ORIGINAL ARTICLE

VULNERABILITY ASSESSMENT TO POLLUTION OF GROUNDWATER OF THE MOROCCAN ATLAS CAUSSE (REGION EL HAJEB - IFRANE) BY SEVERAL METHODS USING GIS

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ABSTRACT

Background: Groundwater is often threatened by contamination from different types of pollutants. Prevention against pollution is an important step in which scientists provide more and more effort, by studying the vulnerability of aquifers. The region of El Hajeb – Ifrane occupies an important place in Moroccan territory, as well by its geographical location and its water and agricultural potential. At the causse of middle Atlas, the water table is located in a fractured carbonate reservoir and karstified having high fracture permeability which probably makes it vulnerable to anthropogenic pollution. **Objectives:** The study of vulnerability in areas prone to pollution of various kinds is very important for the management of water resources. Our study aims to map this phenomenon using GIS and modeling methods in the causse of middle Atlas (region El Hajeb : Ifrane) (e.g. DRASTIC.). **Methods:** The vulnerability of groundwater reflects the way in which it can be achieved by pollution from the soil surface. The DRASTIC method is the most method used to assess the vulnerability and spatialize over large areas. The parameters taken in this method are: the depth of the water (D), net recharge (R), the materials of the aquifer (A), soil type (S), topography (T) the impact of the unsaturated zone (I) and the hydraulic conductivity (C). Comparison with other methods like (COP, EPIK, PI) was also performed in this analysis. The study data was acquired and converted to several sources in the form of thematic maps through the use of GIS, due to the very large mass of data needed for this treatment. **Results:** The results are presented as thematic maps. The initial diagnosis revealed that it is an environment with medium to low topography, and a karst lithology favorable to the development of high permeability may actually affect the quality of groundwater. Indeed, analysis of the situation of the causse El Hajeb - Ifrane allowed deducing that the vulnerability to pollution of the groundwater is higher in the southern area where the majority of settings are favorable to such degradation. **Conclusions:** The completion of the study by the of a groundwater pollution risk map of groundwater in this region will be a very important tool to help protect the groundwater and for good water resources management and soil in the region.

Keywords: *groundwater, pollution, Karst, DRASTIC*

1. INTRODUCTION

The study of vulnerability in areas prone to pollution of various kinds is very important for the management of water resources [1, 2, 3, 4, 5].

Indeed, groundwater is a very important renewable resource in the Middle Atlas Northern. It is operated primarily for drinking water and for agriculture. The progressive urbanization of the territory, the development of areas managed for agriculture, livestock and many other human activities threaten the water quality without any mandatory supervision [6, 7, 8].
This study involves assessing the vulnerability of groundwater from the causse of El Hajeb - Ifrane pollution using geographical information systems and modeling methods [6, 9, 10].

The study zone with a total area of approximately 900 km², is located in the medium Atlas causse, bounded on the north by the plain of Sais, in the West by the sudden interruption of the causse, in the south by the important line accident of horst *Tizi-N'Tretten*, and to the east by the causse of Immouzer (Figure 1 & Figure 2). This causse is characterized by carbonate deposits of Lower and Middle Lias [6, 9].

Figure 1 : The location of the study area.

