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Case Study

Estimation of Spatial Distribution of Groundwater Quality Parameters using Geostatistical Methods - A Case Study of (ISFAHAN- IRAN)

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A b s t r a c t

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The increasing, harvesting and utilization of groundwater resources can affect water quality in an area and cause salination and other forms of contamination of the groundwater aquifers in such areas. Thus, information on water quality parameters is becoming very important. Physical and chemical water quality of acceptability point of view, it is essential for consumers and their health. In this study, about 84 wells in the area were used. The data obtained for the parameters of the SAR, Na, Ca, TH, TDS and EC in Excel software for preparing the database was stored in dbf format. To investigate the relationship between the parameters of the method of Pearson correlation analysis using SPSS version 16 were used in the environment. Then, using the GS + and ArcGIS software Cokriging and kriging methods was investigated. Results showed that the results from kriging and Cokriging method showed no significant difference. But the lower RMSE Cokriging methods, zoning maps, groundwater characteristics were obtained with this method in the GIS environment. Due to digital maps produced by the region, solute concentration is higher in the northeast study area due to it being the industrial and urban area. This is the most likely reason for the high concentration of salts in this area. Recent droughts and the indiscriminate use of groundwater salinization risks and loss of agricultural land areas are increasing more than before.

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1. Introduction

Water is a very major part of human life, besides drinking and other purposes related to domestic needs, are so import that now most countries are now experiencing a serious crisis due to the polluting and contaminating of water sources with salts and toxic elements. It is a well-known fact that poorly maintained water standards, will lead to adverse environmental impact and exponentially propagate the transmission of diseases to humans. Water Quality is one of the first and or probably most important steps in the process of eliminating pollution, which applies to quality correct management

[1]. Many countries in the world, especially those countries that have dry climates have been suffering "low water stress" and these have been trying to compensate for this problem through excessive utilization of their groundwater. Now water quality, in those countries is low due to the resulting contamination of their ground water sources. It is estimated that today, more than 5 million people worldwide each year (mostly children) dies from drinking water with low quality [2]. Water is very important to the health and development of all living organisms so much that The World Health Organization (WHO) has been encouraging that all should recognize the twentieth century as the period for universal access to safe drinking water and have been advocating that today the emphasis should be on preserving and optimally using our water resources. Improvement of the same resources and protection against biological and chemical pollution highlights [3]. Country Iran is located in arid and semiarid region of the earth, so different parts of the country's water supplies are of significant importance. There are adequate methods to supply water its different areas, especially in arid and semi-arid regions, including drought combat crisis to help increase the water supplies and water to prevent drying of the host [4]. The quality of groundwater to the aquifer mineralogy faces change which may influence the flow paths and residence time, Groundwater quality during transit routes into the subsurface soil and unsaturated zone [5]. Average annual rainfall in arid and semiarid world, it does not eliminate the need for water, maintenance of underground water resources should be very high. Considering that most of semi-arid regions of Iran the dry, thus the use of groundwater to meet the needs of people seem to be imperative, but increasing utilization of groundwater resources can affect the water quality in an entire area; for example this can cause ground water aquifers to become salinated, polluted and also a reduction of water levels. Thus, information on quality and water quality parameters is imperative [6]. Physically and chemically acceptable water quality is essential for consumers and their health. In some areas, controlling the concentrations of some pollutants is necessary to protect the consumer's health. Such measures include chemical testing of water supply and sources, removing solids and other physical impurities from water supply and adding disinfecting agents to it. These methods are used to ensure that microorganisms are directly exposed to the disinfecting agents. In excessive amounts disinfecting agents, can cause many negative physiological effects, including poisoning (death), irritation of the skin and other areas of the body and bad tasting water, which can't be consumed (drinking). The economic effects include increased consumption of soap, creating stains on dishes, vegetables and slow cooking and being colorless, boilers and bust [7].

The kriging method assumes that the distance and direction between sample points on the spatial correlation effect. This method has the best performance when there is a system to be aware of Correlation distance or skew the data direction. Of these methods, most are used in geological sciences and in oil use. Kriging estimation method is a weighted moving average and is based on logic and the best linear unbiased estimate is available [8]. The location estimation Cokriging method also can be estimated based on the correlation between different variables. In fact, support variables used in this method, suggest that this feature can lead to more carefully estimates of savings in costs to less sampling [9]. The purpose of this study of water quality parameters to estimate the spatial distribution of plain Golpayegan is using geostatistical methods [10]. Rizzo and Mouser [11] investigated the land use statistics for groundwater quality analysis and quality indices, including concentrations of Cl, So4, Na, Ca and salinity; they also considered microbial population as support variation in Cokriging methods. Results indicated that Cokriging had the best accuracy for estimating the quality of groundwater. Misaghi and Mohammadi [12] estimated the underground water by using the traditional methods and geostatistical interpolation, then, mentioned methods were compared. Results of study illustrated that acceptable precision of kriging geostatistical method in comparison with other classical statistical methods. Ahmed [13] utilized the kriging estimates the spatial dependence of water quality variables like total dissolved solids (TDS) and also concluded that kriging is a high potential for this purpose. Thus, Liu et al [14] performed the using geostatistical methods and GIS to assess the risks of heavy metals in rice fields. On the other hand, Flipo et al [15] in another study estimated the nitrate pollution aquifers located in the French Grand Maureen by the using aforementioned methods and physical models.

2. Materials and Methods

The study surveyed in Golpayegan town, Isfahan Province. Fig. 1, Location Study area and shows the distribution of sampling points. Its height from sea level is 1818 meters. The average annual temperature in the region with 17.2 ºC, the coldest month and warmest month in July with an average degree of February in 0.7-22.7 °C. Annual rainfall in the plain Golpayegan 257.3 mm and maximum rainfall in station Sarab handles with 491.7 mm and the lowest in Muteh station with 7.200 mm of rainfall.

