E3 Journal of Environmental Research and Management Vol. 5(9). pp. 0169-0179, September, 2014
Available online http://www.e3journals.org
ISSN 2141-7466 © E3 Journals 2014

Full Length Research Paper

Assessment of the vulnerability of an aquifer by DRASTIC and SYNTACS methods: Aquifer of Bazer – Geult Zerga area (northeast Algeria).

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Accepted 30 August, 2014

Prevention against the pollution of ground water has become nearly three decades a major concern for specialists in the field of water. Several methods have been to this effect adopted since 1987. This study is an approach to aid in the protection and prevention of pollution of groundwater in the shallow aquifer of the Bazer-Guelt Zerga basin and that at the mapping of vulnerable areas to pollution. It was conducted in the butts to identify areas of high risk of contamination, regardless of the type and nature of the pollutant and to determine how to better assess vulnerability. Application of DRASTIC and SINTACS this method allowed evaluation. A comparative study based on Kendall test and statistical analysis different classes of vulnerability has been developed. DRASTIC method is represented by three concentration low, medium and high class with the domination of the strong class 72%. SINTACS method has also led to a vulnerability divided between three classes low, medium and high with the domination of the strong class 75.6%. Comparative study showed that the two methods are statistically identical with concordant results. Their application in the field is warranted. Analysis of surfaces by two classes of methods (DRASTIC and SINTACS) revealed that 86% of the map of area have identical index.

Keywords: Vulnerability, DRASTIC, SINTACS, Bazer-Guelt Zerga , Algeria

INTRODUCTION

Groundwater is an important resource exploited for human consumption and for use in agricultural and industrial areas. These waters are often treated by contamination by pollutants of different kinds: biological, chemical or physical. Prevention against groundwater pollution is an important step to which scientists agree more effort, particularly by studying the vulnerability of groundwater.

Vulnerability is a construct designed to help planners to protect aquifers as an economic resource. There has not yet been a general agreement on that the strict definition of vulnerability should be, and the term vulnerability has come to mean different thing in different contexts .If refers generally to the sensitivity of groundwater to contamination .This concept is based on the assumption that the physical environment may provide somme degree of protection to groundwater against human activities (Boughriba et al.,)

The concept of vulnerability to pollution of an aquifer is defined as the intrinsic susceptibility to changes in the quality and quantity of groundwater in the space and time due to natural processes and / or anthropogenic activity (Aller et al., 1987; Civita, 1990).

The region Bazer-Gelt Zerga has boomed in agriculture, urban and industrial activity . This increased the need for drinking water, irrigation and industrial firstly and secondly the water resources of the shallow aquifer has been overexploited and polluted. This work was done in order to create maps of vulnerability to pollution by inorganic pollutants using the following parametric methods: the DRASTIC standard (Aller et al., 1987) and SINTACS method (Aller et al., 1987), and vulnerability

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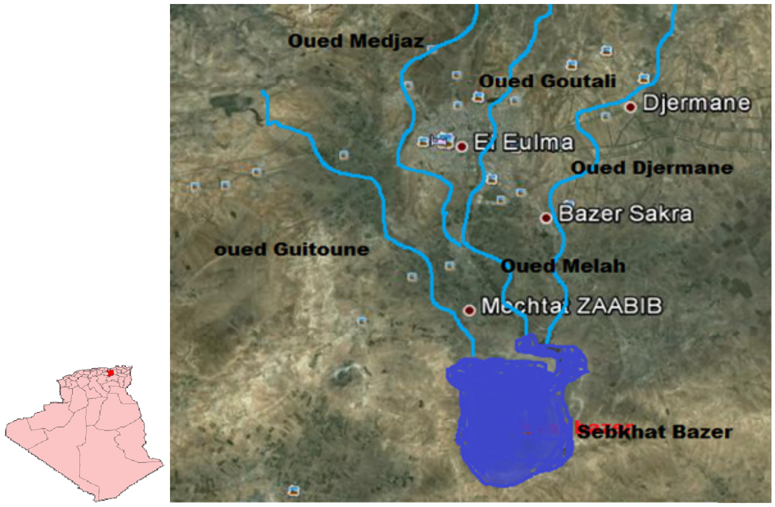


