Bulletin of Environment, Pharmacology and Life Sciences
Bull. Env. Pharmacol. Life Sci., Vol 3 [11] October 2014: 175-180

Online ISSN 2277-1808
Journal's URL:http://www.bepls.com
CODEN: BEPLAD
Global Impact Factor 0.533
Universal Impact Factor 0.9804

ORIGINAL ARTICLE

Evaluation of EC and CL spatial Variation and Zoning of Groundwater Designed for use in Sprinkler Irrigation Plain Borojerd

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ABSTRACT
Ground water is the most important source of water for agriculture, drinking water and industry. Therefore, the quality assessment has particular importance. The purpose of this study was to determine the most appropriate interpolation method to analyze spatial variations of some of the most important characteristics of groundwater, including the EC and CL in Borojerd plain the northeastern Lorestan Province. For this purpose, zoning mapping data from 22 wells were used. Interpolation methods used in this study include the geostatistical method of kriging and IDW and RBF methods. The results showed that both EC and CL circular kriging model due to having a lower RMSE is the best method. The results showed that the most restrictive in terms of water quality for irrigation sprinkler systems located in regions of Central and East Borojerd and the water obtained from these wells cannot be used in sprinkler irrigation systems.
Keywords: *Interpolation, geostatistics, zoning, kriging, sprinkler irrigation.*

Received 21.05.2014 Revised 03.07.2014 Accepted 22.09. 2014

INTRODUCTION

Since water is one of the basic sources of production in the country, the necessity and importance of careful study and understanding of water resources and timely statistics is clear. Given the importance of groundwater resources in our country, in terms of quantity and quality of resources must be carefully study and proper procedures are utilized correctly and with maximum efficiency and ultimately reach the consumer. For optimal management of water resources and the protection and enhancement they require is to position data fields, water amount and distribution of chemical elements in a defined geographical area. Parameters affecting the quality of irrigation water can be named CL and EC Can be defined using the classification of sprinkler irrigation and limit defined by two parameters, CL and EC prone areas to run irrigation systems to water quality rain suit each region will determine the GIS environment [1].

Interpolation methods can be used to study the dispersion properties of ground water. There are several methods for interpolation. One of the methods to estimate the spatial variation of variables of water quality is geostatistical methods. The main difference is that classical statistical methods in classical statistical samples drawn from a population, are independent of each other and do not give any information about a sample the next sample. However, geostatistical methods, the spatial correlation between the values of variables are examined in a region. In general we can say that the geostatistics will examine those variables that are spatially structured or spatial relationship exists between in different quantities, distance and direction to get those [2].

Of geostatistical methods for mapping of groundwater quality variations can be noted kriging and cokriging interpolation methods, inverse distance method and the radial basis function as the classical methods.

Shabani [3] during studies of spatial analysis, pH and TDS in groundwater plain Arsanjan, most suitable geostatistical methods can be examined. In this study, 83 wells were sampled. Method of ordinary kriging, simple kriging and deterministic methods such as inverse distance methods, the radial function, universal and local estimator were compared. In general, ordinary kriging for interpolation of TDS and pH were recommended.

Sheng et al. [4] Evaluation of groundwater quality in Ping Tong plain, Taiwan conducted using kriging. In this respect, indicators, EC, TDS, chloride, sodium, magnesium, calcium, sulfate, iron and manganese were measured in 30 wells. Ostovari et al. [5] examined the spatial variation of water quality indices for Lordegan plain drip irrigation. In this study, indices, EC, TDS, TSS, pH and LI index of 32 agricultural wells were evaluated. Variogram was plotted for each component and the proper model was fitted. In a comparison of kriging and inverse distance, kriging was about 15% higher precision. The maps showed Lordegan aquifers except the northern part was suitable for drip irrigation. Taghizadeh Mehrjardi et al. [6] study spatial variations in groundwater salinity using geostatistical kriging and IDW in Rafsanjan plain and RMSE were used to evaluate methods. Finally, the model showed that the Rafsanjan plain geostatistical kriging provided a good estimate of the salinity of the area. Fetouani, et al. [7] study the groundwater quality in the North East Morocco Tryfa agricultural plains of ammonium Nitrate used ordinary kriging method to study groundwater quality zoning map.

In this research for the analysis of spatial variations in water quality parameters EC and CL Borojerd plain using the interpolation methods, have been trying to determine the best method, Zoning maps and two qualitative parameters are defined according to the classification of sprinkler irrigation are plotted and analyzed.

