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Assessment and Zoning of Groundwater Quality in Shiraz Plain Using GIS

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Abstract: The results of the evaluation of different interpolation methods for each of the parameters studied in 2006 showed that for calcium, bicarbonate, sodium, adsorption ratios of sodium and sulfate (the Kriging method) and for the electrical conductivity parameters, the total soluble concentration and magnesium (IDW2 method) and for chlorine (IDW1 method) have the lowest MAE and MBE and in 2013, for the parameters of bicarbonate, calcium, total soluble concentration and magnesium (IDW2 method) and for sodium parameters, the adsorption ratio of sodium and sulfate (Kriging method) and for electrical conductivity and chlorine parameters (LPI method) were the best methods. Finally, the classification of the district water showed that in 2006 the only Barmshoor, Doodeman and Shagholein stations had limitations of drinking as term of TH parameter and in 2013 Barmshoor and Doodeman stations were in the most unfavourable waters as term of TH and TDS parameters.

Key words: Water quality, Shiraz plain, Kriging method, interpolation, classification.

Introduction

Water is the most abundant substance in the world, but it is very limited in quality for drinking and farming purposes. These type of water is decreasing every day and, conversely, demand for using water is increasing (Ghobadi, 2010). Therefore, the main concerns of experts and practitioners is lack of water resources and its management in recent years (Kanani, 2007). Nowadays, the amount of groundwater and its quality is decreasing (Bamdad Machiani et al., 2014). Quality assessment of groundwater resources is one of the important issues in water resource development projects of the country (Hoseinsarbazy and Esmaili, 2014). Understanding the quality of groundwater, as one of the most important and vulnerable sources of water supply, has been an obvious issue in recent decades (Shokuhi et al., 2011).

Underground water is an important part of renewable water ecosystems, which leads to change in quality of these resources and the direct or indirect degradation of other resources because of poor quality management of extraction (Zahtabian et al., 2010). So, water quality is the reflection of its composition which is affected by natural and anthropogenic activities in terms of measurable quantities (Kumar, 1997). As a result, domestic and industrial effluents contribute to the increase in concentration of different pollutants in ground water (Reghunath et al., 2002). Nowadays, the most important environmental hazard that requires maintaining the quality of ground water and studying the changes of quality resources by continuous sampling is the unsustainable development of human societies. Therefore, recent development in the introduction and expansion of non-classical methods have led to an increase in the likelihood of using land statistics

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to explore a place in understanding of the quality of groundwater resources (Rezayi et al., 2010).

Land statistics is a computational process in which the value of a quantity at a given point is estimated on the basis of the specific weight of the points with adjacent information. The quality of groundwater has spatial and temporal changes, and ground statistics techniques are important because of the consideration of spatial correlation of data and their expression in mathematical models (Sun Kang et al., 2009). Therefore, land statistical methods, due to capabilities such as reducing the number of sampling, application, and providing more accurate estimates of the spatial position of the variables, on the other hand, in recent years, many scholars have been using land statistical methods to produce groundwater qualitative maps (Habibi et al., 2009; Sheikh Goodarzi et al., 2012).

Many researches such as Mohammadi and coworkers (2011), have investigated the temporal and spatial variations of groundwater quality in Ghazvin plain during the period from 2003 to 2007, which finally understood that the water quality in the seasons of the studied years has reduced. In another study, Khashki and coworkers (2011) understand that the qualitative zonation of groundwater in the Neishabour plain, which showed the effect of salinity from chlorine ion and the high correlation between these two parameters R2 is 0.998. Research of Zolali and Barani in 2012 in Mashhad plain, using a study was conducted during a 9-year period from 1996 to 2004, which showed that although the groundwater of the study area is both desirable for drinking and agricultural quality, but its quality has dropped down from 1996 to 2004.

