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Evaluation of Groundwater quality (Cases study; marvdashtand Arsenjan, Fars province, Iran)

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Abstract

Groundwater quality is an important water resource for irrigation, and agriculture needs. In this paper, fuzzy method (fuzzy set as a class of objects with a continuum of grades of membership) and AHP method (for weighting to each of the layers) were evaluated for groundwater quality classifications. In this paper, a Fuzzy rule-based system is reported to assess the quality of water for portability based upon the concentration of salts. The GIS-based groundwater quality classification needs different parameters maps as inputs, such as Ca, Cl, PH, Mg, So4 and TH. In this research was used groundwater quality data from about 100 bore wells collected between 1970 and 2007. The results showed that the fuzzy method classified the region into 4 classes (low, moderate, high and very high). Generally, about 47% of the studied area is classified as moderate, 40 is classified as high and 13 % of that had low. So application of the fuzzy method is a promising way to determine groundwater quality.

1. Introduction

Groundwater quality degradation due to agricultural practices and conversion of land to agriculture has been well described by Novotny. Aliabadi and Soltanifardwere used Fuzzy and GIS for determination of water quality the results showed that 76 percent of accuracy for the method of Mamdani and 52 percent of accuracy for the method Sugeno was achieved for determination of water quality [1]. Burkart and Stener used fuzzy inference system for nitrogen fertilizer and soil fertility in the crop wheat. According to their findings, the best place to grow wheat was one with a small amount of soil electrical conductivity, high altitude and low slope [2].

Moreover, vulnerability of groundwater to agricultural chemicals has been studied to develop new strategies [2 and 3]. Various papers have already considered engineering applications of neural-fuzzy modeling in hydro-geological-based systems. In one of these studies, Chang et al. have shown that using ANFIS for real-time reservoir operation modeling is practicable and effective [4]. Recently, neuron-fuzzy techniques have been applied to predict groundwater vulnerability using GIS [4, 5 and 6]. Shobha et al. used fuzzy method for assessment of ground water portability in South India [7]. Another articles presented by Liou and Lo [9] have investigated reservoir water quality by applying self-organizing maps and fuzzy theory.

The US EPA (1994) concluded that "more than 75% of the states reported that agricultural activities posed a significant threat to groundwater quality" [11, 12 and 13]. In this paper the aim is using of fuzzy-AHP method to assess the quality of ground water in Marvdasht and Arsenjan, Fars province, Iran.

2. Material and Methods

2.1. Study area

This study was conducted in Marvdashtand Arsenjan, Fars province in southeast of Iran. The study area located between 29° 18´ to 30° 25´ northern latitude and 52° 14´ to 53° 30´ eastern longitude (Figure 1). The area of the study area is 3941 km2.

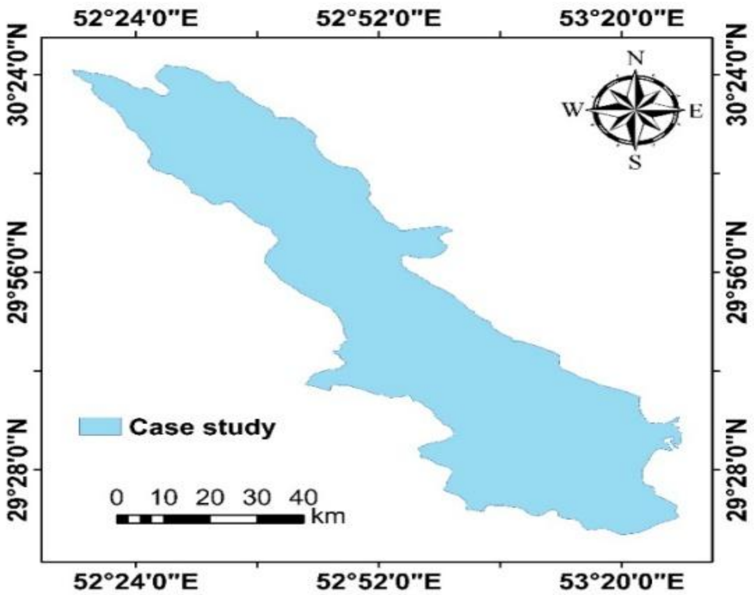


Figure 1: Location of the study area.

In the study for access groundwater quality was used Ca, Cl, PH, Mg, So4 and TH. The summary of data information is in the Table1.

