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Evaluate the spatial variability of EC and TDS in groundwater of Dez irrigation network

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Abstract: Today, due to water shortage in the country, especially in arid and semi-arid, optimal management of groundwater resources is essential. Given the scarcity of surface water resources in these areas as well as the loss of their, main source of water for agriculture, industry and drinking water is groundwater. The purpose of this study was to map the spatial zoning quality parameters including TDS and EC and assess changes in these parameters in the Dez irrigation network. For this purpose, the data of 64 wells were used for Dez irrigation network and geostatistics interpolation methods such as kriging and co-kriging and inverse distance method were investigated. After normalization of data was, variography operation is performed. Using cross validation method and using less MAE, appropriate interpolation method was selected. Results showed that the zoning TDS and EC, exponential Cokriging compared with other interpolation methods are evaluated with high accuracy. The results of the spatial variation of parameters showed that TDS and EC are the highest in the eastern areas of the network. West region enjoys a better condition but the center has the best condition. According to the results, groundwater quality in the study area is relatively good.

Key words: Groundwater quality; Kriging; IDW; TDS; EC

1. Introduction

Ground water after glaciers is the largest of the Earth's freshwater resources. It is noteworthy that groundwater constitutes only six percent of the Earth's water and however, it provides 98% of fresh water available for human use (Todd, 2005).

About a third of the world's population is dependent on groundwater and over 70% of groundwater resources are consumed by agriculture. The development of agriculture and industry has increased the harvest of these resources and uncontrolled withdrawal of groundwater reservoirs caused the rate of aquifer recharge and groundwater levels drop. Decline in groundwater levels cause problems like dryness of wells, reducing the flow of rivers and lakes, degrade water quality, increased pumping costs and lead to water and land subsidence.

Iran locates in arid and semi-arid regions of the world. About 95 percent of water use is agricultural. More than 80% of the demand comes from groundwater and this is necessary to evaluate the quantity and quality of groundwater. Groundwater quality and quantity to be used for different purposes, it is important and necessary. Analysis of water quality groundwater studies is one of the most important parts. Variety of physical and chemical quality of ground water is a function of geology and human activities in each area. The hydro studies, areas characterized by high quality groundwater for drinking purposes, agriculture and industry. To investigate the spatial variability of groundwater used for the interpolation methods. There are several methods to evaluate and interpolate of characteristics of groundwater. Each of the methods has different accuracy depending on local conditions, variables type and adequate data. Including interpolation methods for the preparation of maps of groundwater quality changes can be noted geostatistical methods (kriging and cokriging) and inverse distance weighted (IDW). Geostatistical analysis has been useful to determine water variables in space and time (Isaaks and Srivastava, 1989; Goovaerts, 1997). Many studies have successfully used interpolation techniques with and without the use of the Arc GIS Geostatistical tool.

In the study conducted by Hu et al. (2005), spatial variability of grounwater quality and risk of NO3 pollution in groundwater in the central North China Plain were determined using the OK method.

Zimmerman et al. (1999) evaluated and compared the accuracy of OK, universal Kriging and IDW methods based on an analysis of synthetic data from a computational experiment.

Geostatistical methods, Kriging and co-Kriging, were applied to estimate the sodium adsorption ratio (SAR) in a 3,375 ha agricultural field (Pozdnyakova and Zhang, 1999).

Adhikary et al. (2010) investigated the quality of groundwater for irrigation and drinking on the outskirts of Delhi, India using GIS and geostatistics. The present study investigated the quality of groundwater of Dez irrigation network and zoning and mapping of EC and TDS.

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2. Study area

Dez irrigation network in southwestern Iran and is located in the North West of Khouzestan province. Monthly average maximum temperature is between 38-35 degrees in the summer months and the monthly average minimum of winter temperatures is between 13-10 degrees and average annual temperature is about 25 degrees. In general, the distribution of rainfall is from mid-November until the end of May next year and seven months in the water year. Average rainfall in the area is 350 mm.