Gong and coworkers (2014) estimated the arsenic concentrations of Texas wells by using comparison of the inverse distance methods, Krieging-Gaussi, Krieging-Sphere, and Cochranjving, finally concluded that the inverse distance methods was better. Also, Baalousha (2010) in a study entitled Underground Water Quality Monitoring Network, using vulnerability and statistical maps, examined the nitrate monitoring network in Heretaunga in New Zealand. The results of this study showed that a number of areas with high vulnerability are not included in the monitoring network. So, a lot of research has been carried out on the quality and development of underground water resources both inside and outside the country. However, the research about study of water parameters in Shiraz plain as a functional model has not been done. So, in this research, problems caused due to the use of contaminated water are studied by measuring the trend of changes, identifying areas prone to drinking, agriculture and green space.

Study Area

Shiraz, Fars province centre, has been on a 120 km long and 15 km wide lagoon, in the east, 52 degrees, 29 minutes to 52 degrees, 32 minutes and north latitude, 29 degrees, 33 minutes to 29 degrees, 41 minutes and 900 km south of the capital. The height of Shiraz is 1448 metres above sea level and it changes to about 1700 metres in the west region. The study area is within the Zagros morphology range, which includes the Zagros Mountain and have peaks in northwest–southeast.

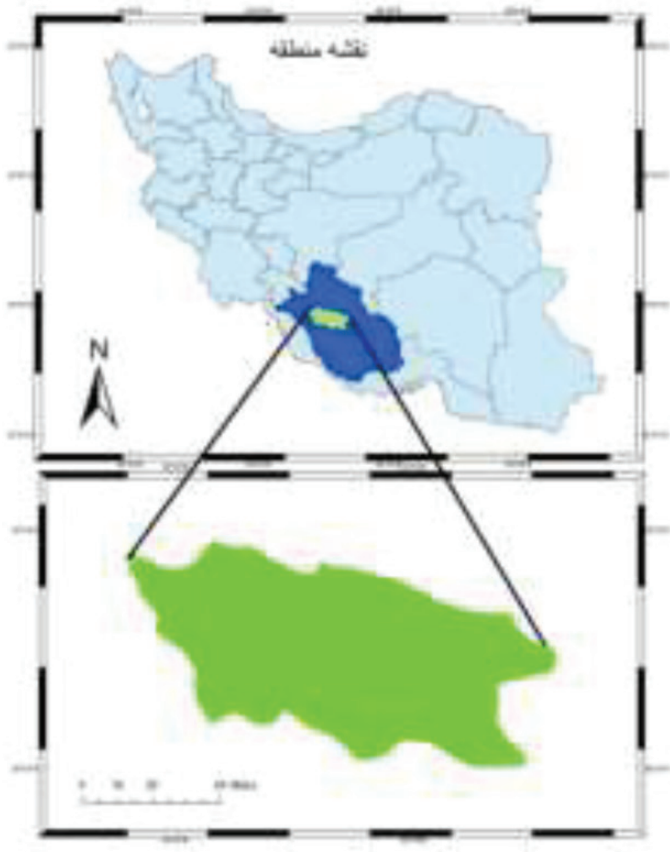

Figure 1: Map area of study.

Materials and Methods

Given that the nature of the research is an applied type, analytical descriptive methods will be used simultaneously. The theoretical foundations used in this study were obtained through library and internet studies.

Also in this study, the histogram of the data and its parameters were investigated for histological analysis of data as a statistical analysis of each of the qualitative parameters. For controlling the quality, accuracy and homogeneity of data, sequencing test was used in SPSS software environment. After examining the normal elongation or skewness of the data distribution, the Shapiro-Wilk test or Kolmogorov-Smirnov test is used to ensure that the data is normal. And finally Pearson Correlation Coefficient (*r*) was used to determine the correlation between water quality parameters.

Stages of Statistical Analysis of Land

For each statistical study, the following steps should be taken (Dasgupta and Forrest, 1995):

A. Analyze the nature of the data
B. Calculate the experimental variogram
C. Fit the model to the variogram
D. Interpolation

Fit the Model to the Variogram

In order to fit the model into a variogram, three methods are used.