Table1: statistic informationofdata

Parameters	*Minimum*	*Maximum*
Ca (mg/liter)	1.5	80
Cl (mg/liter)	0.2	320
pH (mg/liter)	6.9	8.5
Mg (mg/liter)	0.29	86.5
So4 (mg/liter)	0.2	34.6
TH (mg/liter)	150	7042

2.2. Inverse Distance Weighted (IDW)

Due to the lake of sample points of groundwater and low RMSE using Inverse Distance Weighted (IDW), for preparation of interpolation map for each layers was used IDW method. IDW interpolation explicitly implements the assumption that things that are close to one another are more alike than those that are farther apart. To predict a value for any unmeasured location, IDW will use the measured values surrounding the prediction location. Assumes value of an attribute z at any unsampled point is a distance-weighted average of sampled points lying within a defined neighborhood around that unsampled point. Essentially it is a weighted moving average [2]:

$$\hat{z}(x_0) = \frac{\sum_{i=1}^{n} z(x_i) d_{ij}^{-r}}{\sum_{i=1}^{n} d_{ij}^{-r}} \tag{1}$$

Where x_0 is the estimation point and x_i is the data points within a chosen neighborhood. The weights (r) are related to distance by d_{ij}.

2.3 Fuzzy AHP method

Fuzzy logic was initially developed by Zadeh (1965) as a generalization of classic logic [14]. Zadeh defined a fuzzy set as "a class of objects with a continuum of grades of memberships". A membership function assigns to each object a grade ranging between zero and one .The value zero means that x is not a member of the fuzzy set and value one means that x is a full member of the fuzzy set.

Traditionally, thematic maps represent discrete attributes based on Boolean memberships, such as polygons, lines and points. Mathematically, a fuzzy set can be defined as following [10] :

$$A = \{x, \mu_A(x)\} \quad \text{for each } x \varepsilon X \tag{2}$$

Where μ_A is the function (membership function, MF,) that defines the grade of membership of *x* in A fuzzy set. The MF takes values between and including 1 and 0 for all A that μA =0 means that the value of x does not belong to A and μA=1 means that it belongs completely to A. Alternatively 0<μA(x) <1 implies that x belongs in a certain degree to A. If X={x_1,x_2,…,x_n} the previous equation can be written as following [14]:

$$A = \{[x_1, \mu_A(x_1)] + [x_2, \mu_A(x_2)] + \ldots\ldots + [x_n, \mu_A(x_n)]\} \tag{3}$$

In simple terms, Equations (2) and (3) mean that for every x that belongs to the set X, there is a membership function that describes the degree of ownership of x in A. The following function was used for salts [8, 12].

$$\mu_A(X) = f(x) = \begin{Bmatrix} 0 & x \le a \\ x - a / b - a & a \prec x \prec b \\ 1 & x \ge b \end{Bmatrix} \tag{4}$$

In order to definition of fuzzy rule was used Table 2:

Table 2: Drinking water quality standards (WHO)

Salt	Desirable limit (mg/liter)	Permissible limit (mg/liter)
Calcium (Ca)	75	200
Chlorine (Cl)	250	1000
Magnesium (Mg)	30	100
Thorium (TH)	300	600

The AHP is a structured technique for organizing and analyzing complex decisions. This method is based on a pair wise comparison matrix. A pair wise comparison matrix is called consistent if the transitivity Equation (5) and the reciprocity Equation (6) rules are respected.

aij = aik · akj (5)

aij= 1/ a ji (6)

Where i, j and k are any alternatives of the matrix.