Figure 1: Map of area study

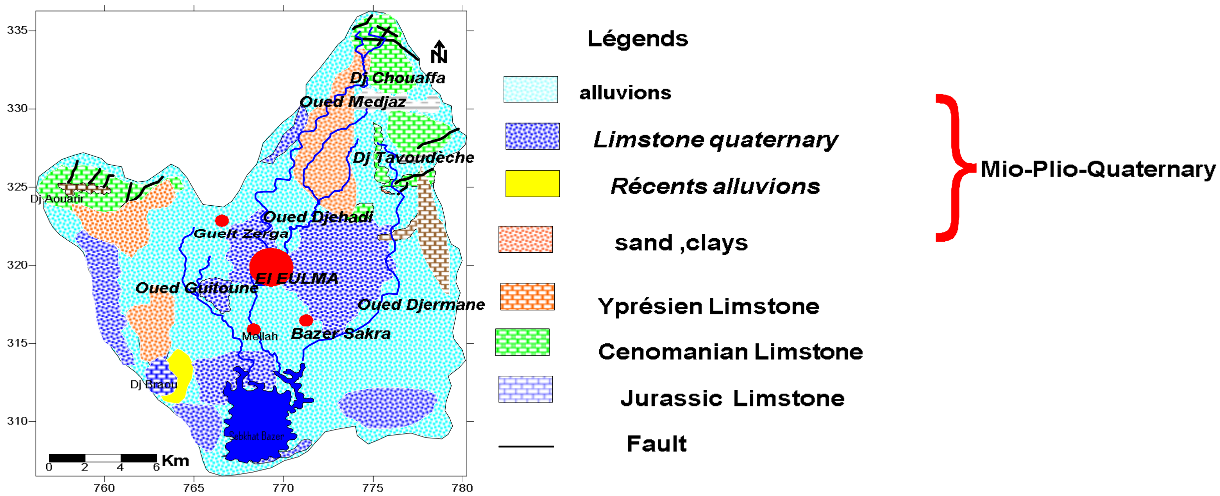


Figure 2: Geological map of study area

assessment to pollution of water resources of the Mio-Plio-Quaternary aquifer of Bazer-Gelt Zerga area

MATERIALS AND METHODS

STUDY AREA

The study area is located in the North East of Algeria, , between longitude 6 ° 38 E and latitude 36 ° 12 N (Figure 1) . Most of its inhabitants are concentrated in the town of El Eulma , Bazer and Guelt Zerga with mor than 250 000 inhabitants working mainly in the production of cereals (barely ,corn) the climate of the study area is considered to be semi arid region , with an annual precipitation being approximately 420 mm. The rainy season extends from October to May, with a maximum rainfall during December and March of each year .The mean monthly temperature varies between -5 and 40 °C , the mean annual temperature of 17°C .The vegetation of the study area is characterized by grasses and herbs . Soils are generally sandy to clayey in texture and mostly classified as arid –soils and are calcareous. Mineneralogically, most of the soils are dominated by kaolinite ,illite ,smectite and chlorite ,typical for most arid and semi arid soils .The presence of smectite suggests specific sites for sodium absorption .

Rocks and unconsolidated deposits in the area can be divided into three geologic units (Vila, 1980): upper cretaceous (Senonian), (2) Eocene and (3) Mio-Plio-Quaternary . Senonian (upper Cretaceous) Figure 2 is generally found in the northern part of the study area