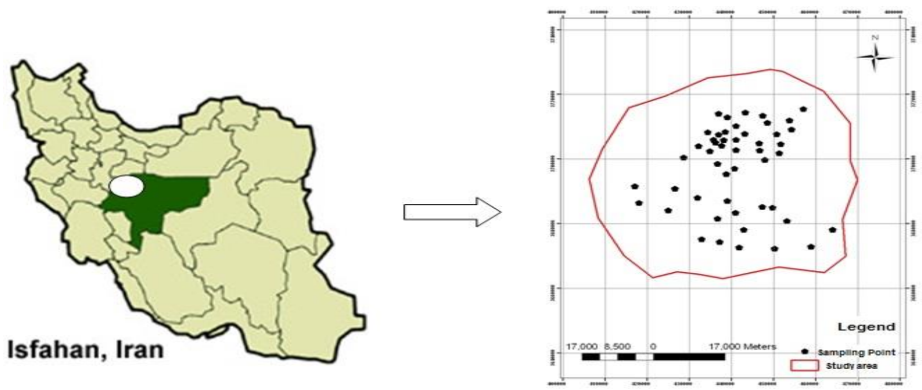


Fig. 1: Location study area and distribution of sampling points

2.1. Data collection

In this study, information from 84 wells in this area was used. The data obtained for the parameters of the sodium adsorption ratio (SAR), Na, Ca, total hardness (TH), TDS, and electrical conductivity (EC) in the Excel software to produce the database was stored in dbf format. Then, using the GS + and ArcGIS software was investigated cokriging and kriging methods. In order to develop and extend information on the point of sampling points and the spatial and temporal variation of each variable needs models that to be investigated variable in order to simulate the missing parts. Estimated nodal geostatistical passive amounts using known amounts and modify a half, they estimate, form modifies a half calculated as follows:

$$M(h) = \frac{1}{2n}\sum_{i=1}^{n}(Z(x_i + h) - Z(x_i))^2$$

$M(h)$: Similar amount in distance variogram (h)

$Z(x_i + h)$: Measured variables in place

$Z(x_i)$: Measured variables in place

n: Number of measurements performed in the range studied [18] .

For evaluation of Cokriging and kriging methods the ArcGIS software the ability to perform the technique of mutual evaluation and statistical criteria, the root mean square error (RMSE) is used the equation to calculate it as follows:

$$RMSE = \sqrt{[\sum_{i=1}^{n}\left(\hat{Z}(x_i) - Z(x_i)\right)^2]/n}$$

$\hat{Z}(x_i)$: The estimated amount at a point

$Z(x_i)$: The amount measured at a point

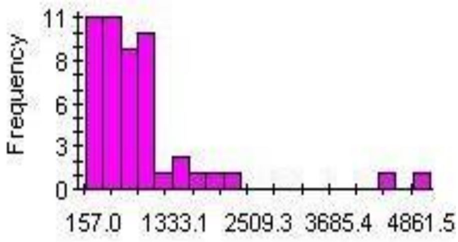
i : Number of points

n : Number of criteria which are observed.

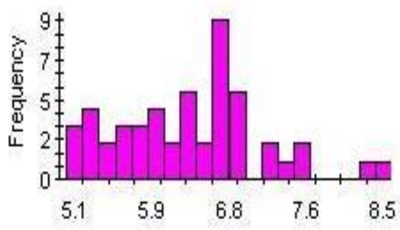
In this method, each step in an observational point was removed and the point was estimated by the using other observational points. This practice is repeated for all points of view and there will be an estimated point at the end of each point of observed, the same parameter was used for verifying regression equations and for estimating selected SAR, Na, Ca, TH, TDS and EC [16].

3. Results and Discussion

Data were analyzed and histogram form was plotted for each considered variable that are given in Fig. 2. With respect to depiction histograms consideration is that the variables TH, Ca, SAR, Na, TDS and EC have been skewed, thus, normalization of data taken from the logarithm and histogram variables after being normalized is visible on the right side of the histogram in the figure.

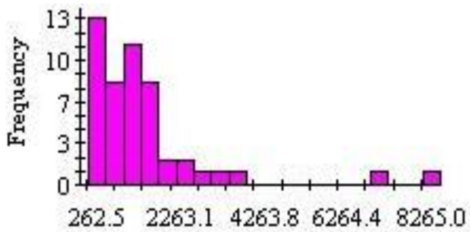


(a) TDS

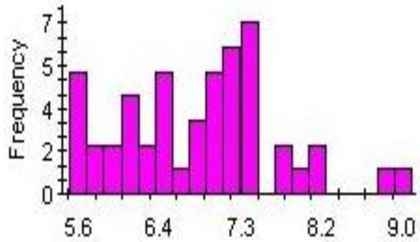


(b) Ln(TDS)

Fig. 2 a, b: Histogram data TDS before (a) and after (b) conversion to a normal distribution of data

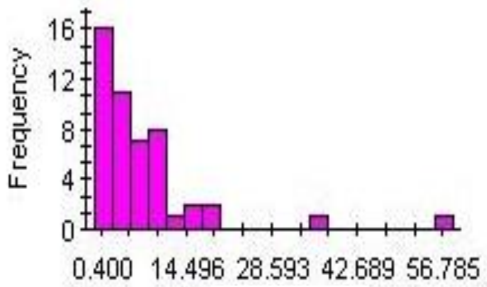


(c) EC

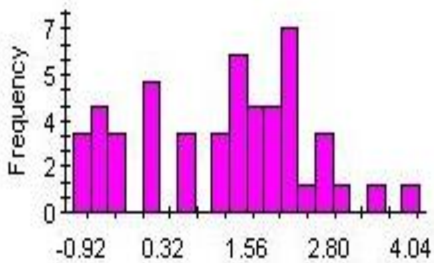


(d) Ln(EC)