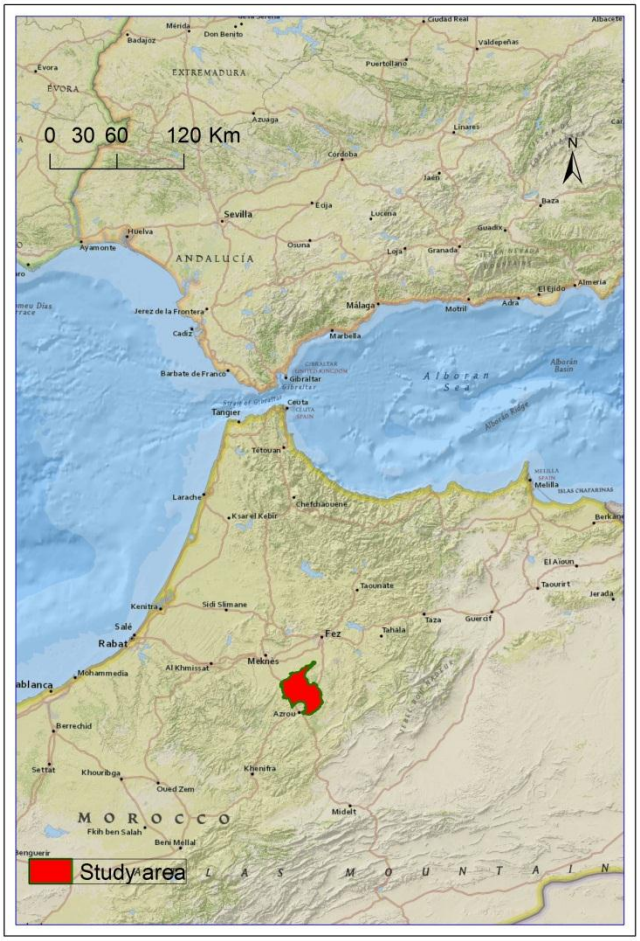
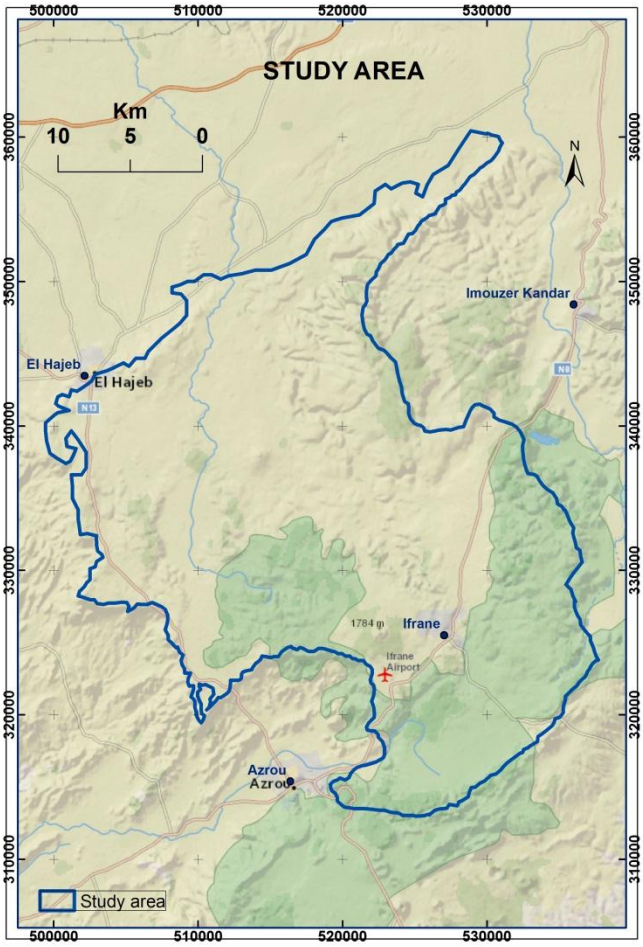


Figure 2 : The map of the study area.



2. MATERIALS AND METHODS

The study of the vulnerability of groundwater to pollution consists on compilation data of several disciplines such as topography, geology, hydrology, hydrogeology, climatology, karst phenomena ... So many maps were used : topographic maps of El Hajeb, Ifrane, Azrou (1/50.000), geological map of El Hajeb (1/100.000), piezometric map and transmissivity, a satellite image Landsat, data of logs and drilling in the area and the use of the Numerical Model of the study area (DEM) [2, 11, 12, 13].

The method for evaluating the vulnerability of groundwater consists on the assessment of different parametersthe different parameters involved in the vertical transfer of pollution from the soil surface, including [14, 15, 16, 17, 18] :

- Topography (slope important indicator of runoff ...)
- The characteristics of the unsaturated zone (lithology, p ermeability, etc.);
- The characteristics of the aquifer (confined aquifer, water table ...);
- The development of the karst system and fracturing [19, 20];
- The groundwater recharge (from precipitation, streams, irrigation water, etc.);
- The nature and thickness of the soil;
- The water depth relative to the ground;
- The land use.

Many methods of determining the vulnerability of groundwater have been developed in the world, varying from the complex with models taking into account physical, chemical and biological processes, methods of weighting of various criteria affecting vulnerability [13, 17, 18].