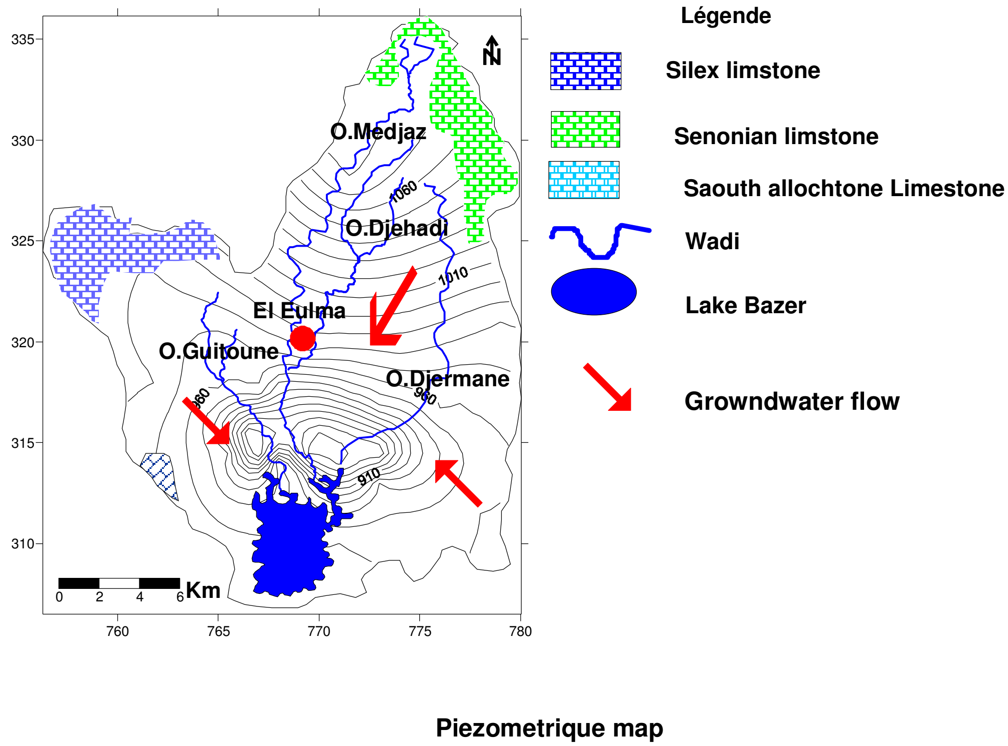


Figure 3: Piezometric map

Senonian units composed of Santonian –Campanian formation and upper Senonian formation .These formation consist of various rocks with about 500 m thick .Eocene units are composed of Ypresian –Lutetian formation .Eocene rocks consist of a succession of marine ,limestone and silt of about 80 m thick .The Mio-Plio-Quaternary is a heterogeneous continental detrital sedimentation . The study area is situated in the alluvial plain of the Mio-Plio-Quaternary .Shallow groundwater mainly occurs at 5-50 m below the surface .Groundwater is recharged by vertically infiltrating meteoric water in the basin and by stream water coming from different reliefs surrounding the inter- mountainous depression of Bazer-Guelt Zerga (Khemmoudj, 2009).

HYDROGEOLOGY

The Mio-Plio-Quaternary upper aquifer systems , located in the the Setifian high plains and more precisely that of Bazer-Geult Zerga area . The average thickness of the upper aquifer system is about 15 m and it is considered on of the most important aquifers in the area. The upper aquifer system outcrops in the centre and south parts of the study area. The groundwater flow system of the Mio-Plio-Quaternary aquifer is presented as groundwater contour map .Two piezometric highs are recognized in the study area. One has a static water level of 850 m and is located in the south of the study area, while the second is in the North with a static 1000 m . The piezometric map suggests that the direction of groundwater movement must be moving as shown Figure 3. Generally, the groundwater flow direction in the study area is converging in the Bazer Lake (Khemmoudj, 2009).

MATERIAL

The identification of aquifers and hydrogeological assessment of the different parameters considered in DRASTIC and SINTACS methods require geological, hydrogeological information, soil topography and weather (Civita, 1990; Civita et al., 1999; Civita et al., 2000; Dibi Brou et al., 2013) .

Low water and high water table (March and August 2012). Figure 2 was measured by an electric probe, weather data (ONJ), mapping and statistical processing of the data was performed by software Map Info 7.5, Golden Software Surfer 11 and Execl stats 2012.

The estimation accuracy of a vulnerability of the aquifer depending on the nature, the amount and the reliability of the method.

The DRASTIC method

The DRASTIC method, developed by the services of the U.S. Agency for Environmental Protection USEPA (Aller

