Monitoring and classifying of ground water pollution, in GIS, using Geostatistical analyst, Case study: Fomanat Basin

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Abstract

Regards to deficit of rainfalls in the recent years, over-use of ground water was developed. Soil and water resources degradation is a challenge that human is face to face with it and it emphasizes on the quality of water used in agriculture. Nowadays, regards to the expansion of scientific management in water resources, using both, a powerful technology which can analyze Georeferencing data punctually and a Geostatistical tool which has adequate precision in surface interpolation were reduplicated. This research was conducted in the fomanat basin in North of Iran, using a Geographic Information System (GIS) to assess the impact of chemical fertilizers on the quality monitoring and classifying ground water pollution. Data used in this study were generated from field measurements of ammonium, nitrate and phosphate concentration in 4 years of a Seri of 10 wells. To achieve the purpose, distribution trend of parameter's concentration are compared with the international environmental standards to estimating pollution ratio. In the next step, the Exploratory Spatial Data Analysis (ESDA) tools were used to exploring data distribution and Geostatistical analyst tools were applied to interpolate data in order to mapping pollution severity in the study area. Results depicted, in the selected area, all wells were in appropriate condition against Ammonia pollution. But two of the wells situated in the VERY HIGH nitrate and one was in HIGH phosphate pollution. Therefore, pollution control to reach to the irrigation standards suggested. In this way, crop yield and quality will improve.

Keywords: Ground water, Geostatistical analyst, classification, monitoring pollution.

Introduction

Regards to the expansion of scientific management in water resources, using both, a powerful technology which can analyze Georeferencing data punctually and a Geostatistical tool which has adequate precision in surface interpolation were reduplicated. In recent years, Geographical Information Systems (GIS) have been increasingly used to support hydrological models and water resources management. The lecture attempts to demonstrate how the appropriate use of GIS in hydrological and water management studies can help to achieve better results more efficiently. Geostatistical Analyst creates a continuous surface by using sample points taken at different locations in a Landscape such as measurements of some phenomenon like radiation leaking from a nuclear power plant, an oil spill, elevation heights or surface and ground pollutants. Application of geographic information system (GIS) techniques in modeling and monitoring ground water pollution and geostatistical method in interpolating have been recently developed (vankuilenberh et al., 2004- pohlman, 1993-, Bandar-abadi, 2001- solaimani et al.,2004). This paper compares 2 Geostatistical interpolation techniques to submit an efficient way to classifying ground water

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pollution. Then 3 pollutants of ground water (ammonium, nitrate and phosphate) are mapping based on the international environmental standards according to the best interpolation technique.

Methodology

Study Area

Fomanat basin extending from 37°5'N to 37°23'N and 49°13'E to 49°37'E which located in the middle of Gilan province, north of Iran (figure 1). The study area is a part of Fomanat basin which the slope of the project area decreased from High Mountain (~ 2300 m) in the southwest to plain (~ 0 m) in the north. Most of the area covers with the quaternary travertine. A part of agriculture land's owners use private water wells to irrigate their farms. In this area not only fertilizers but also surface water infiltration cause to pollute ground water.