Dez irrigation network has a total area of 1340 square kilometers and has 67 observed wells that in terms of changes and behavior in groundwater levels are under control and monitoring. These wells are scattered on the plain. To evaluate the quality of ground water from 64 wells was used. Electrical conductivity (EC) and total dissolved solids (TDS) were measured in 2012.

3. TDS

Total dissolved solids (TDS), refers to the total amount of all inorganic and organic substances – including minerals, salts, metals, cations or anions – that are dispersed within a volume of water. By definition, the solids must be small enough to be filtered through a sieve measuring 2 micrometers. TDS concentrations are used to evaluate the quality of drinking water systems. TDS concentrations are equal to the sum of cations and anions. Sources for TDS include agricultural and urban run-off, industrial wastewater, sewage, and natural sources such as leaves, silt, plankton, and rocks. Piping or plumbing may also release metals into the water.

While TDS is not considered a primary pollutant, high TDS levels typically indicate hard water and may lead to scale buildup in pipes, reduced efficiency of water filters, hot water heaters, etc., and aesthetic problems such as a bitter or salty taste. The United States Environmental Protection Agency (EPA) recommends treatment when TDS concentrations exceed 500 mg/L, or 500 parts per million (ppm). The TDS concentration is considered a Secondary Drinking Water Standard, which means that it is not a health hazard (USEPA, 1978).

Electrical conductivity (EC) is a parameter related to total dissolved solids (TDS). EC is actually a measure of solution in terms of its capacity to transmit current. The importance of EC and TDS lies in their effect on the corrosivity of a water sample and in their effect on the solubility of slightly soluble compounds such as $CaCO_3$. In general, as TDS and EC increase, the corrosivity of the water increases.

4. Interpolation methods

4.1. IDW

IDW interpolation explicitly implements the assumption that things that are close to one another are more alike than those that are farther apart. To estimate a value for any unsampled location, IDW will use the measured values surrounding the unknown location. Those measured values closest to the prediction location will have more effect on the predicted value than those farther away. Thus, IDW assumes that each measured point has a local influence that diminishes with distance. Weights of the points closer to the prediction location greater than those farther away, hence the name inverse distance weighted and the general formula is as follows:

$$Z(S_0) = \sum_{i=0}^{n} \lambda i . z(si)$$

$Z(S_0)$ is estimated values in S_0; $Z(S_i)$ is observed values in S_i, λi: Weights assigned to each measurement point, n: The number of measurement points around the area. Weight equation is:

$$\lambda_i = d_i^{-p} / \sum_{i=1}^{n} d_i^{-p}$$

That di is the distance between observed and estimated points, P; the optimal power (p) value is determined by minimizing the root mean square prediction error. Geostatistical prediction includes identification and modeling of spatial structure. Continuity, homogeneity and spatial structure of studied variables are studied using variogram. Next stage is geostatistical estimation using kriging technique which depends on the properties of the fitted variogram which affects all stages of the process.

4.2. Variogram analysis

Variogram method is a suitable technique forestimating spatial variability of a variable. Calculation of variogram graph is one of essential stages in geostatistics which is defined as follow:

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

Where: γ (h): value of variogram for pair points with distance h, n(h): Number of pair points with distance h, Z(xi): observed value of variable x and Z(xi+h): Observed value of the variable with distance h from x. Variogram is the variance of different points with distance h. The obtained variograph of measured samples is called experimental variogram which is a vector value that is a dependent of distance and direction. The properties of variogram include threshold (sill=C0). The threshold is the maximum value of variogram which is spatial variance of the variable. The lowest value of variogram includes spatial effect which shows variance of errors of measurements. The effective range demonstrates the distance that variogram has the highest value [9].

4.3. Kriging

Kriging is a prediction method that considers values of a variable in unsampled points as a linear composition of the values of surrounding points. Considering the values of variable Z in n measured points as follow:

$Z= (Z(x_1), Z(x_2),....Z(x_n))$

Estimation of Z in point X_0 using kriging estimation is defined as:

$Z^*(x_0) = \sum\lambda_i. Z(x_i)$

The most important part of kriging is statistical weighs assigned to λi. To avoid bias of estimation, the weights should be determined in a way that summation is equal to one and the variance of estimates should be minimized.