A. Integration method that is calculated for fitting for each variant of variograms.
B. Minimum squares weighted method which according to the results has less computation and more accuracy.
C. Kriging Jack Nayef method, which attempts to estimate variogram parameters and eliminates one of the distinct points at time, and estimate the Kriging method.

Interpolation

Land statistics method estimates are based on the spatial structure in the target environment. Generally, statistical estimation of the land statistics methods is a process where in the value of a quantity in the points with distinct coordinates can be obtained using the same quantity in other points with distinct coordinates (Hasani, 2007). The estimation of land statistics is one of the most accurate estimation methods because it uses many factors, such as distance, anisotropy, and spatial variability (von Wolfersdorf et al., 1998). From the perspective of the land statistics, each sample is related to a certain maximum distance with the samples around them. This distance, called the range, represents the distance that statistical estimators can be used (Oliver, 2010).

Water Quality Zoning for Drinking (Shuler method), Agriculture (Wilcox method) and Green Space (FAO method)

The quality of drinking water is obtained from a diagram called Schuler diagram. According to the values obtained from the parameters, the quality of drinking water is obtained using this chart. Also for agricultural purposes, Wilcox has developed a diagram of SAR and EC values that are used in water quality studies to categorize water quality in agriculture. Using the diagram, the waters are classified into four classes in terms of quality. Finally, after selecting the best interpolation method for each air barometer, in order to examine the changes in the best way, their spatial zoning maps were designed to verify the quality of water for green space using the FAO method in the Arc GIS software environment (Ayers and Westcot, 1985). In this method, four problems of salinity, permeability, specific ionic poisoning and various issues are explained separately, and a method for evaluating each problem and the management necessary for each problem is proposed. Each of the four problems is divided into three classes: (1) without limitation, (2) moderate restriction and (3) severe constraints.

Preparation of Spatial Zonation Map of Plain Quality Parameters

After collecting and analyzing the data on the quality

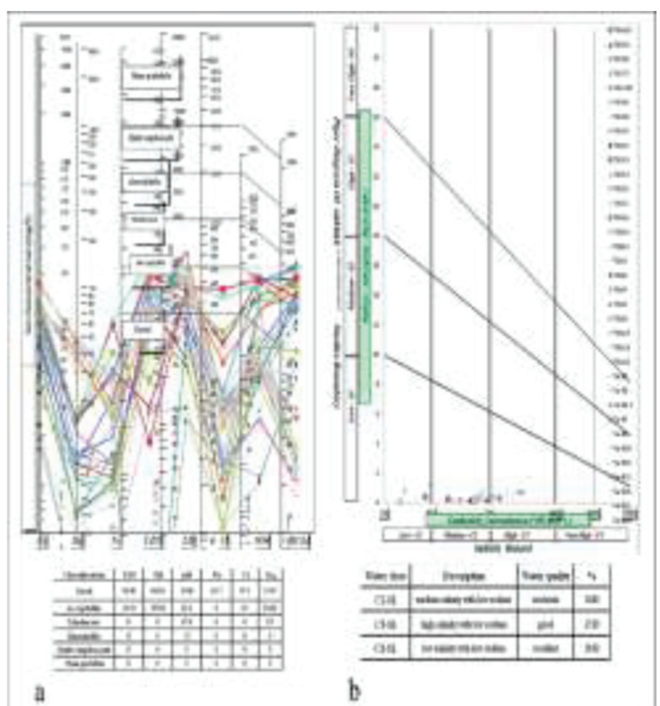

Figure 2: The Schuler charts for the classification of drinking water quality.