Fig. 2 c, d: Histogram data EC before (c) and after (d) conversion to a normal distribution of data

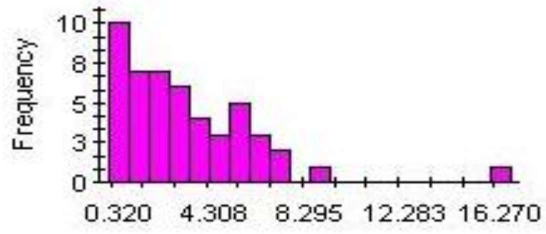


(e) Na

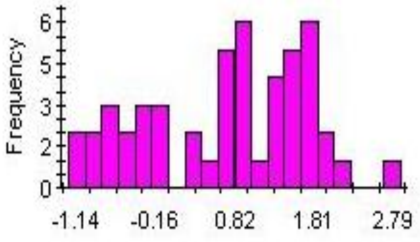


(f) Ln(Na)

Fig. 2 e, f: Histogram data Na before (e) and after (f) conversion to a normal distribution of data

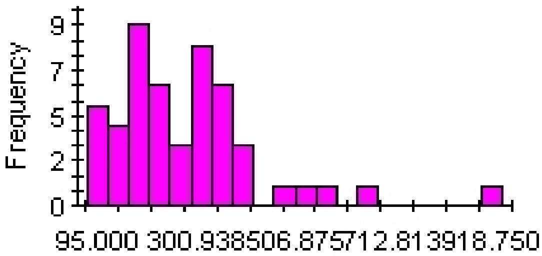


(g) SAR

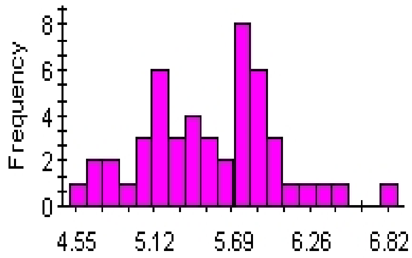


(h) Ln(SAR)

Fig. 2 g, h: Histogram data Na before (g) and after (h) conversion to a normal distribution of data

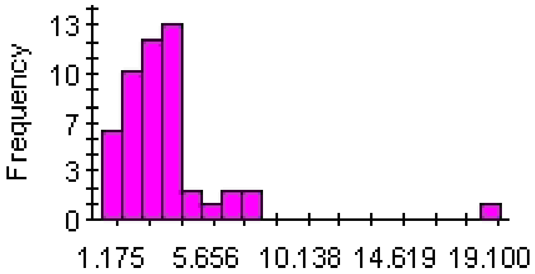


(i) TH

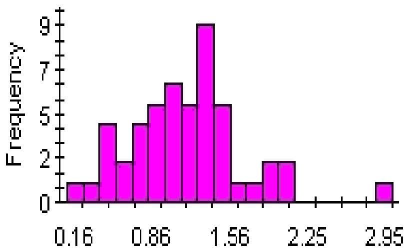


(j) Ln(TH)

Fig. 2 i, j: Histogram data Na before (i) and after (j) conversion to a normal distribution of data



(k) Ca



(l) Ln(Ca)

Fig. 2 k, l: Histogram data Na before (k) and after (l) conversion to a normal distribution of data

To investigate the relationship between the parameters TH, Ca, SAR, Na, TDS and EC Pearson method of correlation analysis using SPSS version 16 was used that results are presented in Table 1. According to the operating table of the 99% level had a significant relationship with each other.

Table.1: Correlation coefficients between water quality factors (Pearson correlation coefficient)

	SAR	Na (meq/l)	Ca (meq/l)	TDS (mg/l)	EC (µs/cm)	TH (mg/l)
SAR	1	-	-	-	-	-
Na (meq/l)	0.946**	1	-	-	-	-
Ca (meq/l)	0.454**	0.508**	1	-	-	-
TDS (mg/l)	0.903**	0.979**	0.629**	1	-	-
EC (µs/cm)	0.919**	0.988**	0.615**	0.993**	1	-
TH (mg/l)	0.779**	0.882**	0.805**	0.947**	0.942**	1

**level data, 99 percent via significant relations with each other.

3.1. Geostatistical Analysis

To investigate the spatial correlation and spatial structure of variables was analyzed using specialized geostatistical software GS + half modify data. Using modify the addition of half a spatial structure, the radius of correlation of variables, data static survey, also identified variables and the presence or absence of isotropic data. To perform data analysis on a half Modify SAR, Na, Ca, TH, TDS and EC after normalization, the variogram was plotted for each of the variables with GS + software Fig. 2. The appropriate model for fitting modify the experimental half amount with respect to residual sum of squares (RSS) less than the amount of C_0 / (C_0 + C) to be less than 0.5. This ratio represents the total amount of the variability can be explained by effect piece [18]. Table 2variogram parameters fitted to the data, SAR, Na, CA, TH, TDS and EC, and shows best fitted to the variogram model for each of these factors.