The methodology used in our study is based on the comparison of several parametric methods, called mapping index weighted criteria. The DRASTIC method is the standard one, used in most general in most general model for a first analysis, because it can map large areas. The parameters taken into consideration by these methods are summarized in the following table (Table 1) : [2, 18].

Tableau 1 : The various methods for vulnerability assessement and its parameters.

	Vulnerability methods					
parametrs	drastic	drastic pesticides	sintacs	COP	PI	EPIK
Topography (slope)	X	X	X	X	X	X
Stream network			X	X	X	
Soil characteristics	X	X	X	X	X	X
Net Recharge	X	X	X	X	X	X
Lithology (vadose zone)	X	X	X	X	X	X
Depth	X	X	X		X	
hydrogical & karstic features	X	X	X		X	X
Hydraulic conductivity	X	X	X			
Land use				X	X	X

3. RESULTS

To develop vulnerability maps of the different used methods, several parameters and corresponding thematic maps have been determined, we cite as examples:

3.1. Depth

The depth map of groundwater was drawn from the data of drilling (over 150 drillholes). This map shows the levels of average depths (20 to 30 m) in the southern part and in the peripheries of the Causse and moderately high in the center (up to 90 m).

3.2. Net recharge

It was developed by conducting a water balance of the area studied. The aquifer is recharged mainly by direct infiltration of up to 25-30 mm in effective rainfall means.

3.3. Nature of the aquifer

On the hydrogeological map, the causse El Hajeb - Ifrane is formed with a karstic aquifer, consisting of dolomitic individualized structures and calcareous-dolomitic from Lower and Middle Lias. The flow of deep waters is infiltrated behind the outcrop surface sources at the flexures.

3.4. Soil characteristics

Soils at the study area are dominated by alternating isohumic type layers, calcic-magnesium and sandy very favorable to agricultural activities with an a high average depth. While in the south, the soils are becoming poorer quality and unsophisticated with a variable depth.

3.5. Topography

The slope is an important indicator of the runoff or infiltration of precipitation. It was developed from the DEM of the study area. The general observation shows that excluding Tizguite along the river where the slope may exceed 10% in some cases, other courses are very uneven (less than 2%).

3.6. Lithology

The study area is based on a tabular platform dominated by carbonate structures of the Lias. The stratigraphic distribution is essentially characterized by the passage of Paleozoic to Middle Lias with an outcrop of the Miocene on the northern edge of the causse.

3.7. Hydraulic conductivity or permeability

It expresses the ability of the geological formations to transmit water with potential pollutant under the effect of a hydraulic gradient to the saturated zone. Through hydrogeological data of drilling and boreholesin the region, it turns out that areas with the highest permeabilities are located on the SE-NW diagonal axis which coincides with the major direction of the family of the dominant fracturing which is the accident part of Tizi N 'Tretten at the southern limit of our study area.

3.8. Land use

The agricultural zones in the study area are in continuous growth, they represent currently around 25-30%, forests of cedar and oak and steppe zones cover about 40% of the total area, the rest is form course and uneducated (15-20%).

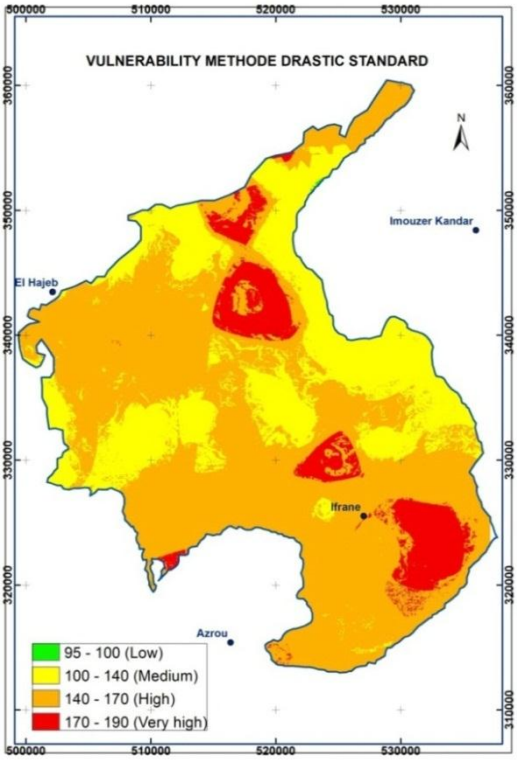
4. DISCUSSION

In this part we will present the vulnerability maps of the different methods used and we will make a comparison of these processes.