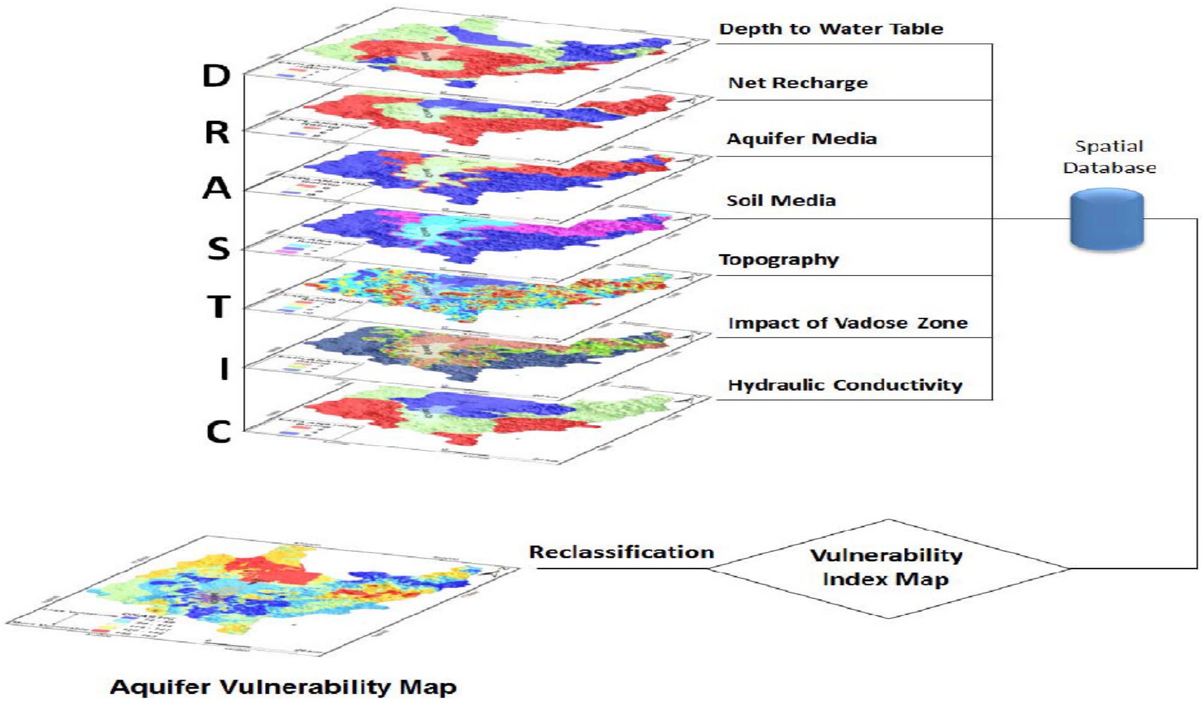


Figure 4: DRASTIC parameters.

et al., 1987), is a method for assessing the vertical aquifer pollution by parametric systems inherent vulnerability; the common principle of these systems is to first select the parameters on which is based the vulnerability assessment. Each parameter is divided into intervals of significant values and assigned a numerical rating based on increasing its importance in vulnerability.

The acronym DRASTIC stands for the initials of the seven factors determining the value of the vulnerability index: Depth to water (D) ; Net Recharge (R) effective recharge of the aquifer; Aquifer media (A) lithology of the aquifer; Soil media (S): soil type; Topography (T): topographic slope of the land; Impact of vadose zone (I): impact of the vadose zone (unsaturated zone); Hydraulic conductivity of the aquifer (C): hydraulic conductivity of the aquifer. The seven parameters index, schematically, a local hydrogeological unit into its main components, which affect to varying degrees transport processes and mitigation of contaminants in soil and their transport time.

A numerical value called parametric weight, between 1 and 5, is assigned to each parameter meter, reflecting the degree of influence. Each parameter is classified into classes associated with varying from 1 to 10. The smallest dimension of the conditions represents lower vulnerability to contamination. A numerical value called DRASTIC vulnerability index and denoted ID is determined: it describes the degree of vulnerability of each hydrogeologic unit. The DRASTIC vulnerability index is calculated by summing the product ratings by the weights of the corresponding parameters. Figure 4 Table1 ID = Dr*Dw + Rr*Rw + Ar*Aw + Sr*Sw + Tr*Tw + Ir*Iw + Cr*Cw (1)

The method SINTACS

SINTACS the method is derived from the DRASTIC method. It was developed in Italy in the early 1990s in order to adapt the mapping to a larger scale in view of the great diversity of hydrogeological Italy (Aller et al., 1987; Civita, 1990; Civita et al., 1999) The parameters characterization of vulnerability that were identified in this approach are the same as those of the DRASTIC method, or Italian: S: Soggiacenza (depth of water); I: Infiltrazione (infiltration); N: Not Azione del Satoru (depending on the unsaturated zone); T: Tipologia della Copertura (soil); A: Carratteri Idrogeologici dell 'Acquifero (hydrogeological characteristics of the aquifer); C: Conductivity Idraulica (conductivity hydraulic).

S:Acclività della Topographica area (average slope of the topographic surface).Unlike DRASTIC, SINTACS the method enables the use, and at the same time in different cells, the weighting factors vary according to the situations. The specificity of this method is the fact that it offers five different scenarios:

Scenario "Normal Impact" scenario for aquifers consist of unconsolidated sediments with a depth of water is not very high, localized in areas with heavy soils. Areas for this scenario correspond to stable regions viewpoint land with whether or not cultivated, low use of pesticides,