Table. 2: Variogram parameters fitted to factors and the best model fitted to variogram

Water quality factor	Model	Segmental effect (C_0)	Threshold (C_0+C)	Radius influence (Km)	$C_0/(C_0+C)$	R2	RSS
SAR	Spherical	0.062	0.33	38700	0.187	0.981	0.0012
Na (meq/l)	Gaussian	0.210	2.43	49450	0.061	0.989	0.1040
Ca (meq/l)	Spherical	0.022	0.29	24200	0.075	0.914	0.0056
TDS(mg/l)	Spherical	0.053	1.59	81100	0.033	0.991	0.0076
EC(µs/cm)	Spherical	0.038	1.66	81100	0.022	0.992	0.0077
TH (mg/l)	Exponential	0.079	0.53	84590	0.142	0.978	0.0036

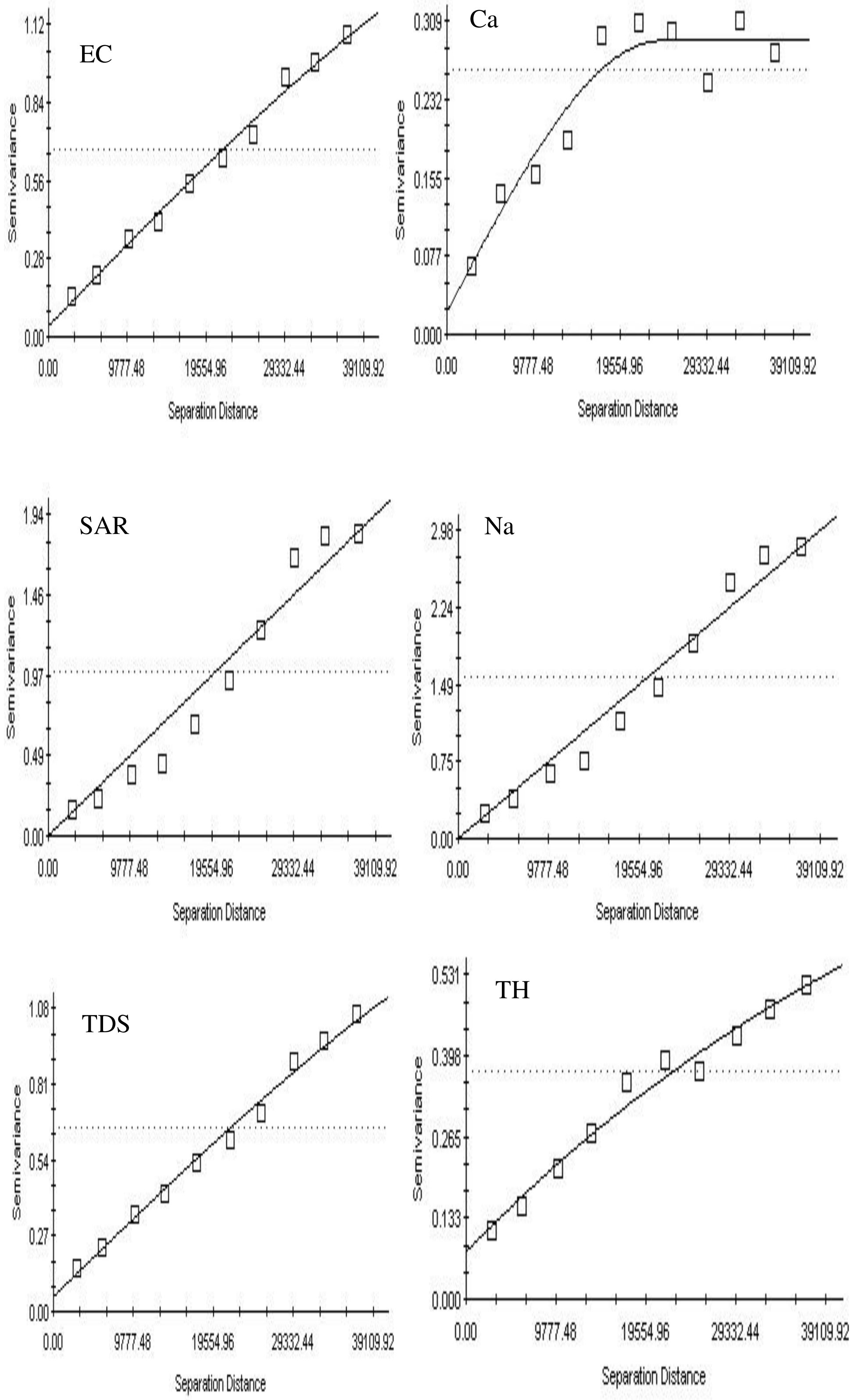


Fig. 3: Variograms related quality of underground water

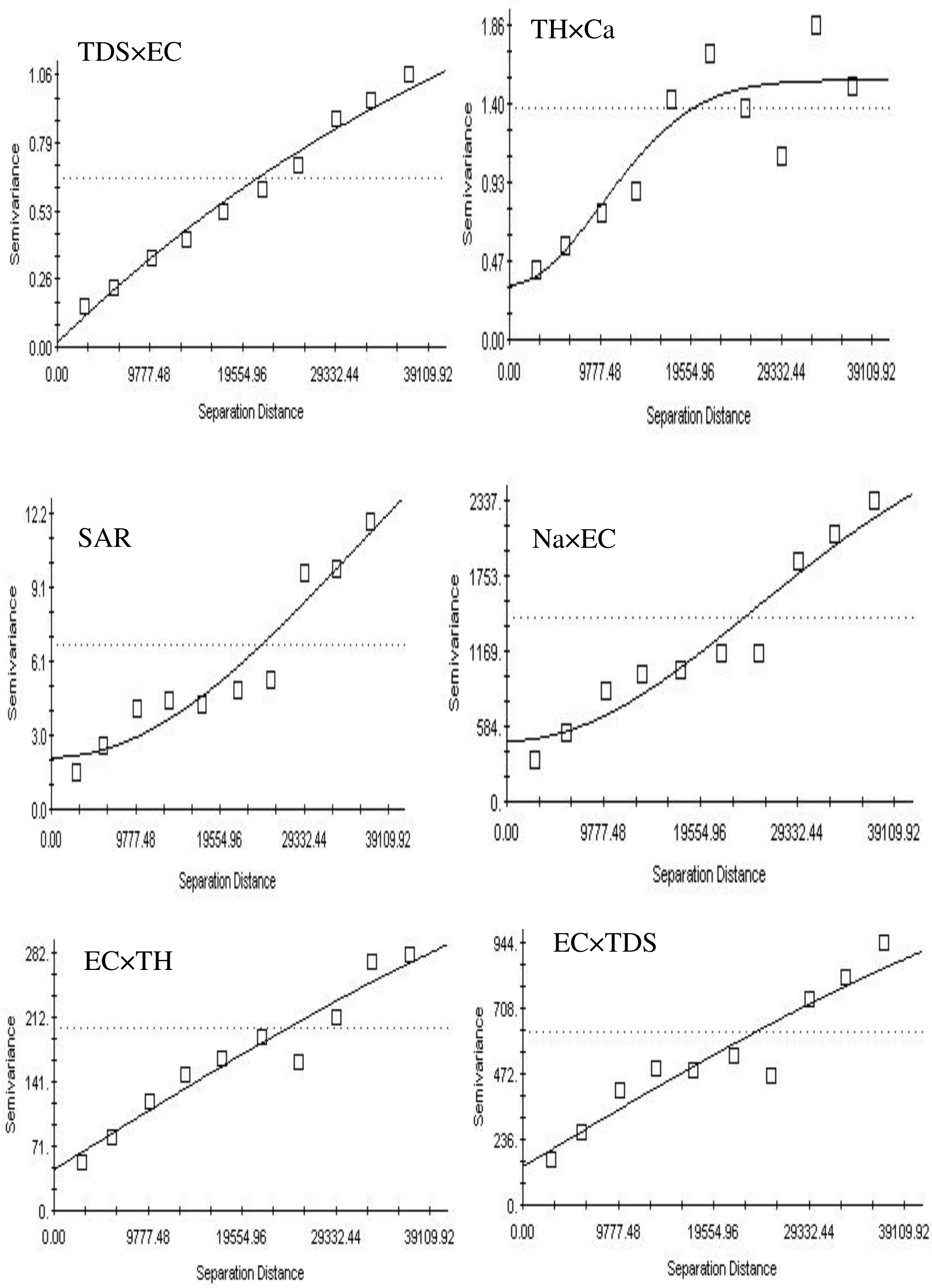


Fig. 4: Interaction variograms related to groundwater quality

In Cokriging method, a factor as an assistance variable after matrix correlations were used for predicting water quality that had the highest correlation coefficient with considered variable Table 1. Related interaction variograms is presented in Fig. 4. In determining the most appropriate interpolation method, of was used kriging and Cokriging between the RMSE. Results showed that was not significant difference between kriging and Cokriging methods Table 3. But the lower RMSE

Cokriging methods, zoning maps, groundwater characteristics were obtained with this method in GIS environment.

Table. 3: RMSE results for estimation of Groundwater quality

Factor Groundwater quality	Kriging	Cokriging
SAR	0.9254	0.9205
Na (meq/l)	0.9261	0.9123
Ca (meq/l)	1.059	1.025
TDS (mg/l)	1.177	1.022
Factor Groundwater quality	Kriging	Cokriging
SAR	0.9254	0.9205

4. Conclusion

