwater quality status, would help validate the vulnerability approach. For this purpose, correlation between standard, LULC modified DRASTIC map and the nitrate concentration was attempted. Nitrate as a contamination gauge can be utilized to identify the groundwater quality development in terms of quality changing. 14 and 21 wells are used for groundwater sampling of nitrate test at wet and dry season respectively. The specimens are tested at September 2017 for arid period and May 2018 for wet period. The results of the analyses of the seasonal distribution of nitrate showed that during wet season, nitrate level is higher relatively to the dry season Fig. 9.

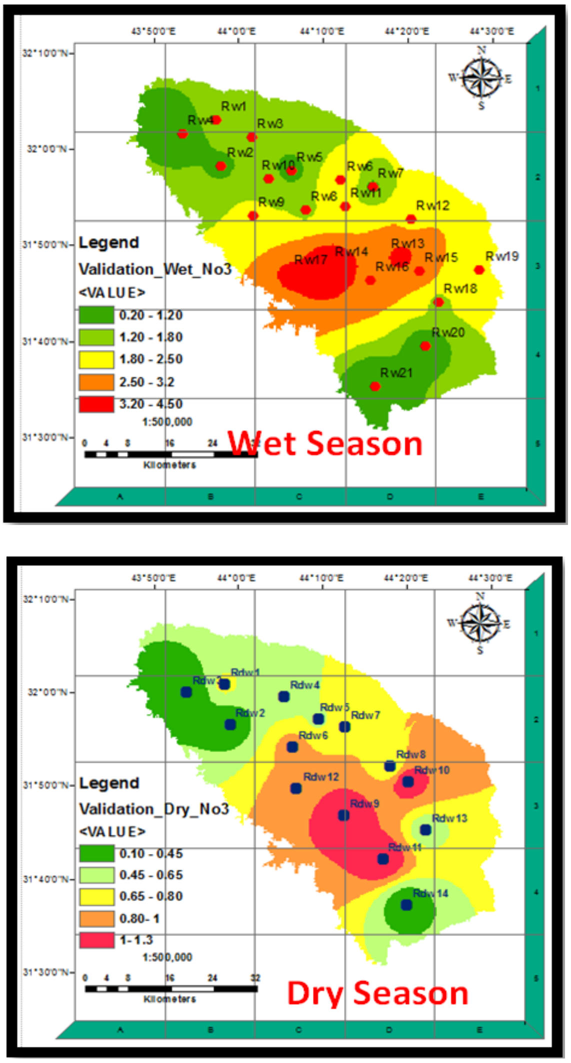

Fig. 9. The Nitrate concentration values (wet & dray seasons)

Pearson's correlation factor was considered statistically among the standard and improved DRASTIC indices values and nitrate concentration values for dry season. The results showed the Pearson's correlation factor of standard DRASTIC is equaled to 0.36 while modified LULC of DRASTIC technique has a higher correlation factor 0.87 and is candidate as the best suitable technique for representing the vulnerability of the studied area. Three bands were selected from study areas for verification of vulnerability maps as shown in Fig. 10. High and low vulnerability zones (Bands A, B, and C) show also similarity to actual nitrate concentrations, this indicates that these methods characterized by quite good accuracy. The study also demonstrates the efficiency of GIS for assessing of groundwater quality.