4.1. Maps of vulnerability (e.g. DRASTIC)

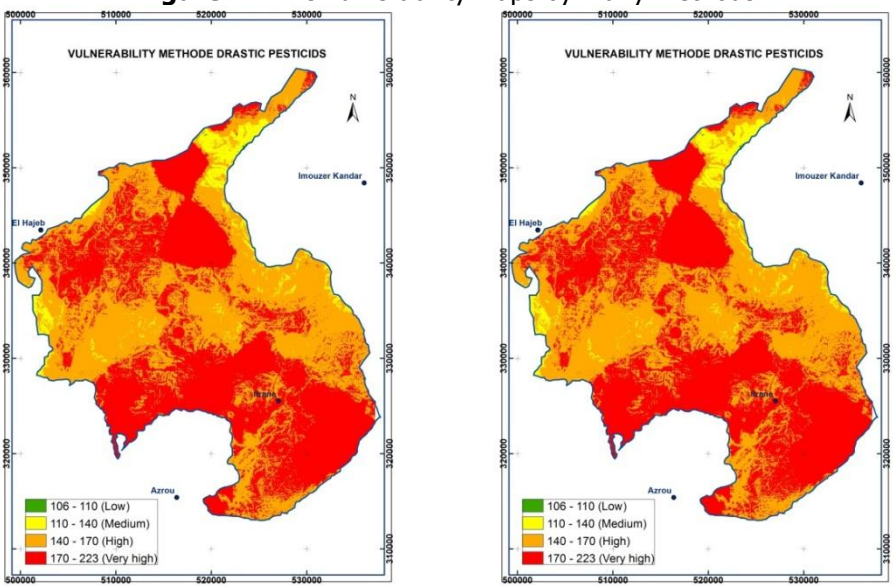
This map (Figure 3) shows significant vulnerability levels (67%) in the entire territory of the study area with an emphasis in the direction of the diagonal axis NW-SE. The rest of the area is subject to an average vulnerability (29%).

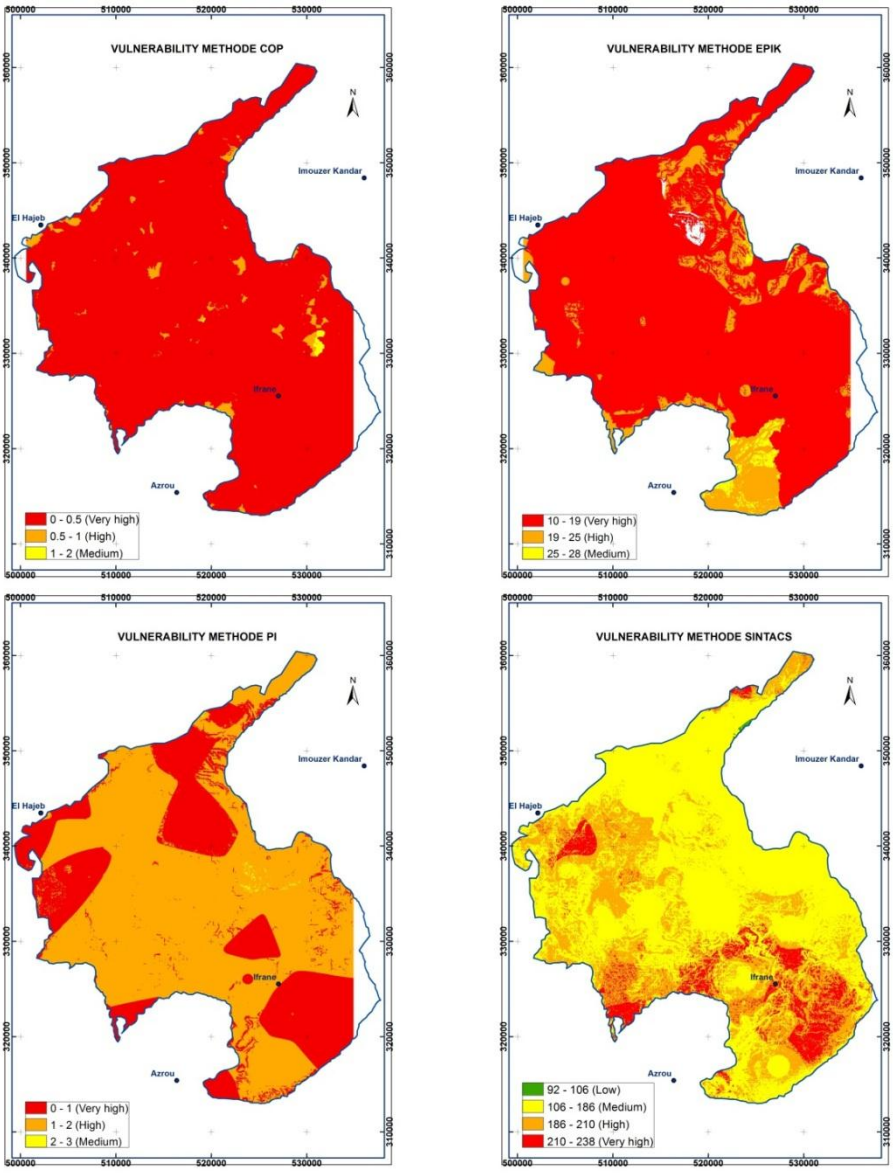
Figure 3 : The Map of DRASTIC vulnerability.