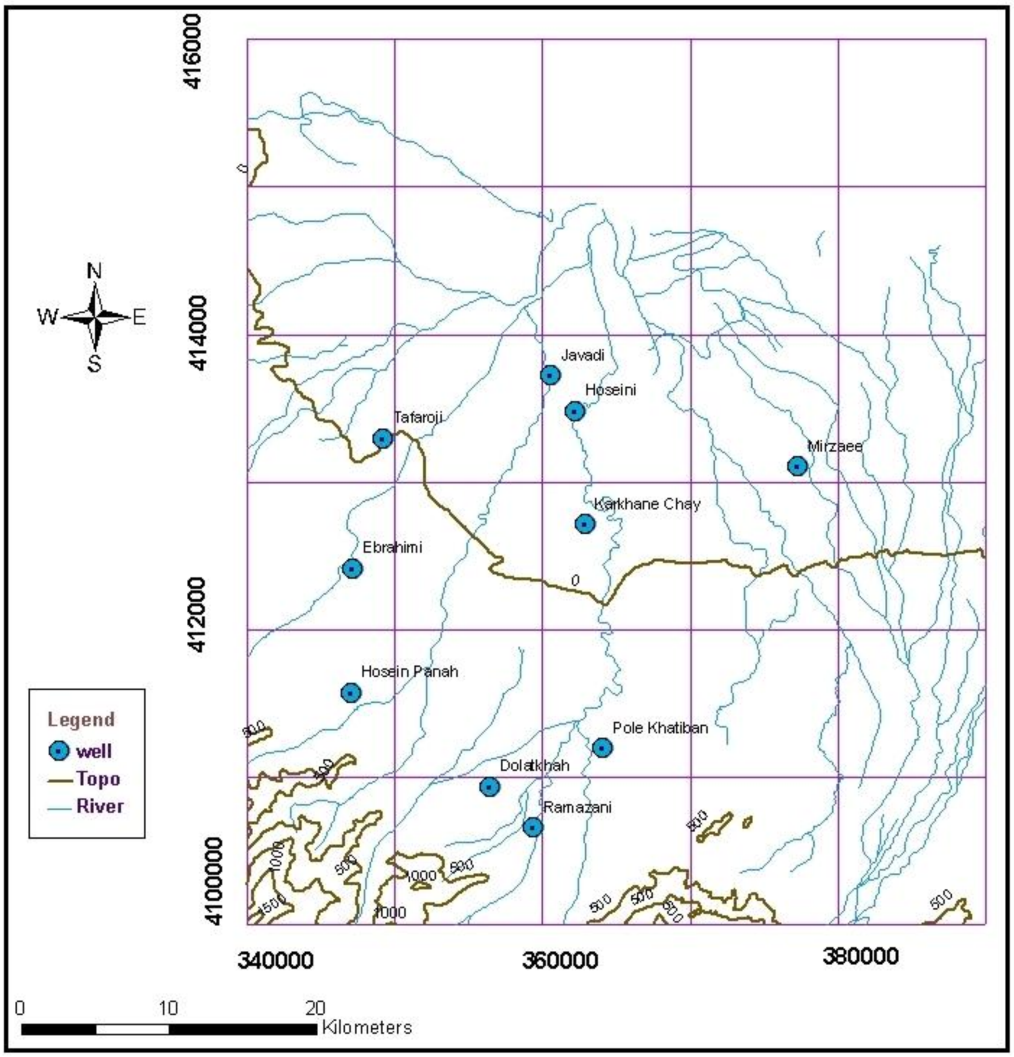

Figure 1- Position of wells in the selected area

Source Data Collection

The main objective of this study is classifying of ground water pollution in an area consist of a Seri of 10 wells based on an efficient interpolation technique. The data used in this study collected from several sources. Topographic maps of basin at the scale of 1:25000 complied by the National Cadastre Center of Iran were used to derived the boundary of the project area. A global positioning system (GPS) device was applied to collect X, Y coordinate data of wells in the area. These characteristics then entered to an Excel file and imported to a dbf format. A feature class was created based on X, Y field and was projected to the UTM coordinate system. Also, data field measurements of ammonium, nitrate and phosphate and concentration were processed and linked to feature class to use in interpolation.

Spatial Data Analysis

After data collection to interpolate water quality parameters, two methods of Inverse distance weighted (IDW) with power of 1 to 3 and simple kriging were used.

IDW Method

Inverse distance weighted (IDW) interpolation determines cell values using a linearly weighted combination of a set of sample points. The weight is a function of inverse distance. The surface being interpolated should be that of a location ally dependent variable (Philip, 1982). At the present work, for each measured element in 10 wells, the normalization histogram was drawn by using geostatistic tool. Then the IDW method with power 1 to 3 was used for data prediction. For each element a cross validation table was driven so the error parameter for each well calculated. Also for each element a classified map was achieved.

Kriging Method

Kriging is an advanced geostatistical procedure that generates an estimated surface from a scattered set of points with z values that assumes that the spatial variation in the phenomenon represented by the z-values is statistically homogeneous throughout the surface. The spatial variation is quantified by the semivariogram. By using trial and error method two model Hole-effect and j-Bessel because of the best results were selected. Cross-validation table and the driven maps in each method for each element were generated.