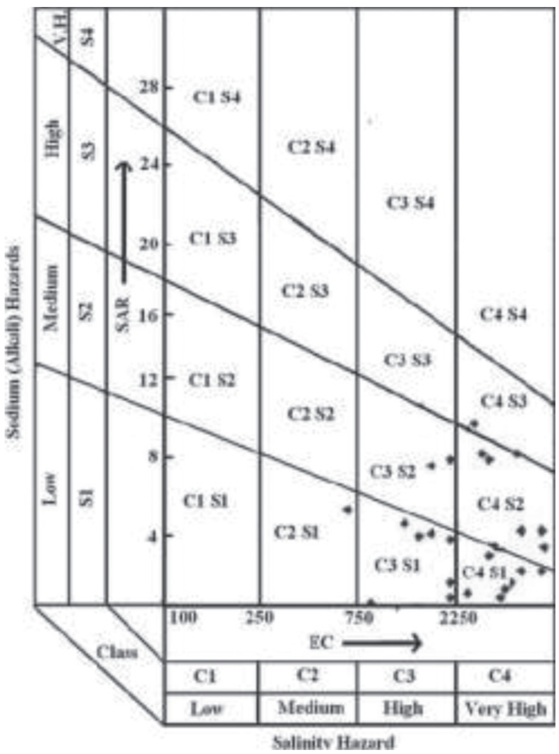

Figure 3: The Wilcox charts water quality in terms of drinking categories.

of groundwater in the observation and selection sites and converting the geographic coordinates of these wells into the metric system (UTM), using the GIS, we prepared a map of zoning these parameters using the technique of the land statistics. However, before carrying out the statistical analysis of the ground, it is necessary to test the normality and ensure the normalization of the data. This was done in the SPSS software environment.

Results and Discussion

Statistical Analysis of Land

Regarding the histogram pattern and related parameters, it was found that all of the parameters studied had skewness; so in order to normalize the data, the logarithmic transmission of the data in the results of each variable was used. The results are presented in Tables 1 and 2.

Test Normal Data in SPSS Environment

Zoning Results

Investigating and comparing the trend of water quality changes in terms of drinking in the years 2006 and 2013.

Table 1: Results of statistical analysis on groundwater events in the study area in 2006

Parameter	*Year*	*Average*	*Criterion deviation*	*Minimum*	*Maximum*	*Skidding*	*Elongation*
Mg (mg.l)	2006	7.24	6.757	0.75	25.5	1.58	1.42
Mg* (mg.l)	2006	1.622	0.88	-0.29	3.24	-0.01	-0.19
SO_4 (mg.l)	2006	8.613	10.65	0.11	36.92	1.66	1.46
SO_4* (mg.l)	2006	1.291	1.608	-2.21	3.61	-0.64	-0.37
pH	2006	7.845	0.206	7.5	8.2	0.1	-0.98
pH*	2006	2.06	0.026	2.01	2.1	0.07	-0.99
Na (mg.l)	2006	4.513	5.676	0.26	21.28	1.8	2.33
Na* (mg.l)	2006	0.846	1.199	-1.35	3.6	0.17	-0.74
Ca (mg.l)	2006	6.825	5.12	2.25	19.2	1.22	4.25
Ca* (mg.l)	2006	1.567	1.074	0.81	2.95	-1.79	1.06
Cl (mg.l)	2006	7.403	1.145	0.38	45.93	2.33	4.89
Cl* (mg.l)	2006	1.145	1.315	-0.97	3.21	0.42	-0.61
EC	2006	1719.122	1467.85	295	5735.5	1.55	1.58
EC*	2006	7.156	0.77	5.69	8.65	0.22	-0.54
SAR	2006	1.062	1.463	0	5.04	2.08	3.08
SAR*	2006	0.852	0.596	0	2.24	1.09	0.88
TDS	2006	1071.436	943.456	213.5	4015.5	2.04	3.51
TDS*	2006	6.709	0.723	5.36	8.3	0.37	0.03

* Normative value

Table 2: Results of statistical analysis on groundwater data of the study area in 2013