The results of the other maps are in the figure below (Figure 4).

Figure 4 : The vulnerability Maps by many methods

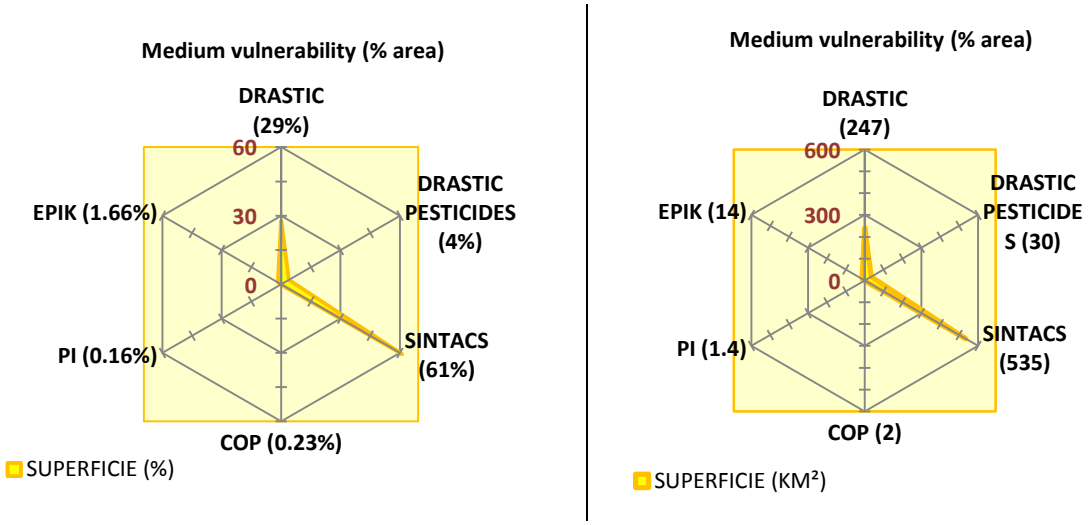




Furthermore and in order to be able to compare the results of adopted methods, three main classes of vulnerability were studied between the different methods in terms of area affected by each class (% of medium, high and very high vulnerability). The calculation of these static zonal was facilitated through GIS software [3, 19, 20].

