Determination of Groundwater Quality Using a GIS-AHP Based System and Compared with Wilcox Diagram (Case Study: Rafsanjan Plain)

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ABSTRACT

Determining the quality of groundwater is one of the key elements of water usage in drinking, agriculture and industry sectors. Rafsanjan plain is one of the most economical plains in the country due to the existence of pistachio orchards. Therefore, proper management and careful study of groundwater in this plain is an essential need. The present study was conducted to evaluate the groundwater quality of the Rafsanjan plain with agricultural applications. In the first stage, after selecting the effective parameters in water quality assessment, weighting was performed by Analytic Hierarchy Process (AHP) method and then the groundwater quality of the study area was determined using GIS software and bases on water quality standard provided by University of California. According to the results of the final zoning of groundwater quality, about 1.6% of the study area has very good quality, 20% has medium quality, 52.7 has poor quality and 25.7 has very poor quality. In addition, based on the statistical analysis of Wilcox diagram, 1.5%, 16.2%, and 60.2% of the wells in the study area had good, medium and poor quality, respectively. Moreover, 22.1% of the wells are not included in the diagram due to very poor quality. This research revealed that a GIS-AHP based method can analyze these kind of data spatially and consistent results could be obtained.

KEYWORDS

Determination of Groundwater Quality, Rafsanjan Plain, Analytical Hierarchy Process, Geographical Information System, Wilcox Diagram.

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1. Introduction

One of the most important sources of water for agriculture purposes is groundwater specially in Rafsanjan plain in Iran because of low precipitation and its very vast pistachio orchards. Therefore, it is crucial to perform further research to use the new and accurate tools to determine groundwater quality of plains [1].

The objective of this research was to determine groundwater quality of Rafsanjan plain, with a simple, valuable and powerful tool such as GIS and AHP method. Finally, Wilcox diagram which is a statistical based method was used to validate the results of water quality zoning map and verify its authenticity and integrity.

2. Methodology

2.1. Study area and Data

The study area is Rafsanjan plain located in central Iran with an area of 12513.7 km^2 and an altitude varying from 1400 m to 3443 m from see level. The annual mean precipitation is 107.6 mm which obligated the farmer to use mostly the groundwater resource.

For data collection, 68 wells were chosen for sampling. The data were collected by Regional Water Organization of province in winter 2016. These data were chosen based on the criteria for assessing the suitable water for agriculture purpose which are corresponding to two parameters used in the Wilcox diagram as well (Figure 1). These parameters are Electrical Conductivity (EC), Total Dissolved Solids (TDS), Sodium Absorption Ratio(SAR), Chloride (Cl) and Bicarbonate (HCO3).

2.2. Method of research

The first step to achieve the goal was to map spatially the effect of each parameter in the study area based on sampled data. In order to find out the affected zone by each parameter/well, the Kriging interpolation method was carried out in ArcGIS software which is one of the best statistical methods. After reclassifying operation, resulting maps were derived which represent different level of parameters distribution spatially.

The next step consists to integrate the resulted maps and to create final map which will represent the quality map of groundwater. However, each of these criteria has different importance in groundwater quality assessment. In order to find out which one has more contribution a set of options which are based on various criteria, multi-criteria decision making methods must be used [2].

One of these methods is Analytical Hierarchy Process (AHP). It represents an accurate approach to quantifying the weights of decision criteria. Individual experts' experiences are utilized to estimate the relative magnitudes of parameters through pair-wise comparisons. Each of the respondents compares the relative importance each pair of items using a specially designed questionnaire and a weight will be calculated for each parameter [3]. Expert Choice software was used to calculate the weight of each criterion.

In final stage the parameters will be combined multiplying with assigned weight and the groundwater quality map will be calculated.

2.3. Validation

Nowadays, Wilcox diagram is a very common classifier for agriculture waters quality. In this category two factors; electrical conductivity and sodium absorption ratio were considered, each of them was divided into four sections causing a total of sixteen water quality groups. Different groups in the Wilcox diagram were fitted. Figure 1 shows this diagram.

Now comparing the results obtained by GIS-AHP method with Wilcox diagram will be performed to validate the proposed method.

