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ORIGINAL ARTICLE

Geostatistical Evaluation of Ground Water quality Distribution with GIS (Case Study: Mianab-Shoushtar Plain)

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ABSTRACT
Management of ground water is very important to meet the increasing demand of water. Ground water deterioration is receiving increased attention. In this paper, an application of interpolation techniques (IDW, kriging and cokriging methods) is shown to quantify the spatial variability and to interpolate the ground water quality as measured in part of Mianab plain. Various ground water quality variables (i.e. SAR, TDS, EC and SO4) were found to be spatially evaluated. Results showed that kriging and cokriging methods are superior to IDW method. The spatial dependence of the ground water quality variables was assessed using variogram parameters which varied from 5375 to 8799 m. Results showed that cokriging method has higher accuracy than others. Using cokriging method and GIS, map of Ground water were prepared. As all parameters show, demolition of ground water quality is concentrated on west and south of the region and deterioration of ground water quality in Mianab Plain is serious problem and is not suitable for drink and agricultural uses.
Key words: *Interpolation, saptial distribution, cokriging groundwater quality.*

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INTRODUCTION

Groundwater is one of the major sources of water. It is affected by a number of natural and anthropogenic factors. As groundwater use has increased, issue associated with the quality of groundwater resources have likewise grown in importance. For many years, attention has been directed at contamination from point sources. More recently, concerns have increased about nonpoint sources of contaminant and about the overall quality of groundwater resources. Contaminants in groundwater commonly result from infiltration containing agricultural fertilizers, pesticides, or contaminants from leaking tanks or pipes associated with industry [1]. Groundwater contamination can be detected by analyzing well water for a series of dissolved ion species. Hence water quality data sets typically contain many variables measured at several spatially scattered locations. Mianab plain is an agricultural region and Productive agriculture depends on the availability of good qualitative water.

Appropriate groundwater quality management measures need reliable quantitative information on groundwater quality behavior. There exists a need to study the spatial behavior of groundwater quality. Knowledge of spatial variability of groundwater quality is essential for making reliable groundwater quality interpretations and for making accurate predictions of quality at any particular location in the aquifer. There are different methods for interpolation of data. In classical techniques, the samples are analyzed independent of the spatial position while in geostatistics methods, the spatial position of the samples is also considered. In other words we should be able to make a connection between different values of a quantity in samples and the distance and direction of samples to each other.

In recent years, many scientists have evaluated accuracy of different spatial interpolation methods for prediction of grand water quality parameters. Barca et al. [2] used Disjunctive kriging and simulation methods to make nitrate risk map in 10, 50(mg/l) thresholds, in Modena plain of Italy. Their results showed that Disjunctive kriging method is the suitable method to study deterioration level of

Groundwater. Delgado et al. [3] used kriging to map groundwater quality parameters in Yukatan, Mexico. Based on the generated maps, they classified the study area into different zones in terms of water quality for agricultural uses. Adhikary et al. [4] analyzed spatial variability of groundwater quality in India. They produced probability maps of groundwater contaminants using indicator kriging. Houshmand et al. [5] used cokriging and kriging methods for spatial estimation of Sodium Absorption Ratio (SAR) and Chloride (Cl) concentration in groundwater. For SAR and Cl data, Gaussian model was proved to be the best semivariogram model. Kriging methods were also used by Rawat et al. [6] to predict spatial distribution of some groundwater quality parameters. Because of various results reported by above mentioned researchers, it is obvious that suitable method of interpolation to estimate one variable depends on variable type and regional factors, thus any selected method for specific region cannot be generalized to others. The aim of this research is to evaluate accuracy of different interpolation methods, kriging, cokriging and IDW, for prediction of some Groundwater quality parameters in Mianab-Shoushtar Plain, western south of Iran for agricultural purposes.