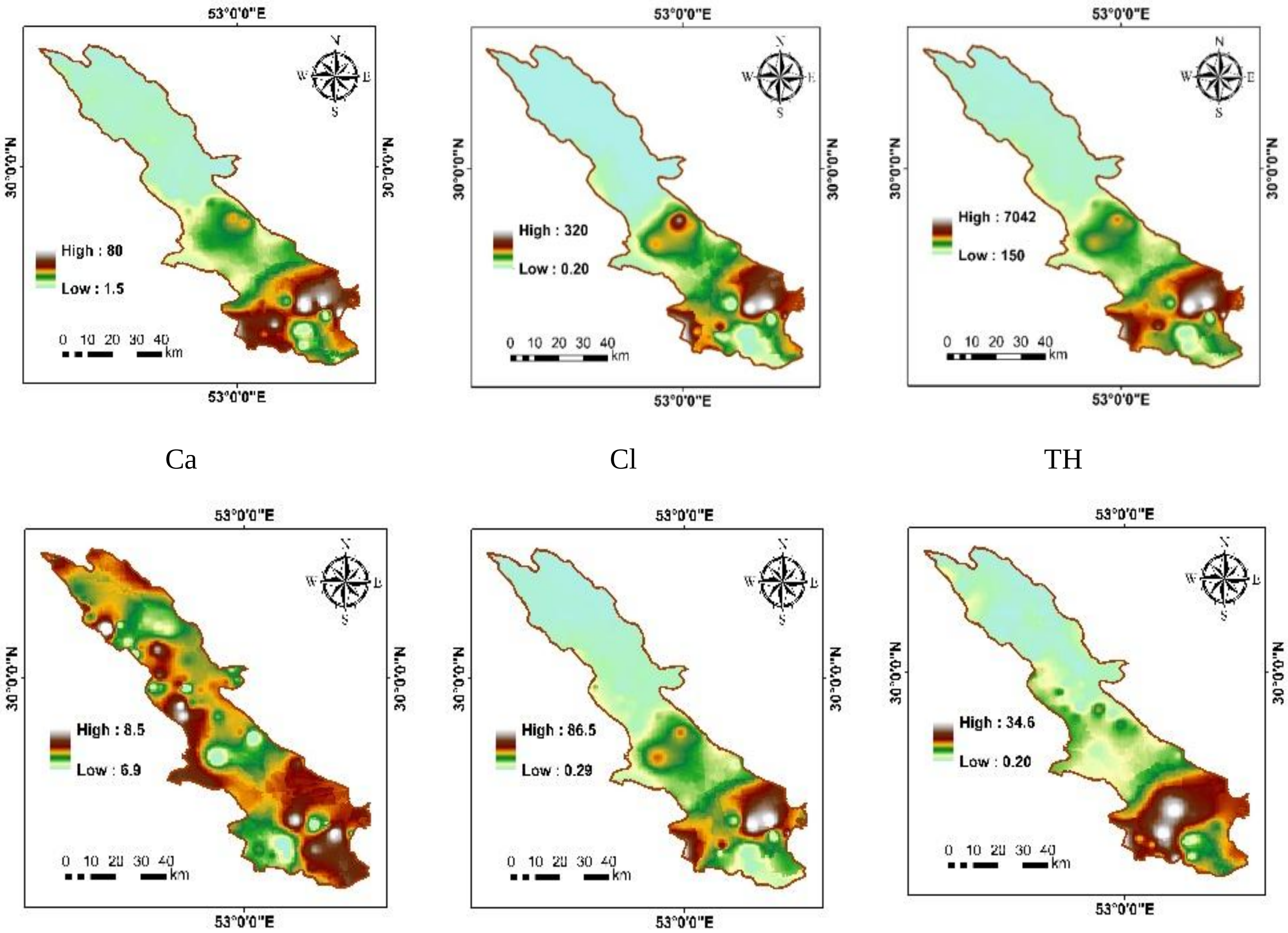
For classification of ground water quality used Table 3. Based on the final map of groundwater quality that classified into four categories include: high, low marginal and moderate to describe the quality of water as shown in Table 3.

Table 3: Groundwater Classification by calculated Fuzzy values [12]

Fuzzy	Groundwater	Class
0 – 0.25	Highly quality	1
0.25 – 0.5	Moderate quality	2
0.5 – 0.75	Marginal quality	3
0.75 - 1	Non suitable	4

3. Results and discussion

In this paper used the IDW for interpolation of groundwater data. IDW interpolation produces show in Figure 2. The lowest outputs in IDW are 1.5, 6.9, 0.2, 0.2, 0.29 and 150 for Ca, PH, Cl, So4, Mg and TH respectively. While the highest output in IDW are 80, 8.5, 320, 34.6, 86.5 and 7042 for Ca, PH, Cl, So4, Mg and TH respectively.