Comparing Methods

In this paper, to estimate error and understand accuracy of each technique, cross-validation was applied. Cross-validation uses all of the data to estimate the trend and autocorrelation models. It removes each data location, one at a time, and predicts the associated data value. The predicted and actual values at the location of the omitted point are compared. This procedure is repeated for a second point, and so on. For all points, cross-validation compares the measured and predicted values. In this paper Mean Absolute Error (MAE) were assessed to determine accuracy of technique. The MAE error is calculated by the equation 1.

$$MAE = \frac{1}{n} \times \sum \left| (X_P - X_m) \right| \qquad (1)$$

Where n is the number of samples, X_p and X_m are predicted and measured data, respectively.

After calculation all predicted parameters for each element, in the next step, MAE for finding the best fitted model were calculated. Regards to the minimum MAE in Hole-effect model, for Ammonia and Nitrate it was selected as the best fitted model which the results are depicted in the table 1 and 2. But minimum MAE for Phosphate element was driven in IDW3 model so, it was chosen as the best model and results are shown in the table 3. In the figures 2 to 4 the generated maps by the best fitted model are depicted. Figure 2 and 3 show Ammonia and Nitrate prediction map by simple Kriging and Hole-effect model. On the other hand, figure 4 shows Phosphate prediction map by using IDW (power=3).

Table 1- Predicted NH_4^+ parameters

Name	Method	IDW			Simple Kriging	
	Power	1	2	3	J-Bessel	Hole effect
	ID	Abs. Error	Abs. Error	Abs. Error	Abs. Error	Abs. Error
Hoseini	1	0.70	0.54	0.51	0.78	0.62
Hosein Panah	2	0.16	0.24	0.30	0.24	0.11
Ebrahimi	3	0.19	0.11	0.06	0.24	0.29
Pole Khatiban	4	0.06	0.01	0.10	0.07	0.03
Dolatkhah	5	0.99	1.26	1.43	0.39	0.48
Javadi	6	0.08	0.42	0.49	0.33	0.09
Mirzaee	7	0.31	0.34	0.37	0.17	0.19
Tafaroji	8	0.73	0.71	0.67	0.79	0.70
Ramazani	9	1.14	1.32	1.44	0.52	0.72
Karkhane Chay	10	0.30	0.35	0.41	0.04	0.19
SUM		4.66	5.31	5.77	3.55	3.42
MAE		0.47	0.53	0.58	0.36	0.34