STUDY AREA

The Mianab Plain (Fig. 1) is in the north of Khouzestan province, Iran. The total geographical area is 453.2 km2. Average elevation in this region is 32 m above sea level. The average annual precipitation of study area with regard to its arid climate (according to Demartone method) is 254 mm and ETP is 2678mm and mean temperature is $24^{\circ c}$. In this study for spatial prediction of Groundwater quality, 73 data from Khouzestan organization regional water were used. After normality test of data, for interpolation of groundwater quality, kriging, cokrigong and IDW methods were used. Finally, with the use of cross-validation, the best method of interpolation was selected. We proceeded to prepare the map of groundwater quality based on this interpolation and the help of Geographical Information System (GIS).

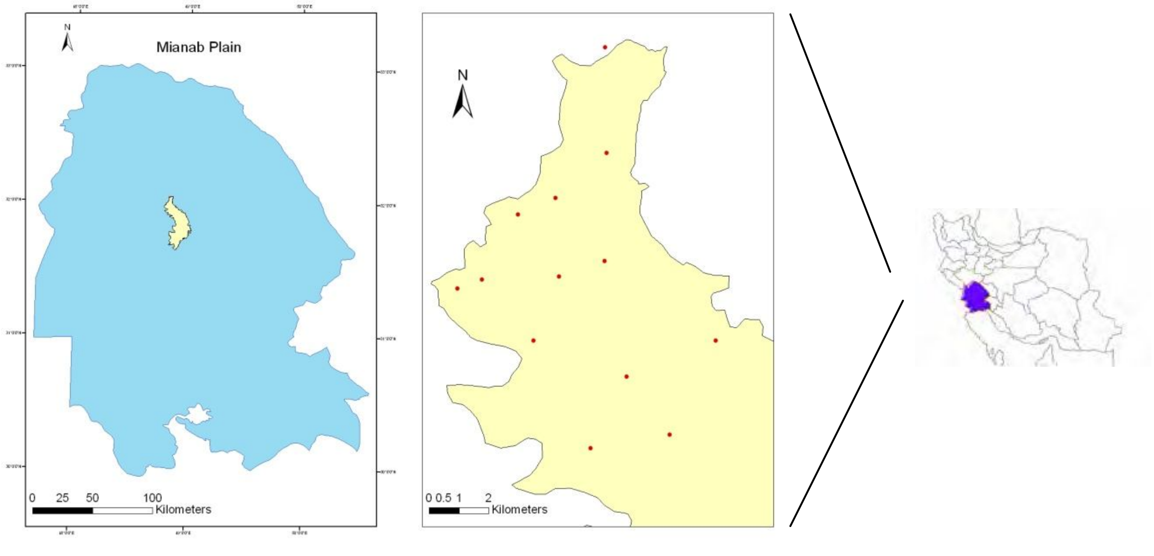

Fig. 1: study area and sampling wells distribution

Interpolation Methods

Interpolation methods are divided to two groups, definitely and geostatistics. In IDW method, weight is function of inverse distance and closer points have more influence in estimating unknown pointes. IDW method general formula includes:

$Z^*(x_i) = \sum\lambda_i.Z(x_i)$

$Z^*(x_i)$ is predicted value at point xi, $Z(x_i)$ observed value at point x_i, λ_i weight or importance of i sample. In kriging method also this equation is used for estimating, but totally it is best way of estimation that find best weight way for $Z(x_i)$ variant. Kriging is an estimating method that is stable on weighty mobile average coincident. This estimator is known as a best unbiased linear estimator. Kriging estimator is based on semi-variogram definition. Variation of variance between of pointes with distance from each other can indicate cross correlation among variable amount, among these points. This related to distance variance which known as a semi-variogram that is indicated by $\gamma(h)$ and defines by this formula:

$$2\gamma(h) = 1/n\sum_{i=1}^{n}\left[Z(xi+h) - Z(xi)\right]^2$$

In this formula $Z(x_i)$ and $Z(x_{i+h})$ are variable values on x_i and x_{i+h} points respectively, n is number of pair samples that used for each distance(h). Every variogram with its parameters means nugget effect, effect range or effect radius and sill are specified. After estimating empirical variables and before estimation process, can select appropriate theoretical model by calibrating suitable mathematical functions to empirical variogram [7Hasanipak,1998). In theoretical viewpoint there are no differences between Cokriging and Kriging methods. Co-kriging method can accomplish estimating process by considering secondary variable which have sufficient data from that and according to cross correlation among main and secondary variables. Co-kriging function is:

$Z^*(x_i) = \sum \lambda_i . Z(X_i) . \sum \lambda_k . y(X_k)$

That $Z^*(x_i)$ is estimated value for x_i , λ_i is weight that related to Z variable, λ_k is weight of secondary variable, $Z(x_i)$ is value of observed main variable and $y(X_k)$ was observed value of secondary variable. Finally, we use the RMSE to evaluate model performances in cross-validation mode. The smallest RMSE indicate the most accurate predictions. The RMSE was derived according to this Equation:

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{n} \left[Z^*(xi) - Z(xi)\right]^2}{n}}$$

$Z^*(x_i)$ is predicted value at point x_i, $Z(x_i)$ observed value at point x_i and n is number of samples. Interpolation and map preparation in Arc GIS software was accomplished.

RESULT

A statistical summary of the groundwater quality properties is presented in Table 1. Data which had high skewness were normalized using logarithmic method. After data normalizing,, experimental variogram was computed. The best model for fitting on experimental variogram was selected based on less RSS value. Also, Table 2 illustrates parameters of Groundwater quality variograms. All parameters of ground water quality have best-fitted variogram model of stable. Also effective range of most parameters is close together and with the range of 5375 to 8799 m.

Table 1: Results of statistical analysis on groundwater quality

variable	min	max	std	mean	kurtosis	skewness
$SO4^{2-}$(meq/L)	2.55	13.13	3.418029	6.319231	-0.00449	0.959542
TDS (mg/L)	1130	3117	668.6511	1754.385	-0.05439	1.150229
TDS (mg/L)**	3.053078	3.493737	0.149399	3.21873	-0.63253	0.834894
SAR	3.69	7.75	1.138405	5.17	0.779911	1.072916
SAR**	0.567026	0.889302	0.090139	0.704535	0.005237	0.665061
EC	1765	4870	1044.71	2741.615	-0.05611	1.149481
EC**	3.246745	3.687529	0.149389	3.412617	-0.63361	0.833941

**Using logarithm to normalize data

Table 2: Best-fitted variogram models of ground water quality and their parameters

Groundwater quality		Model	Nugget (Co)	Sill (CO+C)	Range effect (m)
TDS	kriging	stable	0.1166	0	7124
	cokriging	stable	0	0.151	5375
EC	kriging	stable	0.1166	0	7124
	cokriging	stable	0	0.148	5375
SAR	kriging	stable	0.0422	0	8799
	cokriging	stable	0	0.15	7439
SO4	kriging	stable	11.822	0	5523
	cokriging	stable	0	51.04	5375

Table 3: Results of interpolation methods evaluation using RMSE

Ground water quqlity	Cokriging	Kriging	IDW			
			Exp1	Exp2	Exp3	EXP4
TDS	260.01	675.6	874.6	767	953.7	996.5
EC	322.7	1055	1198.3	1366.5	1490	1556
SAR	0.5256	1.18	1.32	1.49	1.62	1.68
SO4	1.5	3.53	3.95	4.52	4.97	5.24