4.2. Medium vulnerability

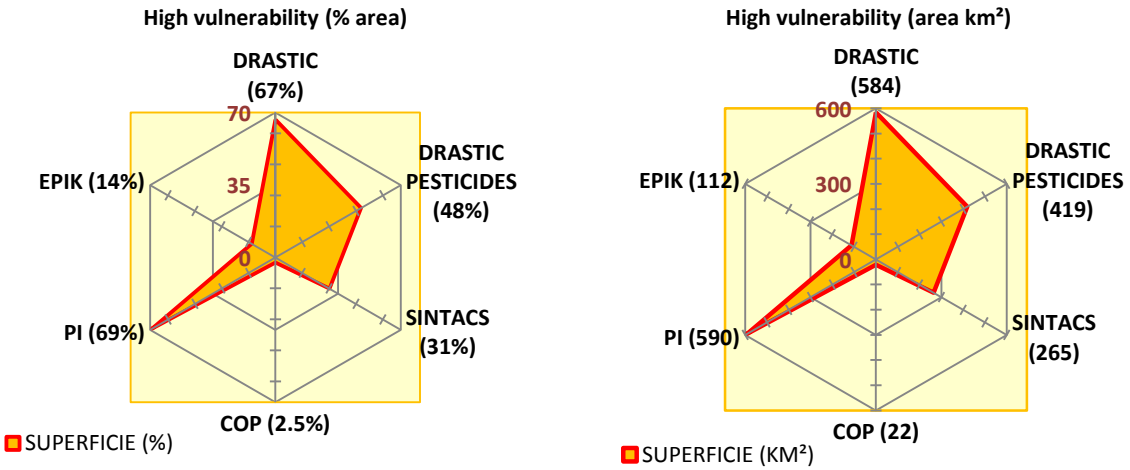
Figure 5: The vulnerability assessment (medium case) by different methods



From the figure (Figure 5) above, the method SINTACS evaluates (2/3) of the study area as moderately vulnerable, against the PI method that estimated that less than 150 ha (0.16%) are moderate vulnerability.

4.3. High vulnerability

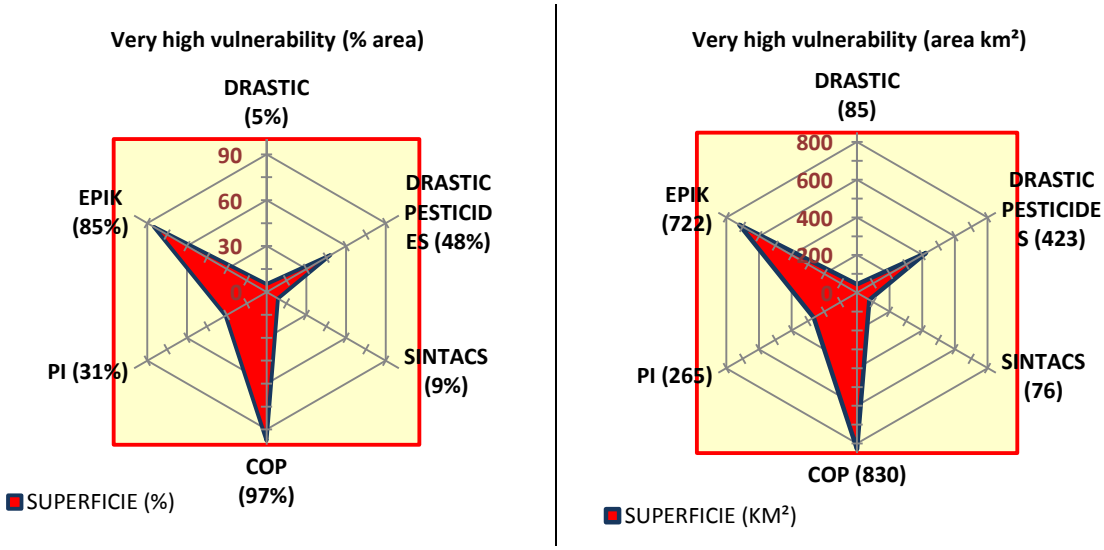
Figure 6: The vulnerability assessment (high case) by different methods.



From the figure (Figure 6) above, we can deduce that the DRASTIC and PI methods evaluate virtually the same intensity parties to high vulnerability (> 2/3). COP method estimates strongly vulnerable only 2.5% of the study area.

4.4. Very high vulnerability:

Figure 7: The figure presents the vulnerability assessment (very high case) by different methods.