Results of the study indicated that related factors will be extracted after drawing variogram and processing suitable model. According to the observations, spatial structure and stability of water quality factors were very strong [factor value C_0 / (C_0 + C) less than 0.25] Table 2, nevertheless, it indicates the high accuracy and spatial continuity model is fitted to the data. The results of the mentioned methods, illustrated the kriging is not better than Cokriging method significantly, but regarding to lower RMSE of Cokriging methods, zoning maps of underground water characteristics were obtained with this method in GIS environment which was in agreement with findings by Dagostino et al. [17], Rizzo & Mouser [11], Mehrjerdy Taghizadeh et al. [18], and Ahmdaly et al [19], Also are consistent with the results achieved by Rizzo & Mouser [11] that for quality factors zonation include Na, Cl, SO_4, Ca and salinity introduced Cokriging method as a suitable method, and Habibyarbtaly et al, [20] according to the method Cokriging groundwater is suitable for most parameters. Regarding to the geo-statistical principle, the variable which has suitable spatial correlation and less estimates variance for estimation need to less sampling, and in this case, the cost of sampling will be diminished [21], these findings were in agreement with the results which were obtained by Misaghi and Mohammadi [12], zehtabyan et al [21], and Ahmed [13], all of them believe and are agree to have low sampling and having low sampling prices by the using geo-statistical methods. According to digital maps produced by the region, salt concentration is higher in the northeast study area which, according to bring industrial and urban area, it is most likely that this is the cause of the high concentration of Salts in this area. Recent droughts and the indiscriminate use of groundwater increased salinization risk and loss of agricultural land are increasing in this region.