MATERIAL AND METHODS

Study area

Borojerd city is located in the northeast of the Lorestan province, Iran. It consists of alpine Zagros region in the West and South, Silakhor plain in Center and the Zagros Mountains in interior East and North. The highest point with an altitude of 3623 meters locates in the Vlash Peak Mountain in West of Borojerd and lowest in the area with an altitude of approximately 1,500 meters is plain Silakhor. Borojerd city of North widths of at least 33 degrees and 36 minutes and a maximum of 34 degrees and 6 minutes and longitude 48 degrees 27 minutes and the maximum is located at 49 degrees 27 minutes.

Borojerd has a mountain temperate climate with temperate summers and cold winters, the maximum and minimum temperatures often 40 to 20 degrees below zero. The city is 480 mm rainfall in the cold season precipitation is mostly snow. In this study, in order to map the spatial distribution of groundwater quality variable data is used from 22 wells of the area aquifer. These data are included in EC and CL. Figure 1 shows the location Borojerd city in the Lorestan province, and Figure 2 shows the location of wells sampled.

Figure 1 – Location of Borojerd

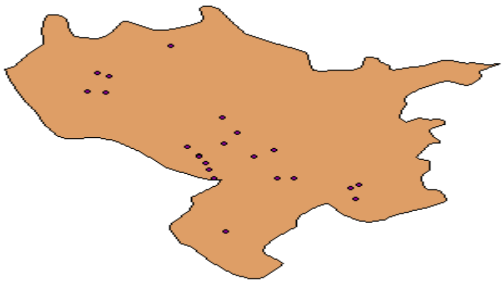

Figure 2 - Location of wells sampled

Evaluation of the spatial continuity of variables:

Variables were used to assess the spatial continuity of the variogram method. The overall objective of the variogram calculation is determining the spatial variability of the variable relative to the distance or time.

Important indicators for each variogram are range, sill and nugget effect. In this study, it used four models of circular, spherical, exponential and Gaussian variogram to determine the best model.

Kriging method

Kriging, a geostatistical estimation method that is based on logic weighted moving average. The best linear unbiased estimator is said to be this way in the form of the relationship is expressed as:

$Z^*(xi) = \sum \lambda i.\ Z\ (xi)$

Z*(xi) is predicted value at point xi, Z (xi) observed value at point xi, λi weight or importance of i sample. The condition of this estimate is that the variable Z is normally distributed [2].

Inverse distance weighting

A deterministic interpolation method is that in this way the value of a variable is calculated based on the average of neighbors in a given area. Thus the inverse distances from the unknown point are considered as the weight. The distance from the point of known and unknown reduce the weight increases and where they are unknown values are estimated using points around a specified radius.

Radial basis functions method

Radial basis function interpolation method is the method which estimation surface passes from observational data. This method is the mode of neural network. Other characteristics of this method are that the observed values of exceeding the maximum or less than the minimum values observed exist in estimation surface [8].

Assessment criteria

The cross-validation method is used for performance evaluation methods. This method temporarily sets of observational data sample points are removed and a value at that point is obtained using other parts. The result of a series of observed and predicted values to values that are used to assess the validity of interpolation methods. In this study, the observed and predicted values using root mean square error (RMSE) were compared.

RESULTS

Since the kriging method for interpolation of data must be normalized before interpolation, the data were examined for normality. Since all data had high skewness, were detected abnormal and taking the logarithm was used for normalization (Table 1).

Table 1 - Descriptive statistics of variables

Variable	Min	Max	Mean	Standard deviation	Skewness	Kurtosis
Cl	0.2	3.8	1.01	1.029	1.436	3.8
Cl*	-1.6	1.33	-0.39	0.88	0.6	2.18
EC	315	1383	589.5	277.4	1.39	4.16
EC*	5.75	7.23	6.29	0.4	0.78	2.61

* Logarithmic

Variogram analysis

Variogram analysis for the variables are plotted EC and SAR seems to be like a circular variogram. Figures 3 and 4 show the fitted variogram of the variables studied. The variogram parameters fitted for each of the quality parameters are given in Table 2.