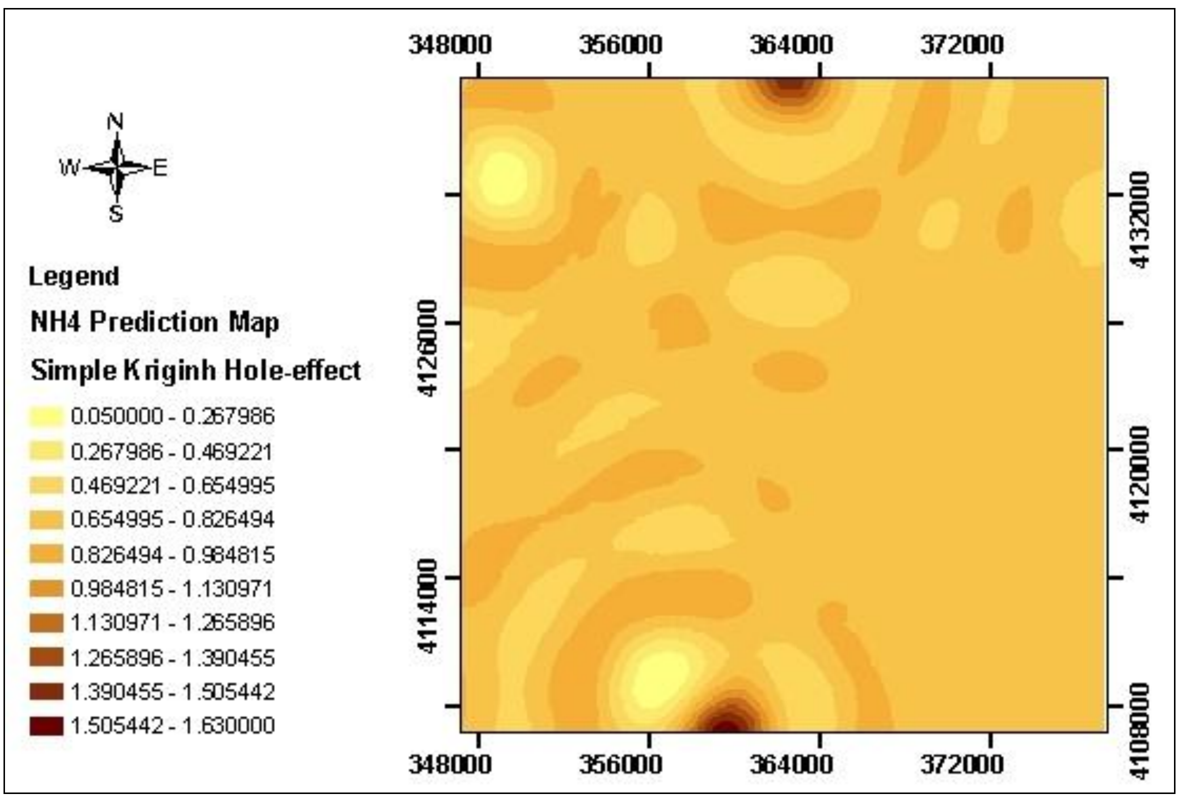

Figure 2- NH_4 Prediction Map

Table 2- Predicted NO_3^- parameters

Name	Method	IDW			Simple Kriging	
	Power	1	2	3	J-Bessel	Hole effect
	ID	Abs. Error	Abs. Error	Abs. Error	Abs. Error	Abs. Error
Hoseini	1	0.96	0.53	0.50	0.57	1.42
Hosein Panah	2	0.81	1.76	2.53	0.13	0.09
Ebrahimi	3	3.66	3.95	4.19	3.46	2.47
Pole Khatiban	4	0.29	0.92	1.21	2.06	0.19
Dolatkhah	5	7.49	7.63	7.84	5.42	6.46
Javadi	6	0.18	0.43	0.50	0.87	0.44
Mirzaee	7	0.24	0.16	0.50	0.94	0.69
Tafaroji	8	3.91	4.07	4.39	4.02	3.26
Ramazani	9	3.52	5.69	6.85	1.75	0.13
Karkhane Chay	10	1.85	1.54	1.25	0.33	2.23
SUM		22.91	26.69	29.75	19.55	17.37
MAE		2.29	2.67	2.98	1.95	1.74