Table 1: The DRASTIC model parameters used in this study

Index	Factor	Description
D	Depth of water	Represents the depth from the groundwater surface to the water table
R	Net recharge	Represents the amount of water that penetrates the vadose zone and reaches the water table .recharge water represents the vehicle for transporting pollutants
A	Aquifer media	Refers to the saturated zone material properties ,which control the pollutant attenuation processes
S	Soil media	Represents the uppermost weathered portion of the vadose and controls the amount of recharge that the infiltrate downward
T	Topography	Refers to the slope of the land surface .It indicates whether the runoff will remain on the surface to allow pollutant to the saturated zone
I	Impact of vadose Zone	This is defined by the vadose zone material ,which controls the passage and attenuation of the contaminated material to the saturated zone
C	Hydraulic condictivity	Indicates the ability of the aquifer to transmit water ,thus determines the rate of flow of the contaminant within the groundwater system
ID	DRASTIC vulnerability index	
r	rating	
w	weight	

Table 2: Scoring for SINTACS settings from the scenario method.

scenario parameters	Impact Normal	Impact severe	Drainage Important	Karst	grounds cracked
S	5	5	4	3	2
I	4	5	4	5	3
N	5	4	4	1	3
T	4	5	2	3	4
A	3	3	5	5	4
C	3	2	5	5	5
S	2	2	2	5	4

fertilizers and irrigation, and urban perimeters widely dispersed;

Scenario "Severe Impact" corresponds to the same types of aquifers subjected to intensive occupation of land with cultivated land intensive use of pesticides, fertilizers and irrigation, industrial and urban dense settlements and cash deposits and solid waste;

Scenario for areas where there is a strong infiltration to the aquifer from a surface water system: Scenario "material from a surface drainage network" Scenario "very karstified Land" Scenario "Land cracked."

After calculating the index, vulnerability classes is determined intervals correspond to indices obtained. Generally, these indices are divided into five classes of vulnerabilities ranging from very low to very high for the DRASTIC method and low to very high for SINTACS method (Table 2)

Comparison of methods for assessing vulnerability

Comparison of the results obtained by applying the two methods allows the vulnerability assessment variations in space. This comparison was performed by statistical analysis of the surfaces on the classes of vulnerabilities, and the correlation test by and the indices of vulnerability.

Alignment of vulnerability classes

Vulnerability classes evaluated by both methods will be tested for compliance and to verify their consistency. The latter will be determined by calculating the coefficient of Kindall, considering the DRASTIC method as the reference method. Coefficient Kindall (W) represents the statistical index that measures the degree of concordance assessed between two or more raters to

Table 3: Intervals values of the index of vulnerability and related classes.

The DRASTIC vulnerability index method	The SINTACS Vulnerability index method	
< 80		Very Low
80 - 120	< 101	
121 - 160	101 - 140	average
161 - 200	141 - 200	High
> 200	> 200	very high