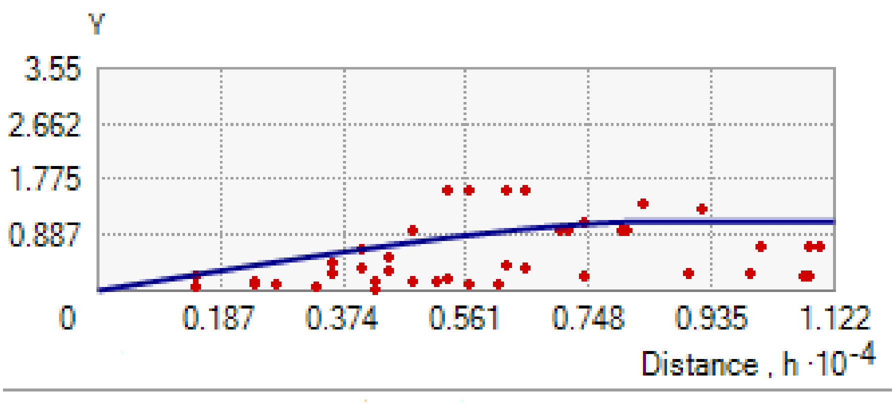

Figure 3- Variogram of Cl

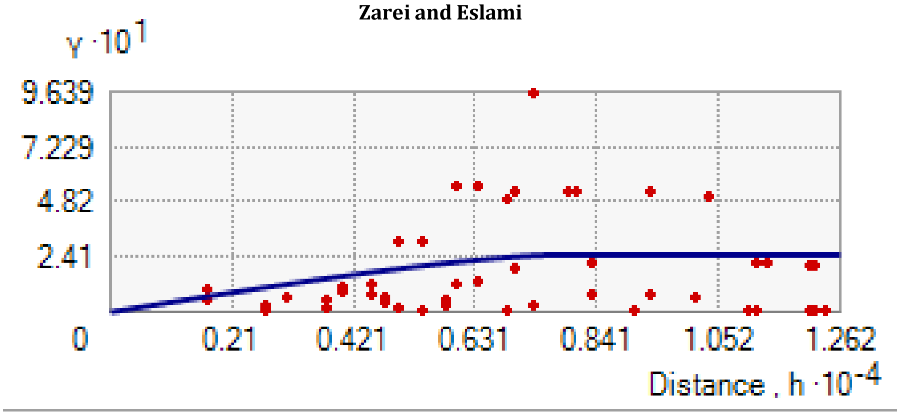

Figure 4- Variogram of EC

Table 2- The best model variogram and variogram characteristics for each parameter

Variable	Model	Nugget (C0)	Sill (C0+C)	Range (m)	C0/C0+C	Spatial correlation
Cl	Circular	0.008	1.09	8180	0.007	strong
EC	Circular	0	0.25	7790	0	strong

Nugget effect than the sill (C0/C0+C) is an indicator of the strength of the spatial variables. If this ratio is less than 0.25, which is indicative of strong spatial correlations and if this ratio is between 0.25 - 0.75 moderate spatial dependence can be represented as the ratio greater than 0.75 would be indicative of a weak spatial dependence [5]. The (C0/C0+C) is less than 0.25 which represents the high spatial continuity and precision of the fitted model which has a significant role in enhancing the estimation accuracy.
Assessments of groundwater quality variable interpolation method are presented using kriging, inverse distance and radial function methods in Table 3. For the amount of CL kriging and RBF methods are most appropriate in certain ways due to lower RMSE.
The circular kriging model due to lower root mean square error and the strong spatial dependence is most useful for zoning. EC is not recommended for deterministic methods use due to high root mean square error. According to Table 3 zoning suitable method for determining the status of EC is the circular kriging model.

Table 3- Evaluation results of different interpolation methods for mapping groundwater quality parameters using RMSE

Interpolation method	Kriging	IDW				RBF				
		Power 1	Power 2	Power 3	Power 4	CRS	SP	MQ	IMQ	TPS
CL	0.6	0.83	0.779	0.8	0.84	0.737	0.734	0.759	0.746	0.9
EC	189.04	236.2	225.01	232	240.5	213.7	212.1	220.2	218.5	295

Limit values for each parameter and problematic area of sprinkler irrigation methods are presented in Table (4) and zonation map has been prepared according to this limits.
So given that kriging most accurate method of estimating the parameters of the interpolation points is unknown, this method was used for the preparation of zoning maps parameters EC and CL. Figures of 5 and 6 show the central and eastern parts of the study area are not suitable for sprinkler irrigation.