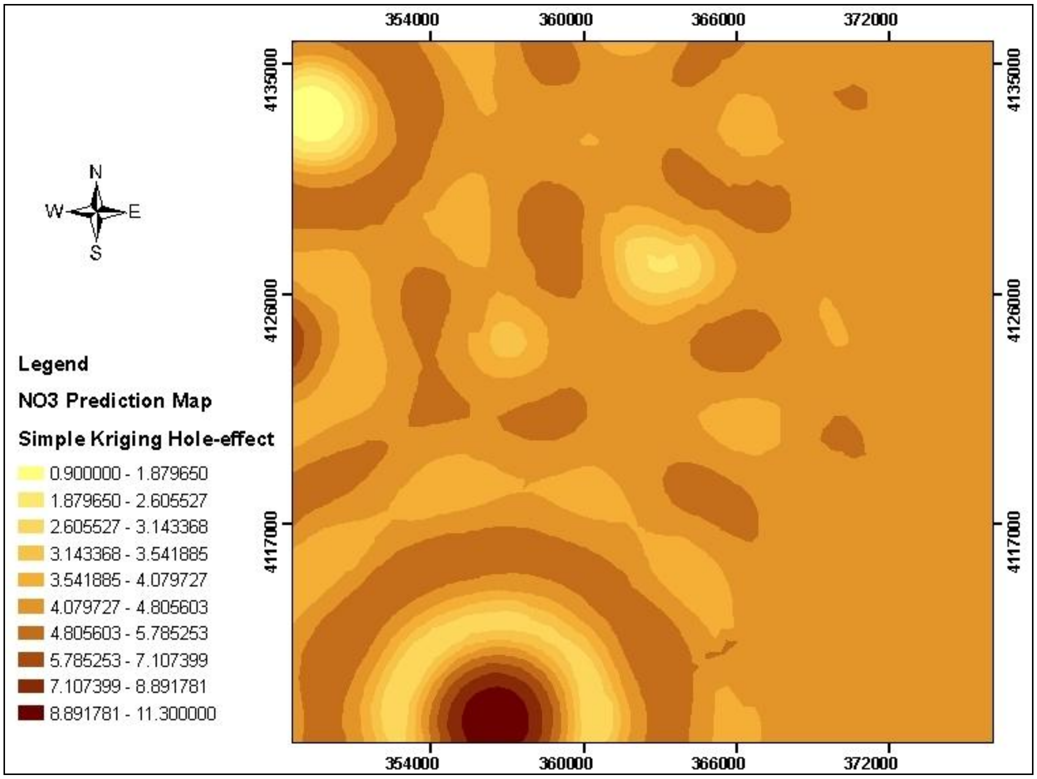

Figure 3- NO_3 Prediction Map

Table 3- Predicted PO_4^- parameters

Name	**Method**	**IDW**			**Simple Kriging**	
	Power	**1**	**2**	**3**	**J-Bessel**	**Hole effect**
	ID	**Abs. Error**	**Abs. Error**	**Abs. Error**	**Abs. Error**	**Abs. Error**
Hoseini	1	0.16	0.01	0.02	0.09	0.01
Hosein Panah	2	0.13	0.11	0.08	0.20	0.15
Ebrahimi	3	0.03	0.00	0.02	0.08	0.19
Pole Khatiban	4	0.17	0.12	0.08	0.05	0.27
Dolatkhah	5	0.09	0.03	0.00	0.10	0.14
Javadi	6	0.21	0.07	0.04	0.04	0.04
Mirzaee	7	0.34	0.28	0.21	0.52	0.25
Tafaroji	8	0.10	0.09	0.07	0.08	0.10
Ramazani	9	0.10	0.04	0.01	0.24	0.03
Karkhane Chay	10	1.02	1.04	1.06	0.87	0.86
SUM		2.36	1.79	1.59	2.25	2.04
MAE		0.24	0.18	0.16	0.23	0.20

