The Comparison of Fuzzy Drastic Model and Conventional Drastic Model to Determine the Most Appropriate Indicator of Ground Water Vulnerability (Case Study: Sarkhoon Plain Aquifer)

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Expanded Abstract

Introduction

Drastic model is an index and overlapping model that has been designed for producing vulnerability scores for different points by combining several thematic layers. Overlapping distinguished methods are the most applicable methods for evaluating vulnerability of aquifers because they are cheap, they can directly reach a defined goal, the used data in the methods are accessible or can be estimated, their final results can easily be described, and they are suitable for managerial decision making. However, ranking system of parameters of this method is an irrational and unreliable system. These classifications are based on Boolean method. If classification is done based on Boolean method, it will cause a zone to displace a story to a higher or lower score with little change which is not acceptable and justifiable. But it seems that one can present a suitable method for classification and ranking using fuzzy theoretical fundamentals compared with Boolean method. In that fuzzy method gives a membership to each theme. This research has been conducted to utilize fuzzy theoretical fundamentals in modeling of drastic hydrogeology parameters. These parameters have inherent uncertainty to determine fuzzy drastic index and compare it with conventional drastic index to obtain the most accurate and suitable inherent vulnerability evaluation index. In this study this index can be evaluated for Sarkhon Zone to find vulnerability evaluation as a guide for managers and authorities as an efficient instrument for taking suitable measures. In this research, the studied zone is aquifer of Sarkhon Plain located in Hormozgan province.

Materials and Methods

Study area

The studied zone is Sarkhon in approximate distance of 25 km from Bandar Abbas in eastern-northeastern range of Geno Mountain. This basin with area of 1046 sq km is located in latitudes of 27°,9´ to 27°,33´ and longitudes of 56°,7´ to 56°,33´ in Sarkhon drainage basin (Fig. 1).

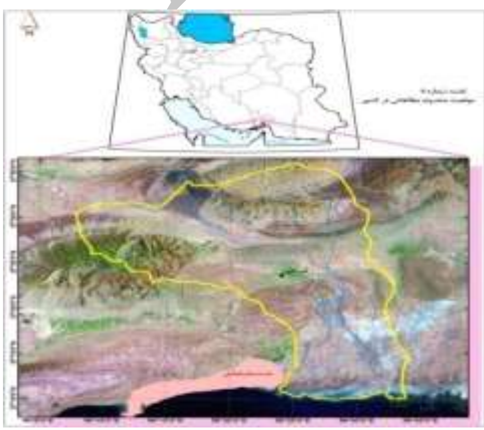

Fig. 1. The study area, Sarkhon Aquifer

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Drastic Index

It is calculated using seven factors affecting potential of groundwater pollution. These factors include depth of water table, net recharge, aquifer media, soil, slope, impact of vadose zone, and hydraulic conductivity. The rank of each parameter varies between 1 and 10 and weight of each parameter varies between 1 and 5 considering its importance. Vulnerability index in this method is obtained by multiplying weight by rank of seven parameters according to Equation 1.

$$Di = \sum_{j=1}^{7} (Wi \times Rj) \quad (1)$$

Di = Drastic Index

Wi =weight factor i

Rj= j rank factor

Fuzzy logic

The use of fuzzy logic has been expanded in many branches of sciences which require classification of information. Since classification of information and demarcation of these classes are of special importance in evaluation of groundwater vulnerability, fuzzy logic can evaluate vulnerability better than the conventional methods.

Fuzzy *Inference System Formation Stages*

1. Determining a ***Fuzzy Rule System based on observational data***
2. Fuzzifying prior and posterior section using fuzzy membership functions
3. Combining different parts of prior section of each rule and determining intensity and impact of the mentioned rule on final output of the system
4. Combining posterior section of rules to obtain final output of system as a fuzzy set
5. Converting final output of system to a classic number using defuzzification method (if necessary, output of the system is expressed as a classic number).

Use of Software

Data were analyzed and the models were applied in ARCGIS 9/3 application. Ranking of the parameters was corrected from fuzzy menu of MATLAB and SPSS 14 application was used to verify the model and statistical analyses.

Results and Discussion

Preparing a plan for ranking the index parameters and databases were prepared in EXCEL application considering the required information of the desired index and parameter. Then, the database was converted into the format applicable in ArcGIS.

Fuzzification of Input Values

The first stage of creating fuzzy system is definition of inputs and membership functions. Input parameters are including depth of water table, net recharge, topographic slope, and hydraulic conductivity. Because other three parameters of the drastic model lack intermediate values, they cannot be fuzzified. Gaussian membership function was used to fuzzify the parameters. Each parameter was independently fuzzified in Matlab application.

After fuzzy input parameters, fuzzy rules base is made. Fuzzy rules are expressed with if-then structure and in each of these rules combined effects of the indices are used from the desired viewpoint.

In this research, Sogno Fuzzy Inference Model was used considering the fixed ranks in each of the rules. In this regard, 100 points were separately drawn in a shape file format. Using Extract Values to Points Tool, values of depth of water table, hydraulic conductivity, net recharge, and slope of these points were assigned to them. The resulted table was transferred out of software as an excel file to determine utmx and utmy coordinates of these points.

Gaussian Membership Function was used for input fuzzy sets; constant membership function was used for output fuzzy sets and ***weighted*** averaging method and Sogno Fuzzy Inference Model for defuzzification in this model. At the end, outputs which are real ranks of these values were obtained based on non-fuzzy inputs which are values of the above layers. Finally, table which has been formed from points with coordinates and ranks were entered into GIS software. Using IDW method, the ranked points were interpolated to obtain ranks of all pixels and plans for ranking of the above parameters.

In Boolean logic which is based on drastic method, many vulnerable zones is with very low and very high potential values. They have been neglected and these zones are considered in fuzzy logic and have gained real and suitable percent of vulnerability.

What is observed in inherent vulnerability zoning map of Sarkhon Plain Aquifer with fuzzy drastic method is that the zone inherent vulnerability index varies from 70 to 127 which is included in low and medium vulnerability classes. About 7.8% of the zone has low vulnerability and 92.2% has medium one.

To verify fuzzy drastic model and conventional drastic model, factor of salinity which is one of the most important factors affecting quality of the aquifer of interest was used as pollution index. The higher the quality of water, the more vulnerable the groundwater to pollutants will be. Negative correlation coefficient also confirms this fact. Correlation coefficient is -0.526 in fuzzy drastic model and -0.066 in drastic model. In fuzzy drastic model, we will have lower EC in case of higher vulnerability which shows fuzzy verification. It can be concluded that drastic fuzzy model is more accurate than conventional drastic model.

At the end, fuzzy model was used as top option of inherent vulnerability of the studied zone and there are low vulnerability of 7.8% and medium vulnerability of 92.2% in two classes. Generally, the results of this research confirm fuzzy modeling of hydro geologic parameters which have inherent uncertainly.

Keywords: drastic, fuzzy theory, overlapping index, spearman correlation, vulnerability assessment.