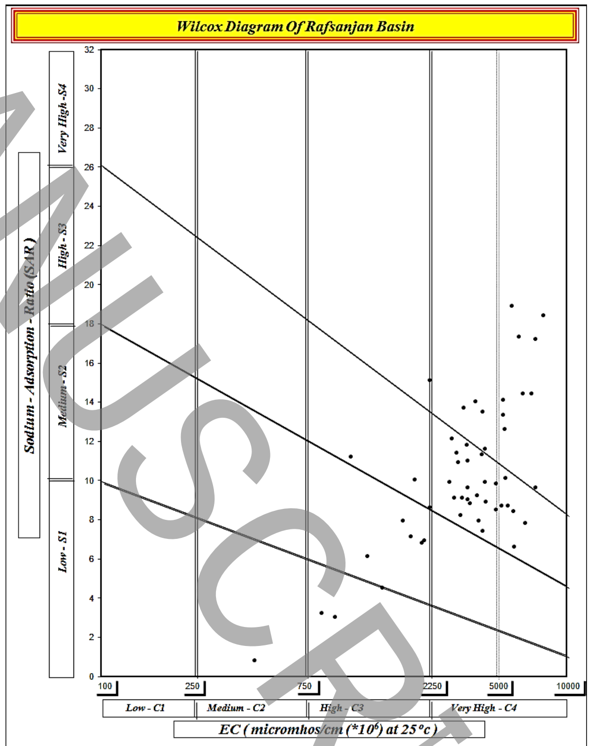

Figure 1. Wilcox diagram

3. Result and discussion

The parameters' zoning maps were combined in ArcGIS with each other considering their weight extracted from analytic hierarchy process (Figure 2) and the final groundwater quality map was calculated (Figure 3). According the final locating water quality map, approximately 1.6% of the area associated with very good quality zone, 20% in the medium quality zone and, 52.7% and 25.7% were located in the poor quality and very bad quality zones respectively.

In addition of providing maps and spatial data quality, the water quality for agriculture consumption was verified based on Wilcox diagram. This method is a statistical method and good quantitative information can be achieved. According the diagram 1.5% water wells with good quality, 16.2% with medium quality, 60.2% with poor quality were qualified and 22.1% due to their poor water quality did not placed in the diagram. By comparing the results, it can be noted that the two methods are close to each other and do not have much difference. Minor differences could be due to differences in the method parameters, selecting the interpolation method for mapping, the relative situation of wells on the zoning map or Wilcox diagram.

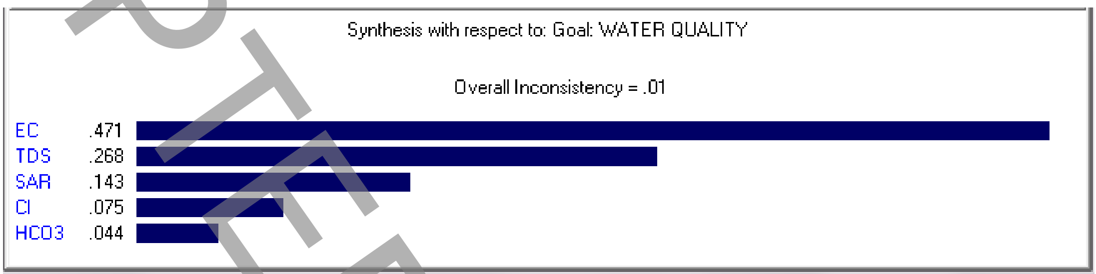

Figure 2. The final weight calculation parameters using AHP

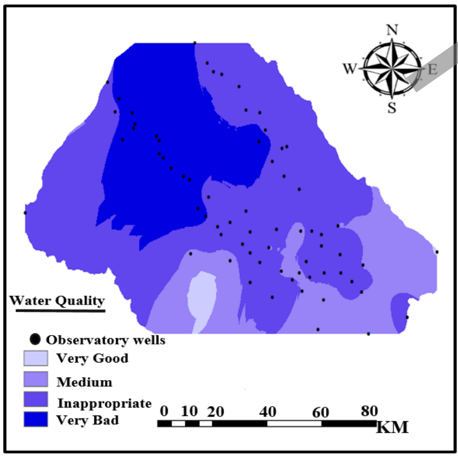

Figure 3. The final Groundwater quality map

4. Conclusions

In this research two methods for locating groundwater quality of Rafsanjan plain were used. One by using GIS and AHP methods, and the other by using the Wilcox statistical method. In fact, comparing the above methods revealed that the produced maps correspond to the results of the Wilcox diagram. Therefore, the proposed method not only helps to locate the water quality zoning but also it could be a big help in decision with more confident. In fact, one of the goals of GIS is to create decision-making power for water management with a point of view to solve the problems spatially.

A number of technical and management solutions to reduce water consumption in agriculture using the groundwater quality map are as follows:

Training farmers and rural people for water consumption and water-saving, managing agricultural water pricing, track and block unauthorized wells, installation of water and electricity smart meters on wells, operating agricultural wells during certain hours of the day, check its suitability for cultivation, use proper irrigation methods and in accordance with the type of culture, commissioning of water transmission lines in the fields and gardens and planting drought resistant varieties.

5. References

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