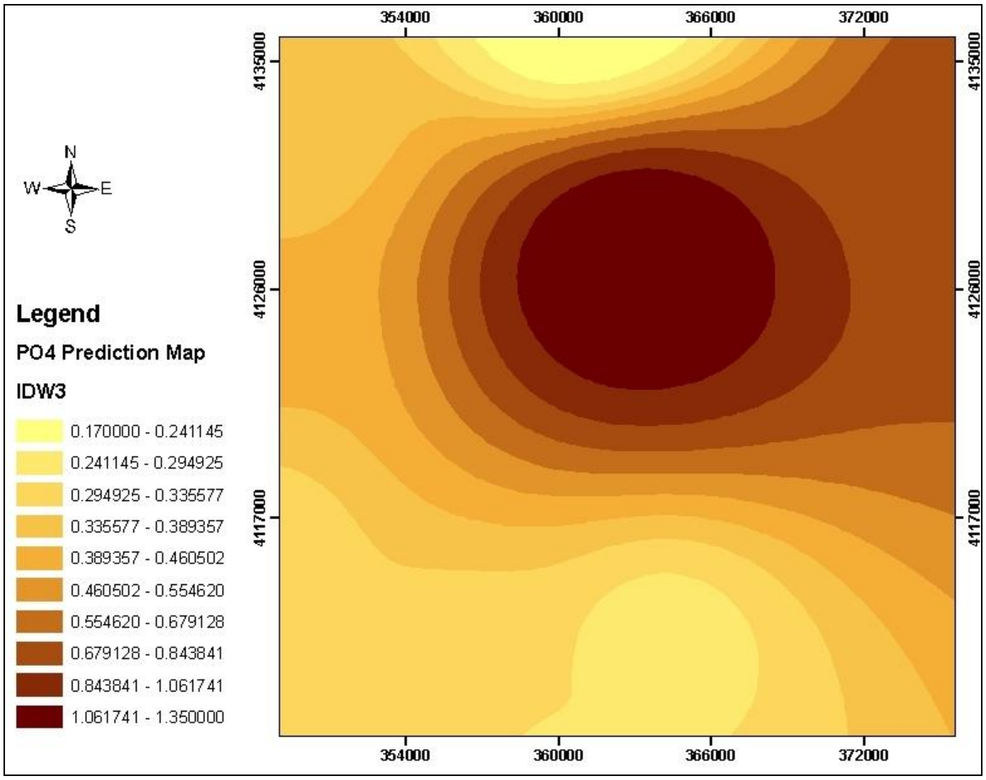

Figure 4- PO_4 Prediction Map

Classifying Based on the International Environmental Standards

Nowadays, environmental problems as one of the most important issues are negotiated. In the recent years the effect of the chemical materials in the agriculture field resulted as disordering in crop yield. Agriculture water quality as one of the main source of pollution for crops must be control. Thus, researchers based on the lots of experiments and search found some limitations to use it. Regards to the AFIF[1]2000 CANADA, the maximum acceptable range for Ammonia, Nitrate and Phosphate rate in the agriculture water are 5, 10, 2 mg/lit respectively. At the present work, after selection the best fitted model for each element, created maps were re-classed. Re-classifying phase was done by consideration 3 to 4 step in each quality range. The ranges were entitled to LOW, MEDIUM, HIGH and VERY HIGH. In this case, each well situated at the proper range. Figures 5, 6 and 7 show the re-classed maps which they illustrate the condition of water quality in the available wells.

[1] . Agri-Food Innovation Found and Water Research Crop.

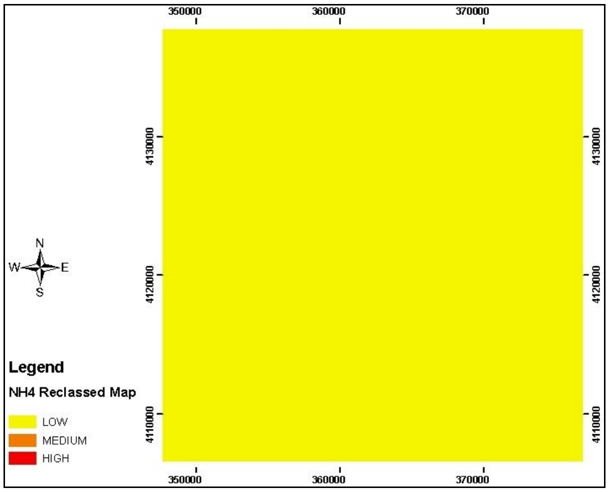

Figure 5- NH_4 Re-classed Map

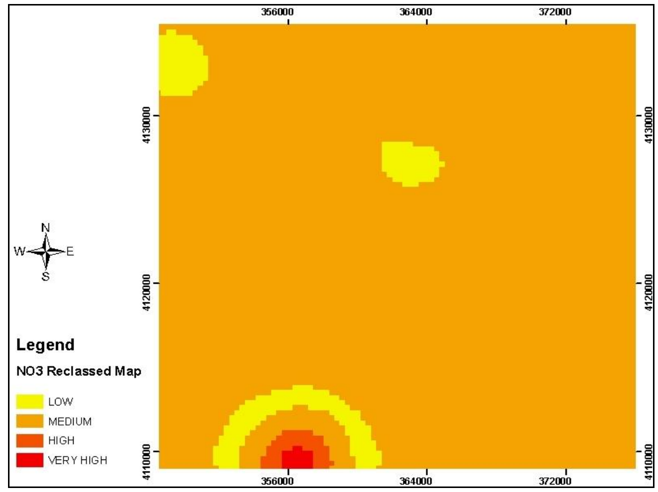

Figure 6- NO_3 Re-classed Mmap

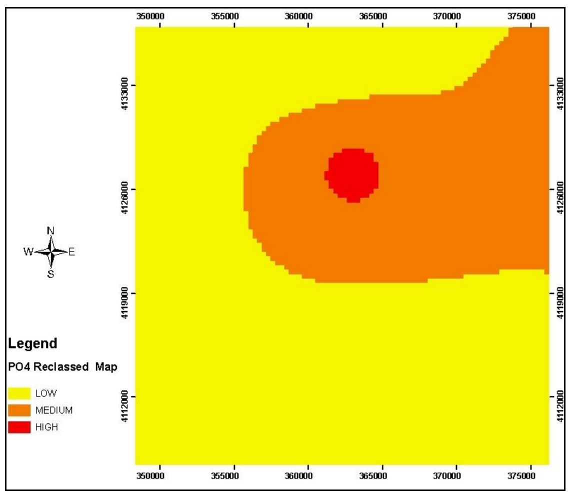

Figure 7- PO_4 Re-classed Map

Result and Discussion

As a conclusion, at the present work, for all of the water quality parameters IDW 1, 2, 3 and Simple Kriging method with J-Bessel and Hole-effect models were run. The minimum of MAE in each method was a reason for selected method. Ammonia and Nitrate had the best results in the Simple Kriging with Hole-effect model and Phosphate with IDW3 method showed the best results. Then re-classifying of the parameters based on the table 4 was done.