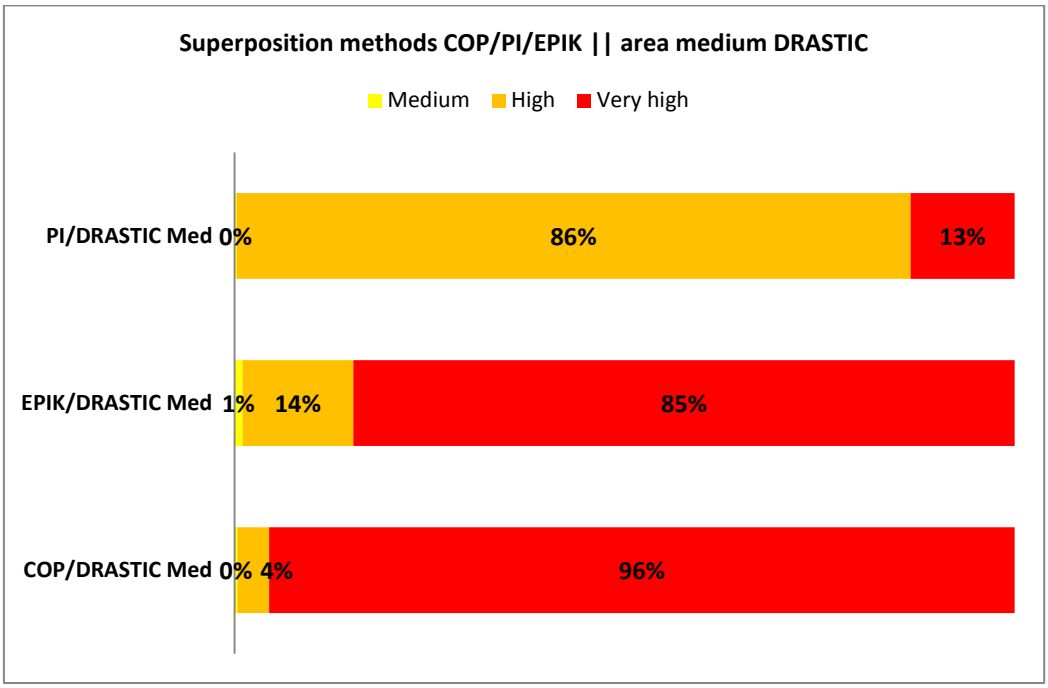


According to the figure (Figure 7) above, very large areas are considered extremely vulnerable by the EPIK and COP methods. The DRASTIC method is that Judge least, areas with very high vulnerability.

4.5. Spatial superposition between various methods

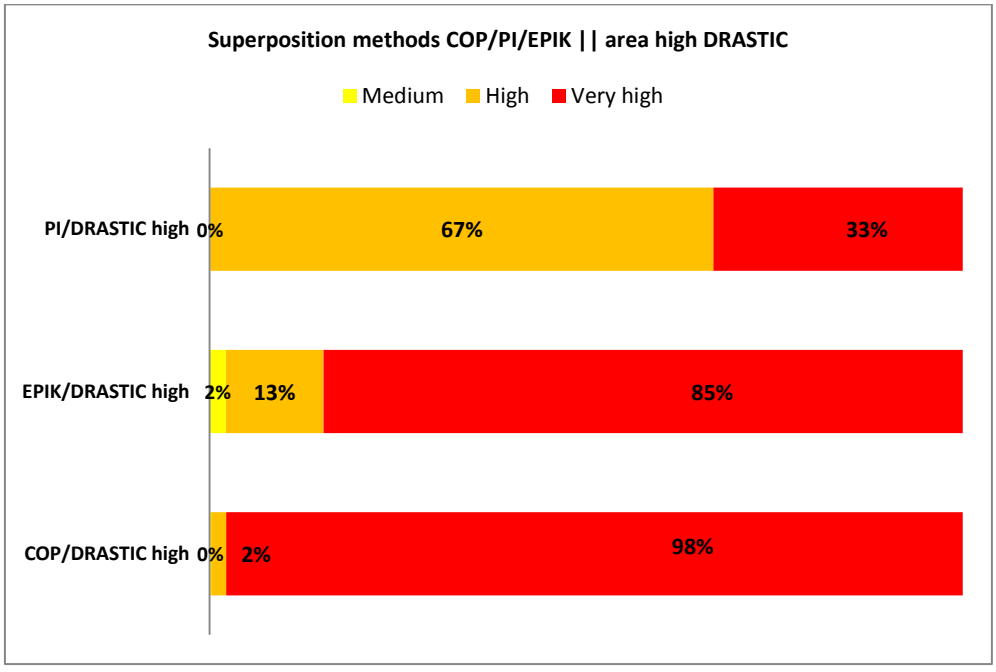
The crossing of the areas and the calculation of the static zonal were facilitated through GIS software. Vulnerability areas evaluated medium, high and very high by the methods COP, PI, EPIK and SINTACS were overlaid with areas defined as medium and high vulnerabilities (most dominant) by the DRASTIC method. The results thus obtained are shown in the following charts (Figure 8) :