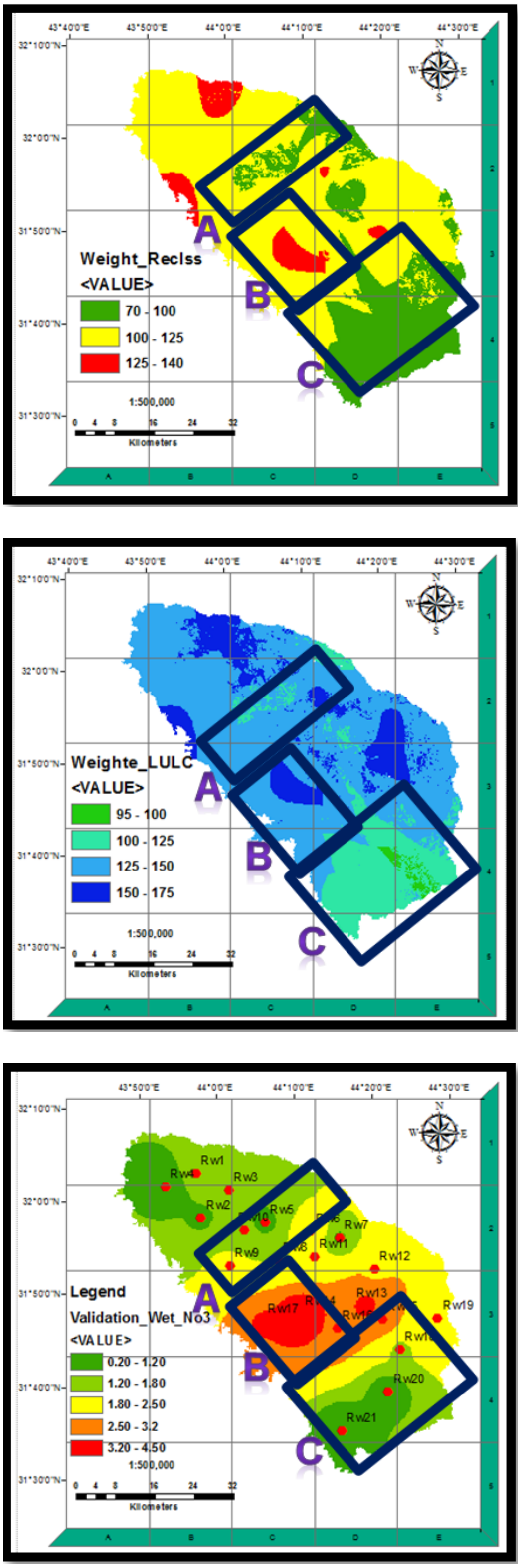

Fig. 10. Visual verification of the vulnerability maps of the study area

The other approach which used in this research to test the validity of vulnerability maps by examines similarity of a spatial type of variability of these maps over an imaginary line passing through points representing the wells where the amount of nitrate was tested Fig. 11. The results show a better match for the patterns of the modified rate and LULC of DRASTIC index maps.

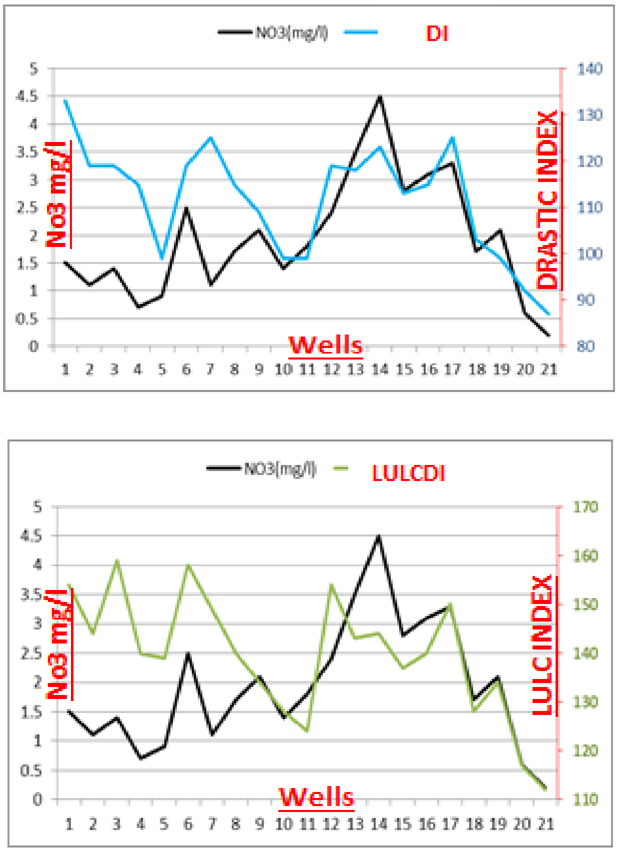

Fig. 11. Spatial variability of nitrate with vulnerability maps through study area.

10.Conclusion

The final vulnerability was obtained by the DRASTIC technique that varies from (70 to 140). The mean value of DRASTIC index for all study area is 109. About (65.6%) of the study area is classified under low vulnerability; the remaining (28.16%) and (6.24%) are under very low and moderate vulnerability respectively. The modified DRASTIC based on LULC index maps per ranging of (95-175). Index range values were distributed into four periods inclusive very low to high vulnerability periods. About (65.3%) of the study basin has moderate vulnerability to contamination. Low vulnerability measured as a second effective class of the studied area with (18.9%). while, high, and very low areas comprise (14.7%), and (1.1%) respectively. The modified LULC of DRASTIC technique has a higher Pearson's correlation factor 0.87 with nitrate concentration values and it is recommended as the most appropriate technique to be applied for the study area.

11.Acknowledgement

The authors would like to thank technical cadres in the laboratories of both the Faculty of Engineering University of Kufa and the Department of Environment in the province of Najaf to provide technical support.

Table 2 Summary of Used Parameters.

No.	Parameters	Units	Range	Rating	Percentage	Relative Weight
1	Depth to Groundwater	m	0 - 1.5	2	4	5
			1.5 - 4.5	3	16	
			4.5 - 9	5	27	
			9.0- 15	7	42	
			15 -23	9	11	
2	Net Recharge	mm/year	< 50	1	100	4
3	Aquifer Media	-	shale	6	71	3
			limestone	6	29	
4	Soil	-	Loam-Clay	3	39	2
			Loam-Silt	4	1	
			Loam	5	8	
			loam-Sand	6	52	
5	Topography	%	0 - 2	10	90	1
			2 - 6.0	9	10	
6	Impact of Vadose Zone	-	Shale	3	8	5
			Limestone	6	41	
			Sand	8	51	
7	Hydraulic **C**onductivity	m/day	Less than 4	1	25	3
			4.0 - 12.0	2	75	

Table 4 Standard and Modified DRASTIC Index Value Based on LULC at Study Area.

Vulnerability class	Standard DRASTIC		Modified DRASTIC	
	Index value	Area (%)	Index value	Area (%)
Very low	70-100	28.16	95-100	1.1
Low	100-125	65.6	100-125	18.9
Moderate	125-140	6.24	125-150	65.3
High	-	-	150-175	14.7

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