4.4. Cokriging

As in classical statistics, multivariate methods, there can be krigings based on correlations between variables, can be used for estimator. Co-kriging equations are as follows [8].

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

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.

To choose the best interpolation method to convert point data to regional data, Cross-Validation technique is used. In this method in every stage, one observing point is omitted and with rest of observing point, that unknown point will estimated. For estimating carefulness MAE and MBE criteria are used.

5. Results

In this study, three methods of interpolation kriging, cokriging and inverse distance weighted for spatial analysis of TDS and EC variables were evaluated. In order to study of spatial correlation and structure of TDS and EC variables using ARC GIS software, variograms of the data were analyzed. According to table 1, it is clear that EC has high skewness and non-normal data. Therefore to normalize the data, a logarithmic function was used. TDS data is normal.

Table 1: Descriptive statistics of variables

Variable	Min	Max	Mean	Standard deviation	Coefficient of variations	Skewness	Kurtosis
TDS (mg/lit)	276	2387	655.7	428.8	0.65	0.51	0.93
Ec(µmhos/cm)	431	3730	998.2	643.3	0.64	1.3	0.6

Variography operation is performed for geostatistical methods and the theoretical model is fitted to the experimental variograms. Then according to the fitted model, interpolation is performed. Models included: circular, spherical, exponential, and gaussian. Table 2 shows characteristics of fitted cokriging model. According to Table 2, effect range of the TDS and EC is 13320 meters. To estimate the spatial variation of the parameters, the geostatistical and deterministic methods of the Arc GIS (version 9.3) software were used. Different methods; Kriging, Co-Kriging and IDW with powers 1, 2, 3 and 4 were selected to estimate the spatial variation of parameters.

According to table 3, cokriging with the least amount of errors (MAE) was selected to evaluate the spatial distribution of TDS and EC. Secondary variable is used for cokriging interpolation method. To select the secondary variables, each variable has a higher correlation with the original variables is selected. EC variable having the highest correlation with the TDS is selected as secondary variable. TDS as well as the variable having the highest correlation were considered as secondary to the EC.

Table 2: Best fitted variogram models of groundwater quality and their parameters.

Variable	Model	Nugget (C0)	Sill (C0+C)	Range (m)
TDS	Exponential	57315	134294	13320
EC	Exponential	141965	288895	13320

Table 3: Evaluation of interpolation methods for mapping groundwater quality parameters

Variable	Idw-1		Idw-2		Idw-3		Idw-4		Kriging		Cokriging	
	MBE	MAE	MBE	MAE	MBE	MAE	MBE	MAE	MBE	MAE	MBE	MAE
Ec	11.39	332.25	16.24	290.6	15.91	265.83	15.16	245.23	1.4	333.93	-2.52	135.42
TDS	3.15	240.64	7.5	211.72	8.11	193.32	8.4	180.47	-0.73	241.97	-0.1	101.28

The spatial variation of EC is shown in Fig. 1. The minimum and maximum values of EC were measured in situ as 431 and 3730 µmhos/cm. The spatial distribution of EC in the plain shows a decrease in EC values towards the central and western parts which can be caused by lime and gypsum-bearing formations in the region (Fig.1). The spatial distribution of TDS values of plain using cokriging interpolation method in the Fig.2 is shown. TDS amount from the west to the east is rising. Most of the plain due to being in the range less than 500 mg/lit according Schoeller classification, potability quality is good. Southwestern and eastern part of the plain, according to the classification being in the range 500-1000 Schoeller, moderate for drinking will be assessed.

6. Conclusion

In this study 64 groundwater samples were used to evaluate the spatial variation of TDS and EC of Dez irrigation network. The main objective was to investigate and map the groundwater quality. Analysis of the spatial coherence of the variables was performed using the selected models and the Kriging, Co-Kriging and Inverse Weighted Distance

(IWD). Methods were ultimately used to find out the spatial distribution of TDS and EC. The results obtained through these methods were compared by MAE. It is found that the Co-Kriging with exponential model is the best technique.