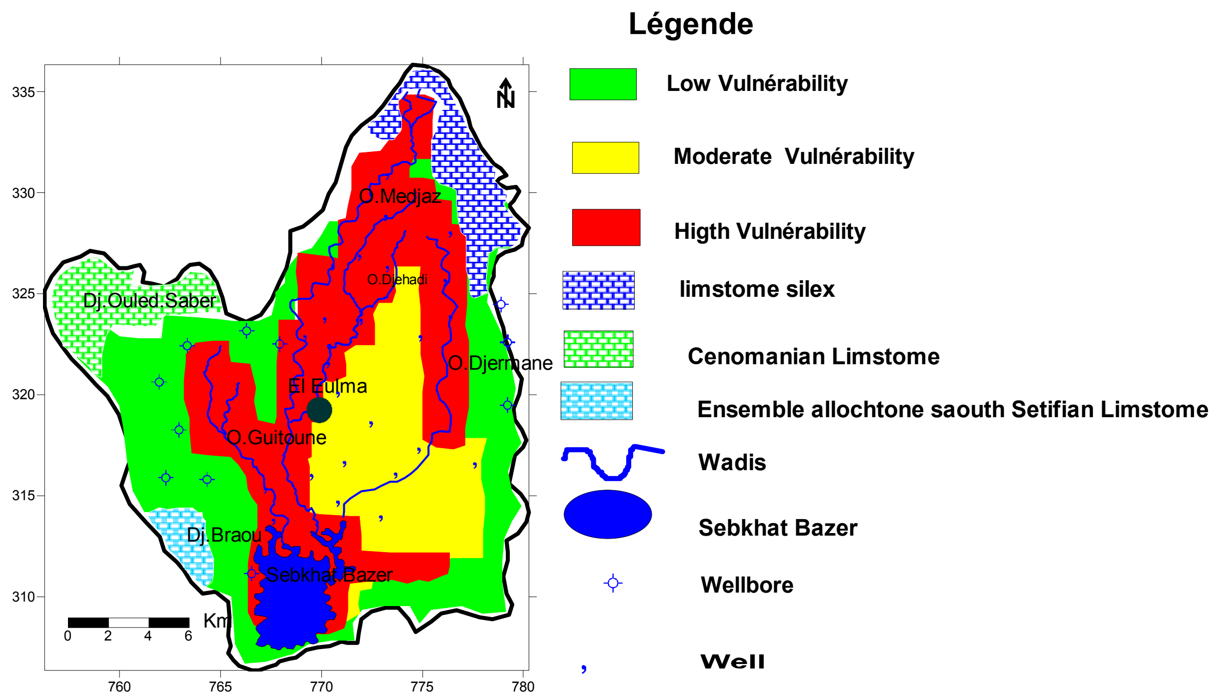


Figure 5: VULNERABILITY MAP BY DRASTIC METHOD

judge the same phenomenon This coefficient of variation margin between 0 and 1. He has a degree of consistency which is more than the value of the coefficient W is close to 1.

Statistical analysis of surfaces

Statistical analysis of surfaces indicates whether the two methods used are identical in vulnerability assessment or overvalued relative to another. This analysis will focus on a number of mesh by two classes of vulnerability maps from the two methods DRASTIC SINTACS.

RESULT AND DISCUSSION

The estimation of different parameters and their combination have led to the assessment of vulnerability indices by both methods Table 3, thereby bringing the two cards vulnerability to pollution. Each method from the observation of the values of the statistical parameters of these indices shown in Table 1, we could deduce existing vulnerability classes, which show the dominance of the class of high vulnerability and lack of strong class Indices evaluated by DRASTIC method range between 79 and 185 represent three classes that constitute the map Figure.5. indices evaluated by the method SINTACS vary between 117 and 217 represent the three classes that constitute the map Figure 6 .

DISCUSSION

Vulnerability map by the method DRASTIC

Indices evaluated by DRASTIC method range between 79 and 185 represent three classes that constitute the map Figure.5 as follows. Low class, reflecting a low vulnerability to pollution accounts for 17% of the mapped area. Low vulnerability index results depths that are relatively large near the edges. The middle class is found