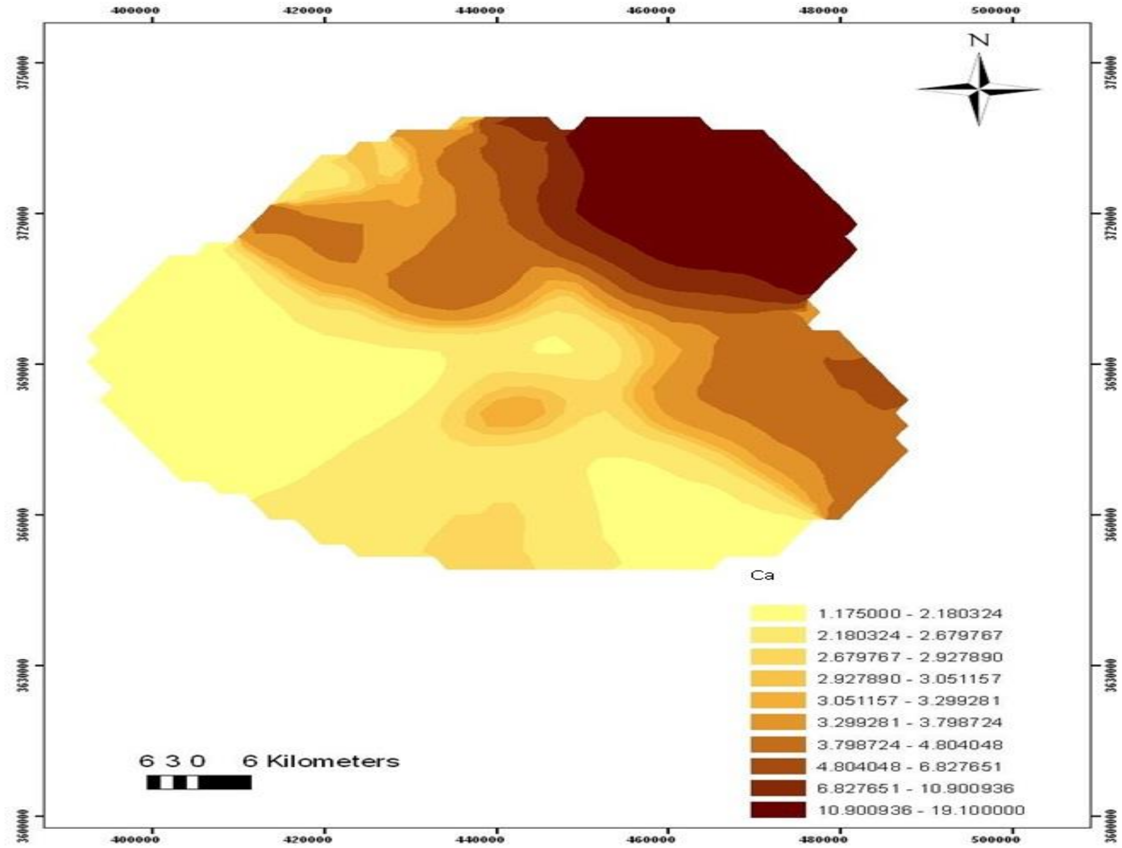


Fig. 5: Zonation map of factor Ca groundwater quality

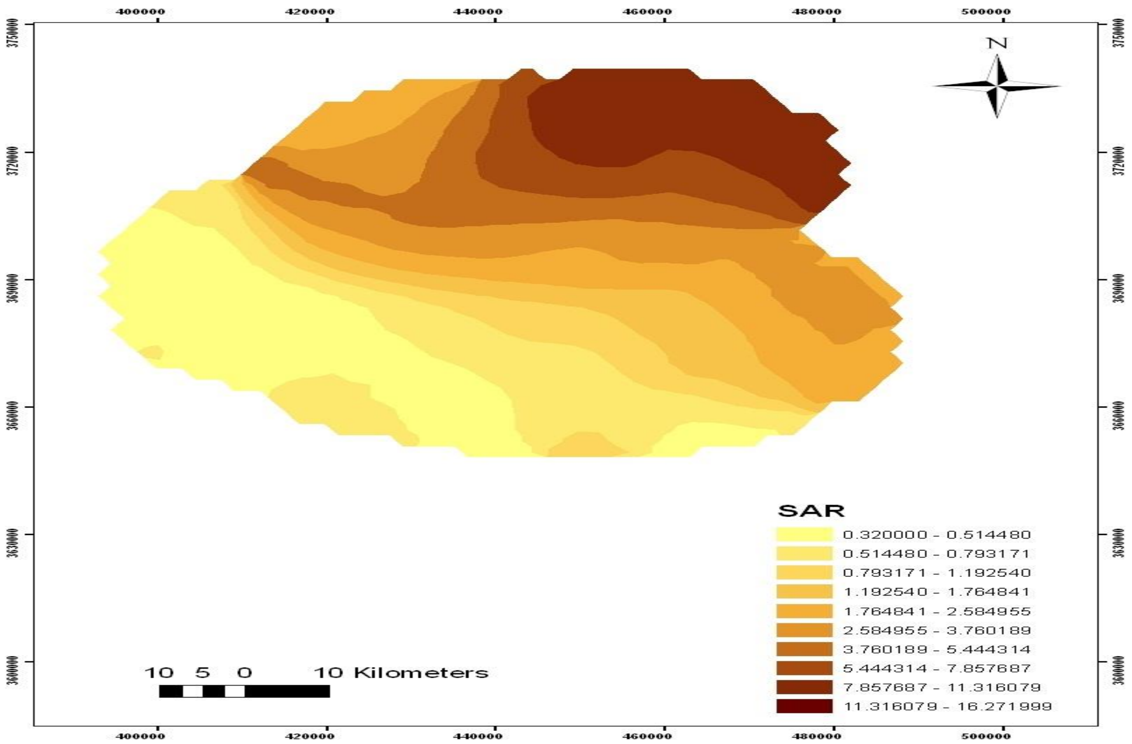


Fig. 6: Zonation map of factor SAR groundwater quality

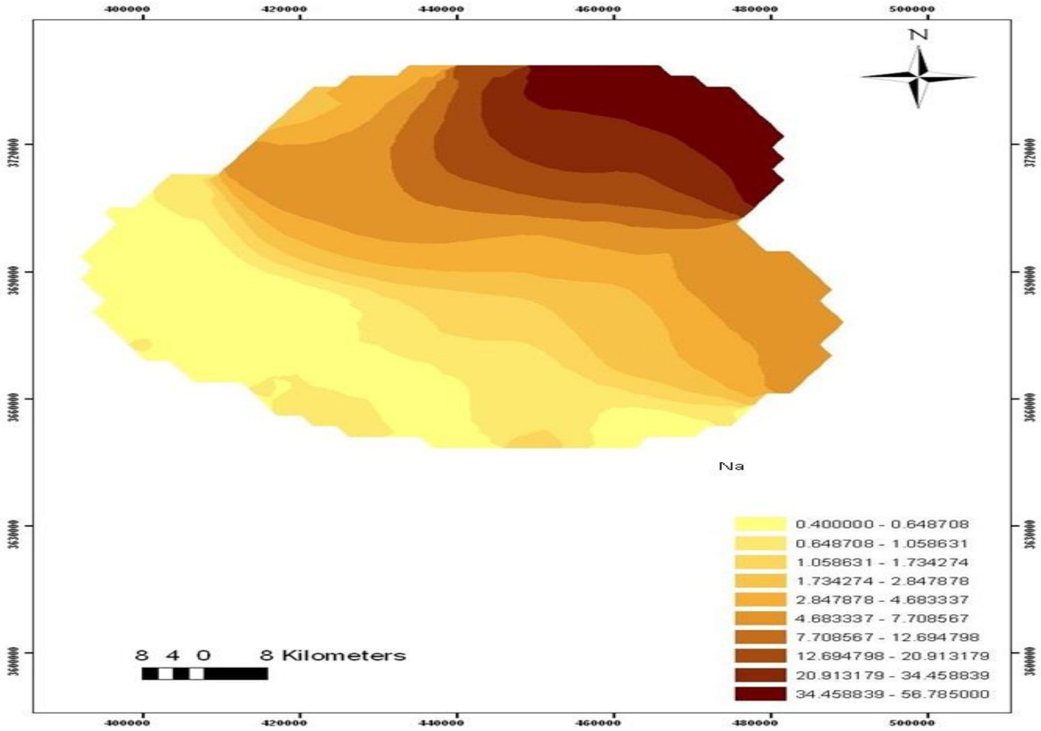


Fig. 7: Zonation map of factor Na groundwater quality

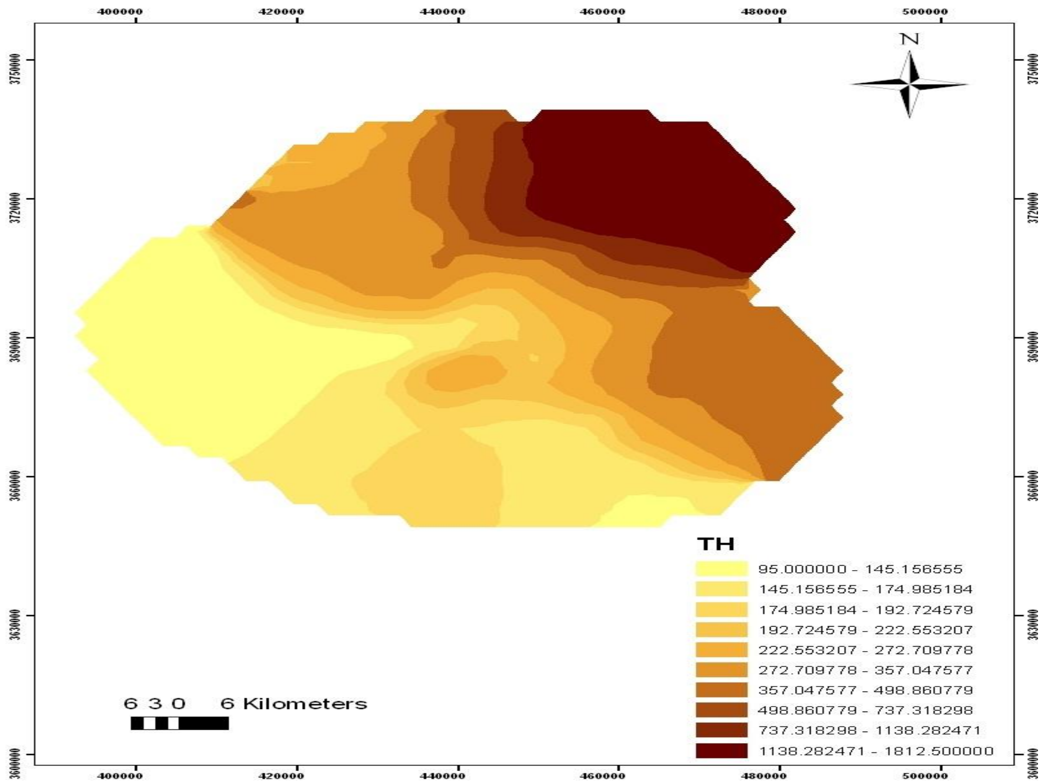


Fig. 8: Zonation map of factor TH groundwater quality