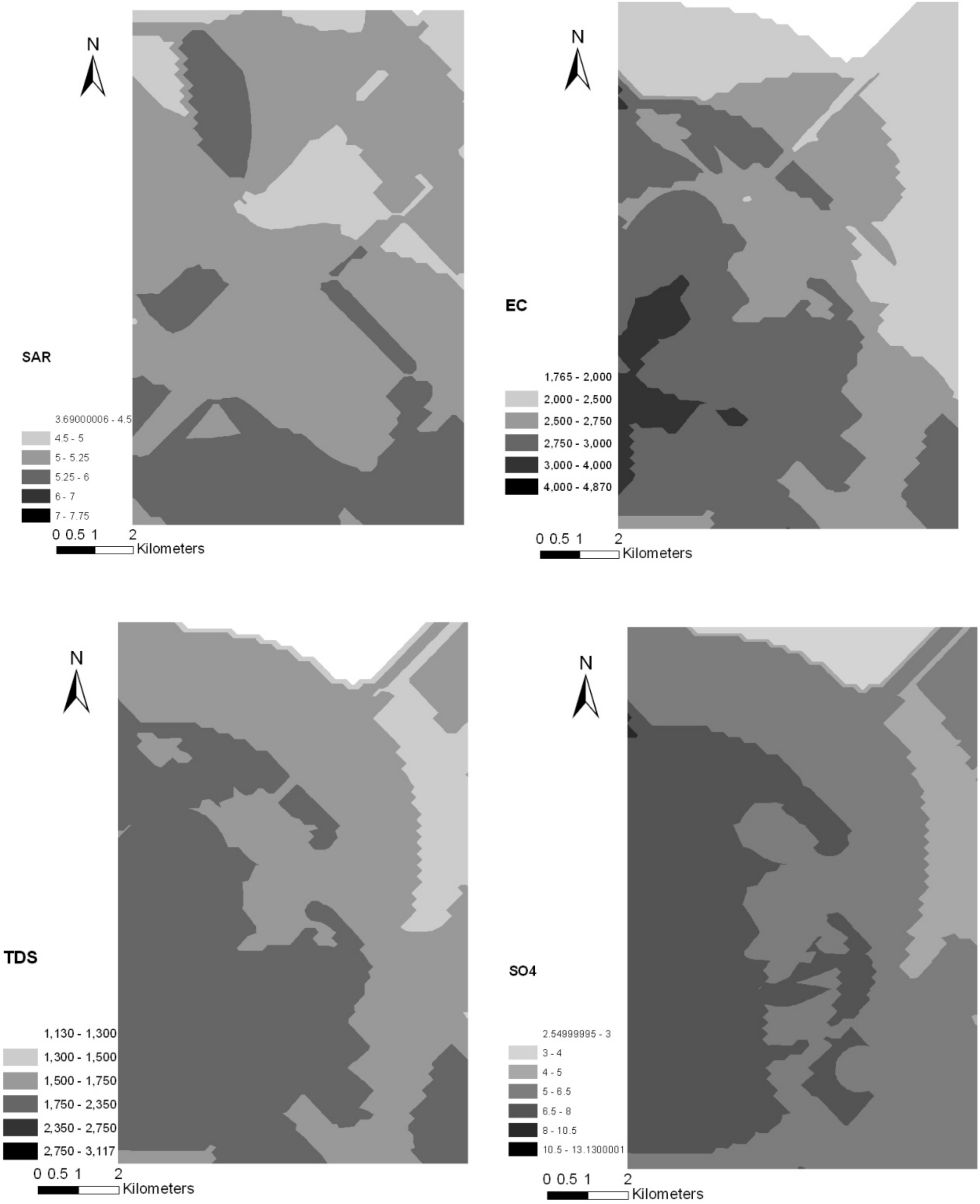

Fig. 2: Interpolation ground water quality map of the parameters of EC, SAR, TDS and $SO4^{2-}$ based on Cokriging method.