Table (4) limits the parameters of sprinkler irrigation method

Degree of water quality	Without problem	probleming	dangerous
EC (mmhos/cm)	< 0.7	0.7 - 3	> 3
CL (meq/lit)	< 3	> 3	-

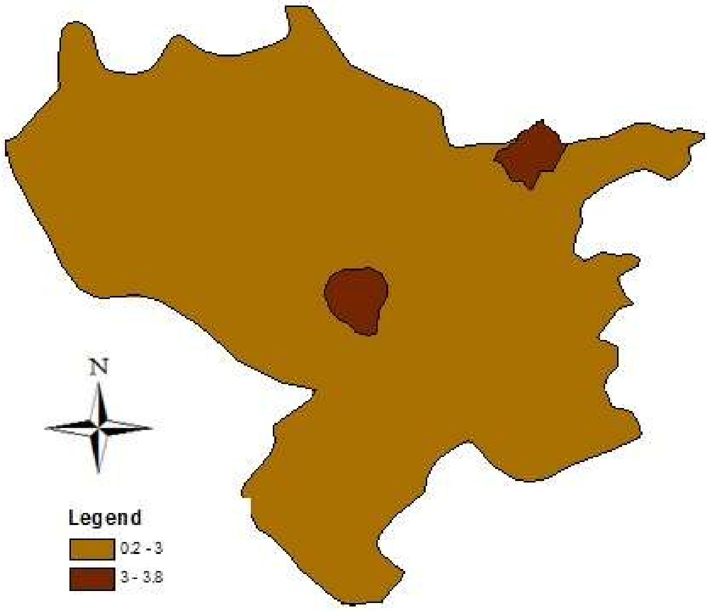

Figure 5- Zoning map of CL (meq/lit)

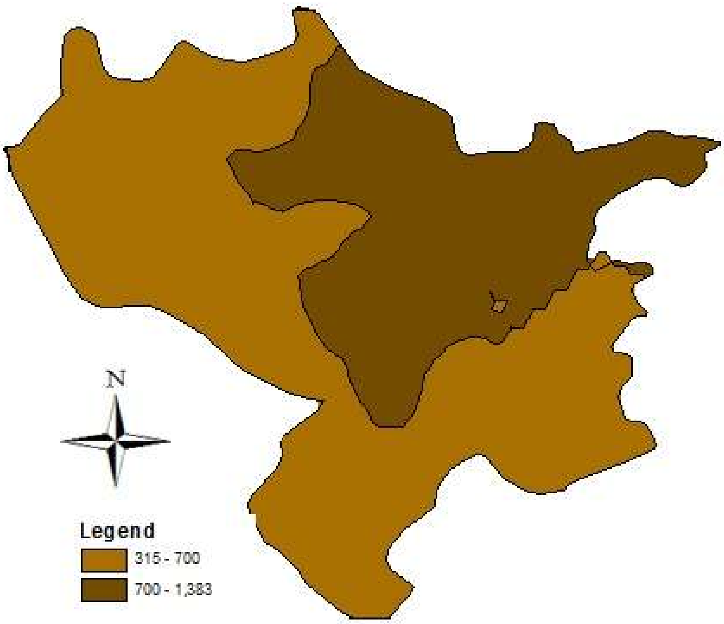

Figure 6- Zoning map of EC (mmhos/cm)

CONCLUSION

This study was to investigate the most appropriate method to analyze spatial zoning changes as the EC and CL of Borojerd groundwater.

Kriging with a circular model is the most appropriate interpolation method for both parameters of Cl and EC. Overall geostatistical method gives better results. These results with results from others include Taghizadeh Mehrjardi et al. [6], Shabani [3] and Saghaei [1] is consistent.

Groundwater zoning of Borojerd according to limit values for sprinkler irrigation in each parameter was performed using kriging. Survey maps showed the greatest limitation is the quality of water for sprinkler irrigation system in central and east regions Borojerd plain. Water from existing wells cannot be used in sprinkler irrigation systems. According to the EC and CL, there is no limitation of use sprinkler irrigation in most parts of the plain.

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CITATION OF THIS ARTICLE
Zeinab Z, Hossein E. Evaluation of EC and CL spatial Variation and Zoning of Groundwater Designed for use in Sprinkler Irrigation Plain Borojerd. Bull. Env. Pharmacol. Life Sci., Vol 3 [11] October 2014: 175-180