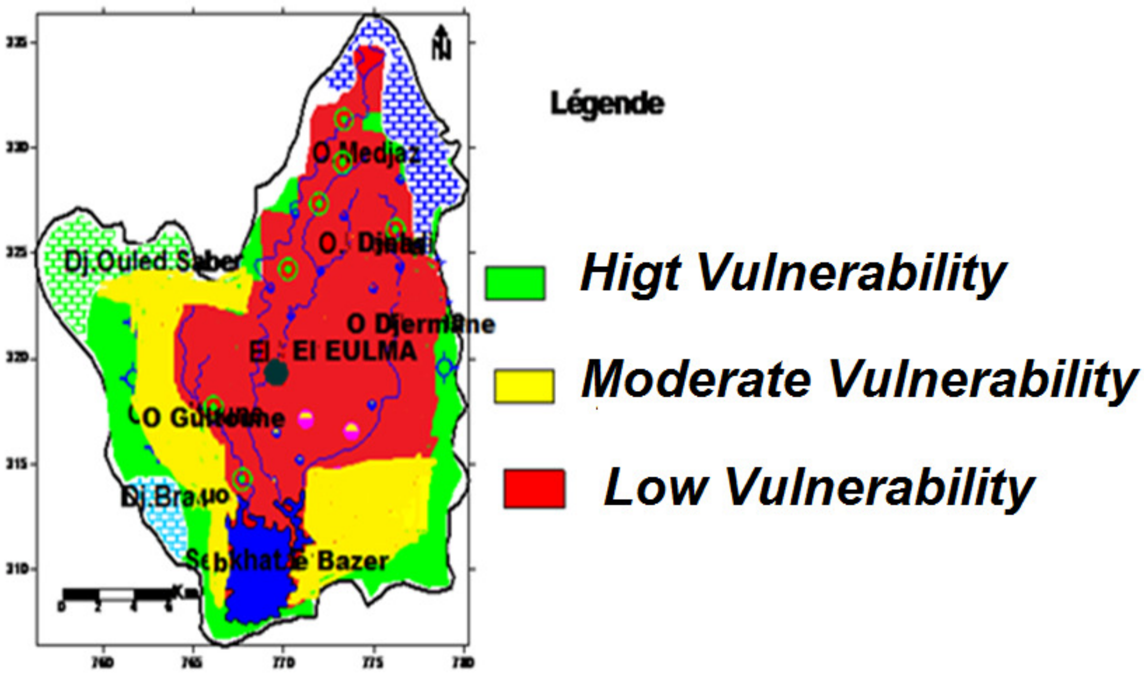


Figure 6: VULNERABILITY MAP BY SINTACS METHOD

Table 4: Index evaluated by the method DRASTIC

Sl n°	DRASTIC Index	Number of Mailes	Surface Km2	Pourcent %	Vulnérability
1	105	1000	85	17	low
2	127	610	55	11	medium
3	185	3990	360	72	high
Total		5600	500	100	

Table 5: Index evaluated by the method SINTACS

Sl n°	SINTACS Index	Number of Mailes	Surface Km^2	Pourcent %	Vulnérability
1	117	820	73	14.6	low
2	139	540	49	9.8	medium
3	217	4240	378	75.6	high
Total		5600	500	100	

to the east of the area between Wadi wadi Djermane Djehadi and gives rise to a less severe pollution, represents 11% of the area of the plain studied. The average degree of vulnerability is caused by a combination of shallower depths than those near the edges and measured hydraulic conductivity of 3.10-4m / s.

High class extends from north to south, it occupies a large area (72%) Table 4, the strong vulnerability index is probably attributed to the low depth of the aquifer varies from (0-5 m) and lithology that consists of alluvial sands and clay.

Vulnerability map by the method SINTACS

indices evaluated by the method SINTACS vary between 117 and 217 represent the three classes that constitute the map Figure 6 Class 117, reflecting a low vulnerability to pollution, it represents 14.6% of the mapped area. Low index result of depths the aquifer near the borders.

The middle class is located in the south east area close to Sabkhet Bazer, represents 9.8% of the area. High class 217 extends from North to South, it occupies a large area 75.6% Table 5. L index very strong vulnerability is probably attributed to the shallowness of

Table 6: Relationship between land use/cove type and nitrates concentrations

	Nitrates concentration (NO_3 mg/L)		
	Min	**Max**	**Average**
urban	10	125	42
Agriculture	12	180	55

Table7: Comparisons by mesh classes for both DRASTIC and SINTACS methods

Méthodes		**DRASTIC**			
	Vulnérability	**Low**	**Medium**	**High**	**Total**
SINTACS	Low	789	31	00	820
	Medium	211	329	00	540
	High	00	250	3990	4240
	Total	1000	610	3990	5600

the aquifer varied between 0 and 5 m and lithology that consists of silt and clayey sands.

Verification using nitrates concentrations

To verify the effect of land use/cover on groundwater quality ,the measured nitrates concentrations in milligram per liter (mg/l) are used as a pollution indicator in the study area ,were obtained from 25 samples analyzed respectively . The minimum ,maximum and average value of nitrates concentrations in each class are shown in table 5. The minimum value is range from 10 to 12 mg/L and maximum value is range from 125 to 180 mg/L Table 6 .However, the average values have shown that agriculture has the highest average nitrates concentrations, followed by urban .This high occurrence of nitrates in groundwater within the agriculture area is attributed to the extensive use of fertilizers. Moreover, the leachate of wastewater from septic tank, wastewater treatment plants, and solid waste disposal sites disposal sites within urban area has also increased the nitrates concentration in the groundwater, and consequently, deteriorated the groundwater quality (Hanbali and Kondoh, 2008) Validation of these maps is necessary because any vulnerability map must be tested and validated by measurements and chemical analyzes of groundwater Figure 7 we used the distribution of nitrate in groundwater and alluvial clayey sands Mio-Plio-Quaternary. The concentrations of nitrates contained in groundwater are between 10 and 180 mg / l. The distribution map of this pollution showed that:

Low rates [10 -50 mg / l] are located in the proximity of borders North, East and South of the basin . The average concentration [50-80 mg / l] is divided between the central area and borders. The high levels [80 to 180 mg / l] occupy the central region, east and north that promotes high Vulnerability maps produced by the two methods have confirmed this trend. Indeed, the high concentration of nitrates areas [50-80 mg / l] overlap with areas whose vulnerability indices are average nitrate concentrations are high [80-180mg / l] are coincident with areas high Vulnerability.

Comparisons of vulnerability assessment methods

The number of cells obtained by the methods and by class (Table 6) is the base of testing Kindall and statistical analysis of surfaces.