Table 4- Re-classifying Range

	NH_4 (mg/l)	NO_3 (mg/l)	PO_4 (mg/l)
LOW	0 – 1.67	0 – 3.33	0- 0.67
MEDIUM	1.67 – 3.35	3.33 – 6.65	0.67 – 1.33
HIGH	3.35 - 5	6.65 - 10	1.33 - 2
VERY HIGH	-	<10	-

Figure 5 relates to the NH_4 re-classed map. It illustrates the range of the Ammonia in all of the selected wells is LOW (0-1.67). Thus, water quality in use is suitable for irrigation purpose. Figure 6 shows the amount of the NO_3 base on the re-classed map. As it is clear, the most of the area is in the MEDIUM range but two of the wells are located in the VERY HIGH range which they are not suitable for irrigation. Nitrate as one of the important water quality pollutant must be lower than 10 (mg/l) for a suitable crop yield. Phosphate re-classed map depicts one of the wells is in the HIGH range, so Phosphate control in this well is suggested. Table 5 shows the water quality condition in the wells. Thus nitrate control as the most important pollutant must be applied in the selected area.

Table 5- Water Wells Quality Condition

Name	NH_4 Quality Condition	NO_3 Quality Condition	PO_4 Quality Condition
Hoseini	LOW	LOW	LOW
Hosein Panah	LOW	MEDIUM	LOW
Ebrahimi	LOW	MEDIUM	LOW
Pole Khatiban	LOW	VERY HIGH	LOW
Dolatkhah	LOW	VERY HIGH	LOW
Javadi	LOW	MEDIUM	LOW
Mirzaee	LOW	MEDIUM	LOW
Tafaroji	LOW	LOW	LOW
Ramazani	LOW	MEDIUM	LOW
Karkhane Chay	LOW	LOW	HIGH

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References

1. Vankuilenberg, J., Degruijter, J., Marsman, B.A. and Bouma, J. (1982) Accuracy of spatial interpolation between point data on soil moisture supply capacity compared with it estimates from mapping units. Geoderma 27, 377-325.
2. Pohlman, H. (1993) Geosatistical modeling of environmental data. Catena 20(1/2), 191-198.
3. Bandar Abadi, R. (2001) An assessment of geostatistacal method in estimating rainfall in arid and semi arid region of southeast of Iran. Master’s thesis. Faculty OF Natural Resource. Tehran University. 162 pages. (In Persian).
4. Solaimani,K., Habibiannejad,M., Akbari,A., Bani asadi,M. (2004) Analysis of depth-area-duration curves of rainfall in semi arid and arid region using geostatistical methods. Desert 11, 31-42.
5. Rasht Regional Water Organization reports (In Persian).
6. Philip, G.M., and D.F. Watson. (1982) A Precise Method for Determining Contoured Surfaces. Australian Petroleum Exploration Association Journal 22, 205-212.
7. Bokani, A, N. Hojat, A. Al shykh, A. (2008) Modeling of ground water pollution using geostatistical analysis in Shiraz. Geomatic Conference. Natioal Cadastre of Iran, Tehran (In Persian).
8. Chitsazan,M. Rangzan, K. Daraninejad, M.S. Taghizadeh. A. (2008) Hydro chemical mapping of rare elements; Arsenik, manganez, Fe using GIS in Midavoud , Khozestan province. Geomatic Conference. National Cadastre of Iran, Tehran (In Persian)
9. Adab.H, Fahalh.GH, Bayati.R. (2008) An Assessment of Kriging and Liner Regression based on DEM to mapping annual rainfall in Razavi Khorasan province. Geomatic Conference. National Cadastre Center of Iran,. Tehran (In Persian).
10. Maleki, R., Samani, J. M. V., Mohammadi, K. (2006) Comparison between MIKE11 and WASP6 softwares in water quality simulation: Case study in Fomant basin. Master’s thesis. Faculty OF Agriculture. Tarbiat Modares University (In Persian).