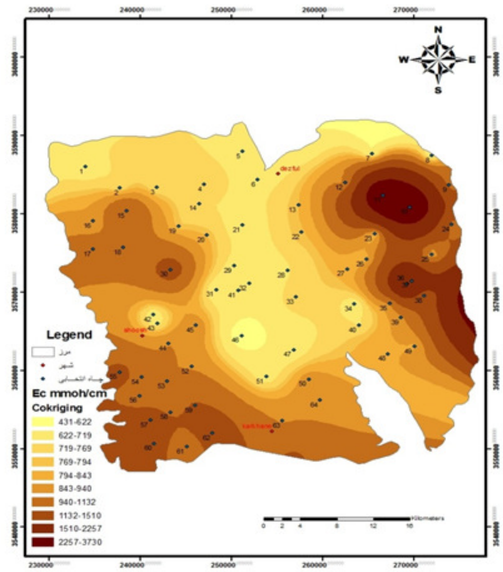

Fig. 1: Spatial distribution map of EC

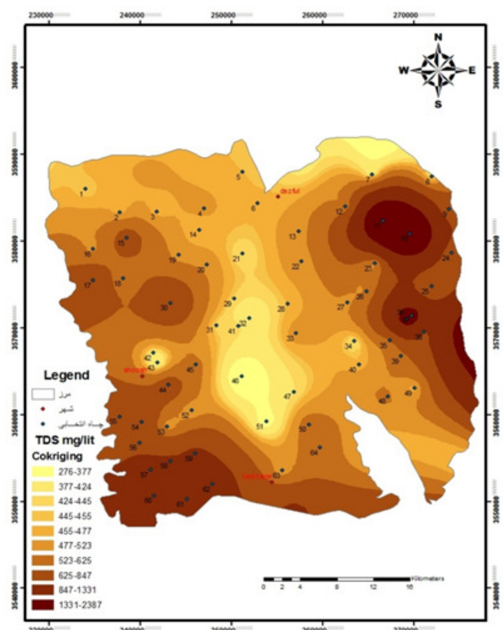

Fig. 2: Spatial distribution map of TDS

According to spatial variation map, electrical conductivity (EC) values range between 431 and 3730 µmhos/cm. High values of EC are recorded in the eastern parts of the region. This increase can be associated with the geological formations and agricultural activities. The higher values of total dissolved solids (TDS) in groundwater are associated with high concentrations of all major ions. The distribution of TDS follows from spatial distribution of EC.

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References

Adhikary,p.p., Dash ,Ch.J., Chandrasekharan,H., Rajput,T.B.S. and S.K. Dubey.(2010). Evaluationof groundwater quality for irrigation and drinking using GIS and geostatistics in a peri-urban areaof Delhi, India. Environ Monit Assess. 167(1-4):599-615. doi: 10.1007/s10661-009-1076-5.

Goovaerts P. Geostatistics for natural resources evaluation. New York: Oxford Univ Pres, 1997.

Hu K., Huang Y., Li H., Li B., Chen D., White R.E. 2005. Spatial Variability of Shallow Groundwater Level, ElectricalConductivity and Nitrate Concentration, and Risk Assessment of Nitrate Contamination in North China Plain. Environment International, 31, 896.

Isaaks E.H., Srivastava R.M. An Introduction to Applied Geostatistics, New York: Oxford Univ Press, 1989.

Madani, H. (1998). Geostatistics Foundations, Amirkabir University Press, p. 659.

Pozdnyakova L., Zhang R. Geostatistical Analyses of Soil Salinity in a Large Field, Precision Agriculture, 1, 153, 1999.

Todd D.K.2005: Ground Water Hydrology. Third Edition, John Wiley & Sons

USEPA. (1978). EPA Method #: 130.2: Hardness, Total (mg/L as CaCO3) (Titrimetric, EDTA). Methods for the Chemical Analysis of Water and Wastes (MCAWW) (EPA/600/4-79/020).

Zimmerman D., Pavlik C., Ruggles A., Armstrong M.P. An Experimental Comparison of Ordinary and Universal Kriging and Inverse Distance Weighting, Mathematical Geology, 31, (4), 375, 1999.