Figure 8: The figure presents the spatial superposition between various methods and medium DRASTIC.



From the figure above, we notice that the EPIK and COP methods evaluate almost all medium area of vulnerability by the DRASTIC method, as an area with very high vulnerability. Whereas PI method evaluates the same area as a territory with high vulnerability.

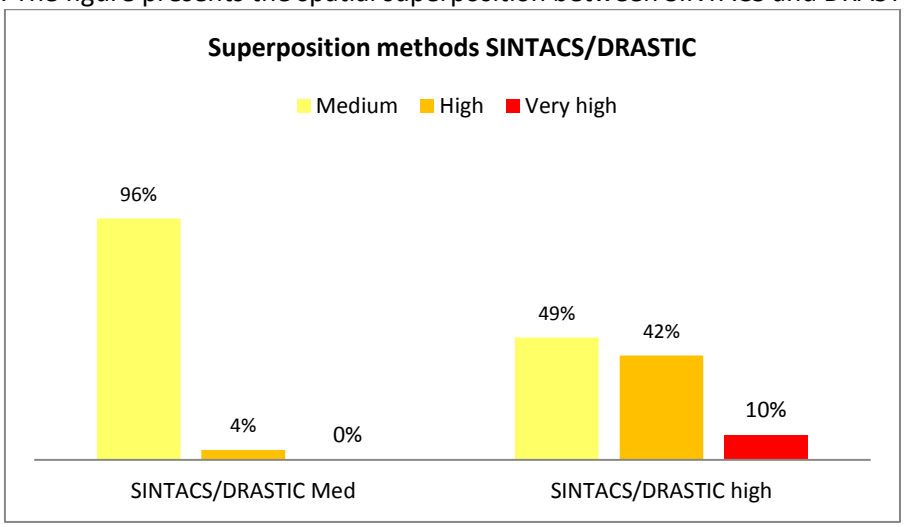
Figure 9: The figure presents the spatial superposition between various methods and high DRASTIC.



From the figure above (Figure 9), we note that the EPIK and COP methods evaluate almost all area that is high vulnerability zone by the DRASTIC method, as an area with very high vulnerability. While PI method evaluates the same area as a territory with high (2/3) and very high (1/3) vulnerability.

We could conclude that the COP and EPIK methods tend to overestimate towards the increase the vulnerability of areas moderately and highly vulnerable by the DRASTIC method. IP method provides certain rationality in awarding degrees of vulnerability classes.

Figure 10: The figure presents the spatial superposition between SINTACS and DRASTIC method.



According to the figure above (Figure 10), the method SINTACS judge practically in the same way as the DRASTIC method medium vulnerability DRASTIC territories, against areas of high vulnerability estimated by the DRASTIC method is assessed as medium or high risk by the method SINTACS.

Areas with very high vulnerability assessed by all methods are a fairly small extent (<5%).

4. CONCLUSION

his study has allowed mapping spatially important parameters for assessing the vulnerability of the Atlas's causse. Considering the elements released previously, a first analysis of the situation of the Causse El Hajeb - Ifrane will deduce that the vulnerability to pollution of the water table is higher in the southern area where the majority of factors are favorable (low slope fractured aquifer and karstified, high permeability ...).

The completion of the study by developing a validation map of physical and chemical analyzes of water samples and the assessment of various pollutants (pesticides, fertilizers,…), will be a very important tool for the diagnosis of water quality of the Atlas's causse through a mapping of the affected areas and / or risk of pollution. The resulting maps are a very important tool to help protect the aquifer and also for good water management and soil in the region.

5. REFERENCES

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