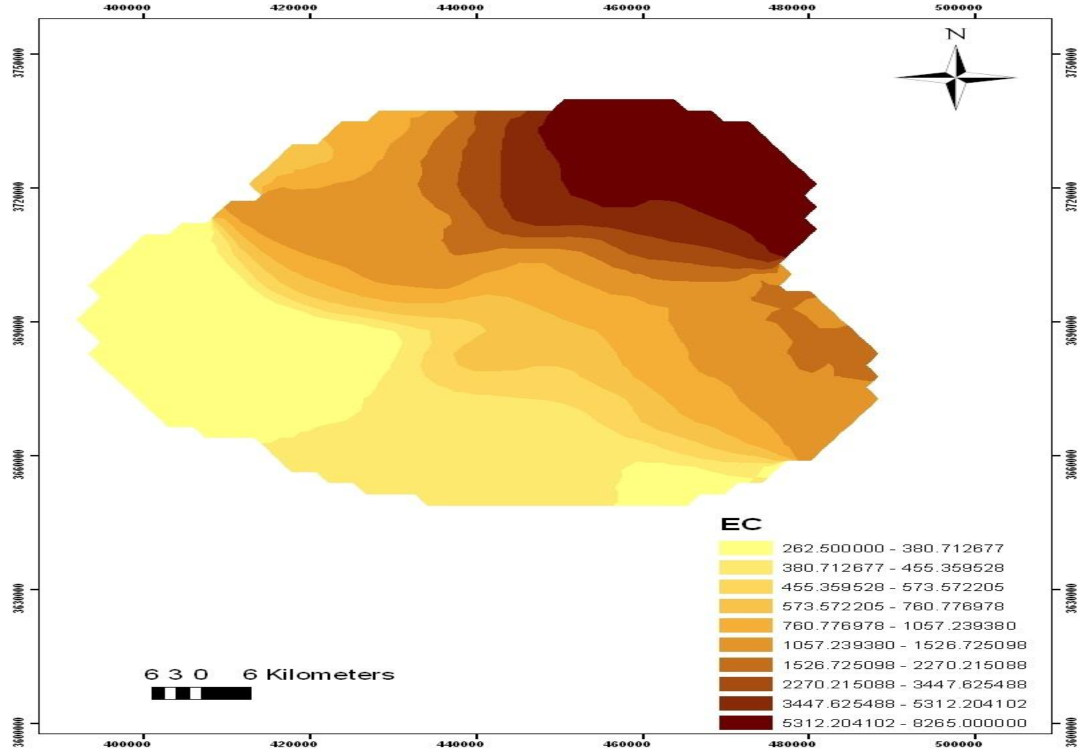


Fig. 9: Zonation map of factor EC groundwater quality

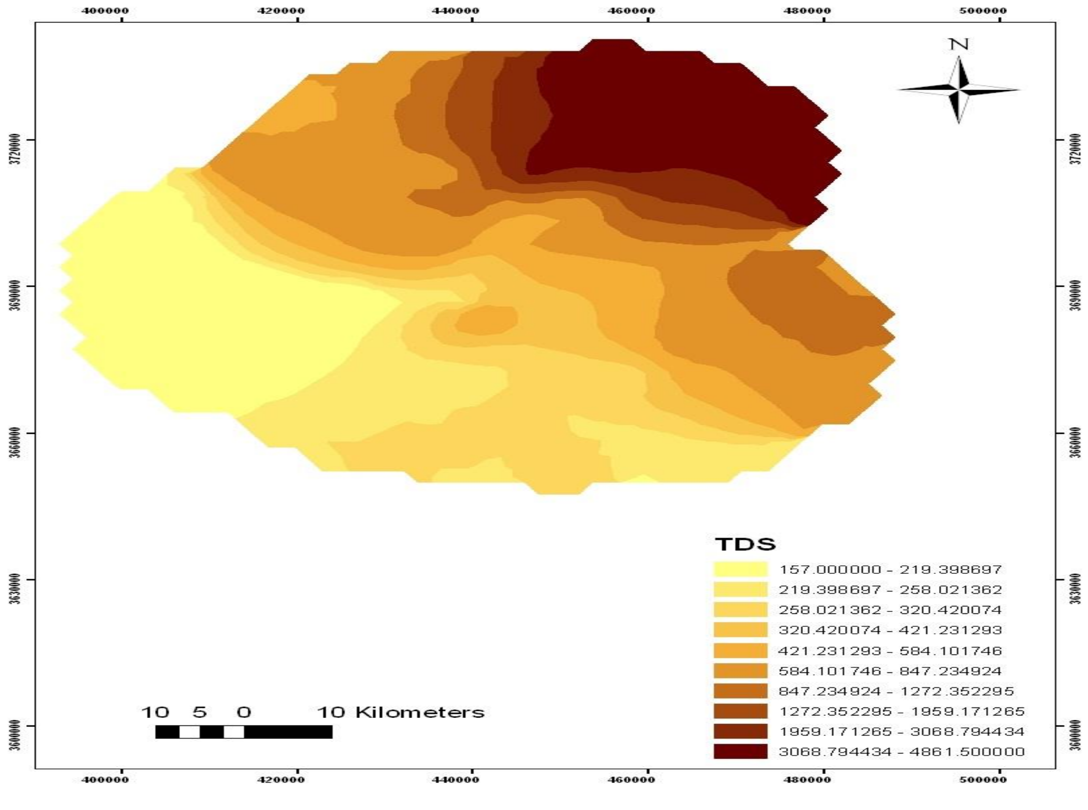


Fig. 10: Zonation map of factor TDS groundwater quality

4.1. Suggestions

1- Research and experiments will be done based on the possibility which concentration parameters in the northeast region are due to it being the industrial and urban region.

2-According to recent droughts and the indiscriminate use of groundwater, which danger salination and area agricultural land, loss of and will accelerate the trend of desertification in the region, place more attention on the correct management of groundwater in this area.

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