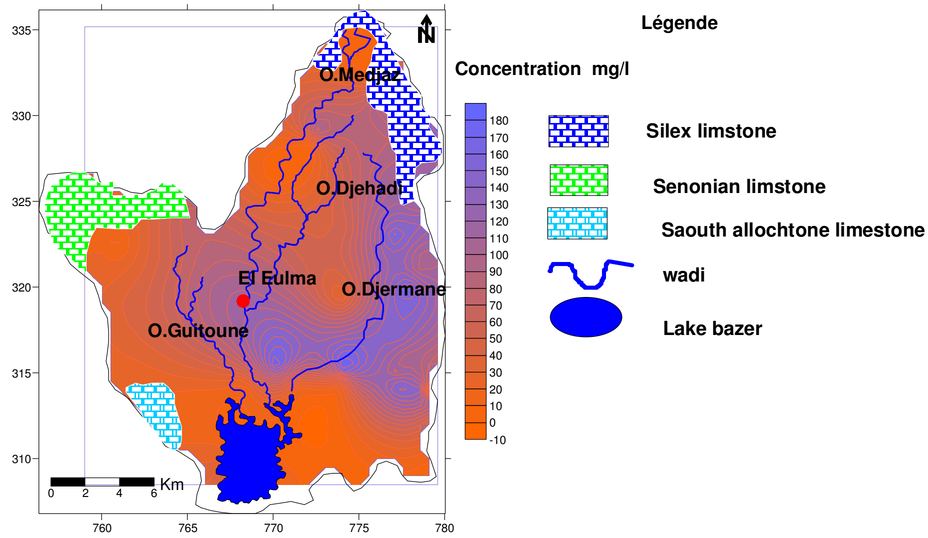
The test kandall

The coefficient calculating Kindall found that this test is reliable since the coefficient value Kindall (W) is positive (W = 0.835).

Statistical analysis of surfaces by class

Comparing the vulnerability mapping to pollution from the two methods, the surface of each class was calculated and converted to percentage. Vulnerability by DRASTIC method is represented by three classes (Low, medium and high), medium and high are 83% with the domination of high class [72%], the middle class [11%] and low class [17%]. (Table 3) Figure 2 SINTACS the method has resulted in a concentrated three classes vulnerability. Weak, medium and strong The medium and high classes represent 85.4%, we note the high vulnerability is (75.6%), the middle class (9.8%) and low class (14.6%) (Table 4) Figure 4.

Comparison of mesh by class, for both methods was carried out by the differences between the two cards vulnerability that results in Table 5 by assigning the values 1,2 and 3 different classes (low, medium and high) obtained by methods by making the crossing of classes has obtained the results in (Table 7). The interpretation of data classes (-3, -2, +3) with a zero percentage, Class 0



Map of Nitrates concentration

Figure 7: MAP OF NITRATES CONCENTRATION

Table 8: Percent of surfaces according to the index differences between DRASTIC and SINTACS methods.

Différent Index	-3	-2	-1	0	1	2	3
Pourcent	0	0	7	86	4	3	0
sum	7			86	7		

represents the largest percentage 86% (Table 8) or DRASTIC and SINTACS methods have identical index. hence confirming the concordance of the two methods achieved by (Dibi Brou et al., 2013; Hamza et al., 2007; Gouaidia et al., 2012).

There are some variations of indices, namely a sub evaluations (7%) and over-evaluation (7%) index DRASTIC method versus the method SINTACS this margin of difference is probably related to the number of 7 parameters are identical for the two methods have almost the same assessments.

CONCLUSION

The application of methods DRASTIC AND SINTACS was estimated indices of the intrinsic vulnerability to pollution of the surface layer of the Bazer -Geult Zerga erea . This vulnerability decreases from the center of the region to the edges. The spatial distribution the concentration of nitrates has confirmed this decrease. analysis of both vulnerability maps resulting from the application of two methods (DRASTIC and SINTACS) revealed the vulnerability focuses on the low, medium and high classes. Comparison of vulnerability maps from Kindall test showed that there is a high concordance between the two methods (DRASTIC and SINTACS): coefficient of concordance Kindall is 0.835.

The analysis of surfaces by two methods classes (DRASTIC and SINTACS) showed that 86% of the mapped area are identical index with undervaluation and overvaluation (7%) of the DRASTIC method compared to the method SINTACS so we can say that both vulnerability maps produced reflects the reality of the pollution of groundwater in the Bazer-Gelt Zerga area . Nitrate is the main source of pollution in the shallow aquifer influenced by the return of the waters irrigation.

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