Ca Cl TH

pH Mg So4

Figure 2: IDW map for each salt in the study area

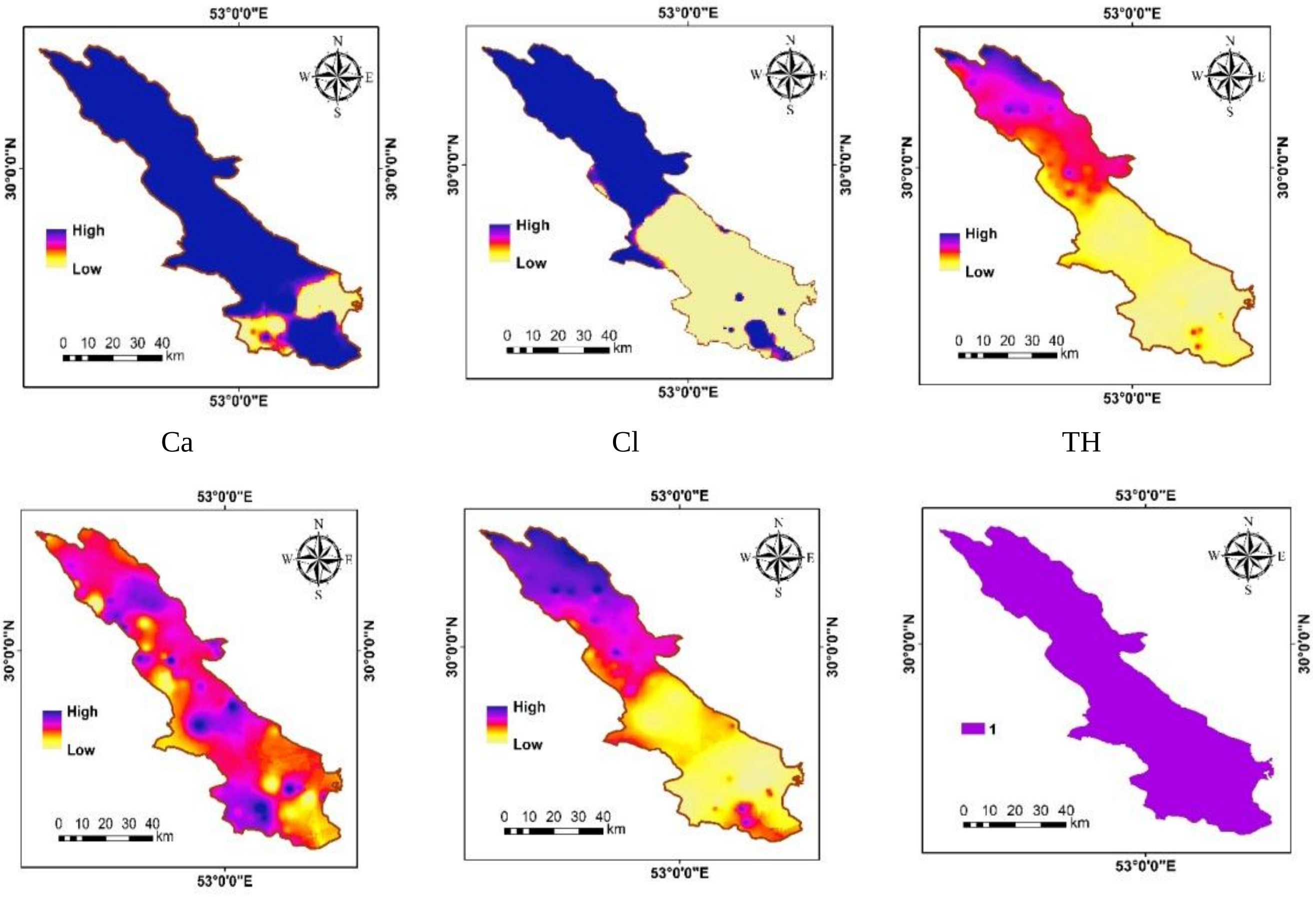
The best fuzzy membership was achieved by using the linear functions (Equations 4). The fuzzy Linear membership function transforms the input values linearly on the 0 to 1 scale, with 0 being assigned to the largest input value and 1 to the lowest input value. For preparation of fuzzy maps for each layer was used ArcGIS software and was created fuzzy map. The resulting maps for each parameter are shown in Figure 3.

In order to groundwater quality map was used AHP weights The AHP weights for each parameters show in Table 4. The Fuzzy-AHP is shown in Figure 4 and the area of the classes show in Table 5.