In cokriging method, after conducting of correlation matrix, a parameter which has the highest correlation coefficient with primary variable was selected as an auxiliary variable. Consequently, Cl^+ (r=0.94), Na^+ (r=0.95), TH (r=0.98) and Na^+ (r=0.98) variables were selected as auxiliary variables for estimation of $SO4^{2-}$, SAR, TDS and EC, respectively. RMSE, for determination of the most suitable method, among Kriging, cokriging and IDW was used. Results showed that geostatistic methods had more considerable accuracy than IDW method. Furthermore, cokriging method increased prediction accuracy and had less RMSE for all studied parameters (Table 3). Finally, maps of groundwater quality were prepared using Arc GIS and cokriging which was the best method for interpolation (fig. 2). Maximum amount of groundwater quality parameters can be seen in south and west of Mianab Plain and there are minimum amounts in east and north.

DISCUSSION AND CONCLUSION

The studied parameters almost had high skewness, due to insufficient number of samples and unsuitable distribution. Therefore data were normalized using logarithmic method. Results showed that effective ranges of most parameters of ground water are closed to each another indicating their high correlation. Results of this paper confirm the importance of appropriate interpolation methods. Using the secondary variable in Cokriging method in our region that lack of data and samples compression are restricted factors in accuracy and quality of interpolation of environmental variables, is so effective and important. Geostatistics is superior to IDW which is similar to the results of Taghizadeh Mehrjardi et al. [9], Nazarizade et al. [10], Barca and Passarella [2]. In the present research, results from evaluation of different methods showed that cokriging method has higher accuracy than others. As all parameters show, demolition of groundwater quality is concentrated on west and south of the region (Fig. 2). For example, EC is very high in western region which high concentration of EC in the area is related to geological factors. Finally, results showed that deterioration of ground water quality in Mianab Plain is serious problem and is not suitable for drink and agricultural uses.

REFERENCES

1. Fryar, A. E., Wallin, E.J., and D.L.Brown, (2000), Spatial and temporal variability in seepage between a contaminated aquifer and tributaries to the Ohio River: Groundwater Monitoring and Remediation, v. 20, p. 129-146.
2. Barca, E. and G. Passarella, (2008). Spatial evaluation of the risk of ground water quality degradation. A comparison between disjunctive kriging and Groundwater geostatistical simulation, Environ Monit Assess.137 (1-3):261-273.
3. Delgado,C., Pacheco,J., Cabrera,A., Batllori,E., Orellana,. R. and F.Bautista. (2010). Quality of groundwater for irrigation in tropical karst environment: The case of Yucatan, Mexico. Agr Water Manage. 97: 1423-1433.
4. Adhikary,PP., Chandrasekharan,H., Chakraborty,D. and K. Kamble. (2010). Assessment of groundwater pollution in West Delhi, India using geostatistical approach. Environ Monit Assess. 167: 599-615.
5. Hooshmand, A., Delghandi M., Izadi A. and Kh Ahmad Aali. (2011). Application of kriging and cokriging in spatial estimation of groundwater quality parameters. Afr J Agr Res. 6(14): 3402-3408.
6. Rawat,KS., Mishra, AK., Sehgal,VK. and VK. Tripathi. (2012). Spatial Variability of Ground Water Quality in Mathura District (Uttar Pradesh, India) with Geostatistical Method. Int J Remote sens Appl. 2(1): 1-9.
7. Hasanipak,a.,1998.Geostatistics.Tehran University pub.p314.
8. Nazari Zade, F. and F. Arshadiyan, B.,and K.Zand Vakily, (2006). Study of spatial variability of Ground water quality of Balarood Plain in Khuzestan province. The first congress of optimized exploitation from water source of Karoon and Zayanderood Plain.Shahre kord University, Persian Version, pp: 1236-1240.
9. Taghizadeh Mehrjardi,R., Zareian Jahromi,M., Mahmodi,Sh. and A. Heidari.(2008). Spatial Distribution of Groundwater Quality with Geostatistics (Case Study: Yazd-Ardakan Plain). World Applied Sciences Journal 4 (1): 09-17.

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