As shown in Figure 5 and Table 3, the fuzzy method classifies the region into 4 classes (low, moderate, high and very high). Generally, about 47% of the studied area is classified as moderate, 40 is classified as high and 13 % of that had low.

Table 4: AHP Weights assigned to each salt based on our input dataset

Parameters	Mg	Ca	So4	TH	Cl	pH	Weight
mg	1	2	3	4	5	6	0.37
ca	1/2	1	2	3	4	5	0.24
so4	1/3	1/2	1	2	3	4	0.16
th	1/4	1/3	1/2	1	2	3	0.10
cl	1/5	1/4	1/3	1/2	1	2	0.08
ph	1/6	1/5	1/4	1/3	1/2	1	0.05



Ca Cl TH

pH Mg So4

Figure 3: Fuzzy map for each input for the study area

Table 5: The area of each class for salt

Class	Area (%)	Area (km^2)
Low	13	512.33
Moderate	47	1852.27
High	40	1576.4
Very high	0	0

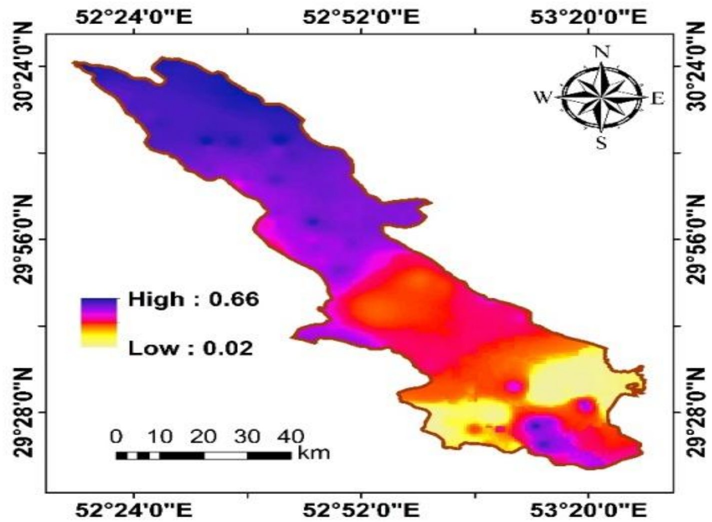


Figure 4: The fuzzy-AHP map

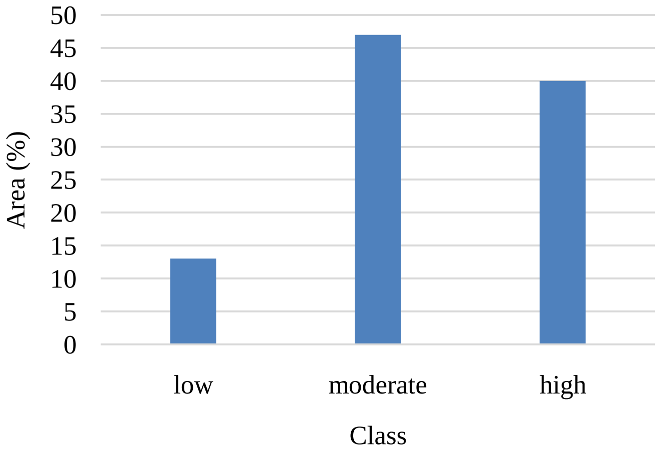


Figure 5: Area of each fuzzy class

The results of the study area showed that using fuzzy method should create groundwater map with high accuracy. Rahimi and Mokarram (2012) used fuzzy logic in GIS for prediction of groundwater quality. The results showed that the fuzzy method had high accuracy for prediction of groundwater quality [12]. Also Aliabadi and Soltanifard used fuzzy method for determination of groundwater quality. The results showed that Mamdani method had high accuracy the determination of water quality [1].

Conclusion

In this paper, fuzzy-AHP method was evaluated for groundwater quality classifications. The GIS-based groundwater quality classification needs different parameters maps as inputs, such as Ca, Cl, PH, Mg, So4 and TH. First of all we used IDW method to interpolate of each parameter, and then used fuzzy method to preparing fuzzy map for each input. Results showed that the fuzzy method classified the region into 4 classes (low, moderate, high and very high). Generally, about 47% of the studied area is classified as moderate, 40 are classified as high and 13 % of that had low. So application of the fuzzy method is a promising way to determine groundwater quality.

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