Parameter	*Year*	*Average*	*Criterion deviation*	*Minimum*	*Maximum*	*Skidding*	*Elongation*
Mg (mg.l)	2013	7.262	5.378	1	22	1.17	0.87
Mg* (mg.l)	2013	1.714	0.789	0	3.09	-0.29	-0.46
SO_4 (mg.l)	2013	6.411	7.929	0.2	23.32	2.03	3.78
SO_4* (mg.l)	2013	1.183	1.286	-1.61	3.48	-0.29	-0.31
pH	2013	7.372	0.396	6.3	8.01	-1.57	2.21
pH*	2013	1.996	0.056	1.84	2.08	-1.71	2.46
Na (mg.l)	2013	4.314	6.234	0.17	21.77	1.73	1.74
Na* (mg.l)	2013	0.547	1.388	-1.77	3.08	0.42	-0.92
Ca (mg.l)	2013	8.175	6.808	1.75	28	2	3.04
Ca* (mg.l)	2013	1.872	0.654	0.56	3.33	0.6	0.46
Cl (mg.l)	2013	9.164	11.251	0.35	37.38	1.54	1.24
Cl* (mg.l)	2013	1.474	1.319	-1.05	3.62	0.02	-0.91
EC	2013	1916.071	1700.39	374.25	5998.75	1.37	0.54
EC*	2013	7.243	0.789	5.92	0.7	0.46	-0.75
SAR	2013	1.214	1.504	0.2	5.72	2.17	3.57
SAR*	2013	-0.29	0.939	-1.61	1.74	0.71	-0.25
TDS	2013	1136.807	1034.652	237	3780.5	1.72	1.75
TDS*	2013	6.744	0.744	5.47	8.24	0.61	-0.25

* Normative value

Table 3: The results of Kolmogorov-Smirnov test for groundwater quality parameters in 2006

	One-Sample Kolmogorov-Smirnov Test						
	EC	*TDS*	*SO_4*	*Cl*	*Ca*	*Mg*	*Na*
N	20	20	20	20	20	20	20
Positive	.229	.301	.305	.313	.337	.241	.241
Negative	-.160	-.182	-.206	-.270	-.126	-.165	-.223
Kolmogorov-Smirnov Z	1.026	1.347	1.363	1.400	1.058	1.080	1.078
Asymp. Sig. (2-tailed)	0.244	0.53	0.049	0.040	0.213	0.194	0.196

Table 4: The results of Kolmogorov-Smirnov test for groundwater quality parameters in 2013

	EC	*TDS*	*SO_4*	*Cl*	*Ca*	*Mg*	*Na*
N	20	20	20	20	20	20	20
Maximum	5998.75	3780.50	32.32	37.38	28.00	22.00	21.77
Positive	.480	.516	.560	.496	.516	.376	.606
Negative	-.050	-.066	0.050	-.066	-.050	-.050	-.050
Kolmogorov-Smirnov Z	2.149	2.308	2.503	2.218	2.306	1.680	2.712
Asymp. Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000

Finally, by mixing the Ca, Mg, Cl, Na, SO_4 and TDS layers with GIS software, the qualitative water status of the region was calculated for drinking by using Shuler classification in the years 2006 and 2013 and the area of each of the classes and groups was calculated. The process of water quality changes across the region was compared together.

Investigation and Comparison of Water Quality Status in Terms of Agriculture in 2006 and 2013

Finally, by covering the SAR and EC layers with GIS software, the water quality status of the area was determined for agricultural use based on the Wilcox classification in the years 2006 and 2013. The area of each group was calculated and compared with each other.

Table 5: Area of various water groups for drinking in 2006

Status	*Good*	*Acceptable*	*Medium*	*Inappropriate*	*Completely inappropriate*
Area (hectare)	103729.042	30730.059	8641.464	2057.142	8.069
Area (percent)	71.456	21.169	5.953	1.417	0.006

Table 6: Area of various water groups for drinking in 2013

Status	*Good*	*Acceptable*	*Medium*	*Inappropriate*
Area (hectare)	101612.882	27442.167	14058.195	2053.595
Area (percent)	69.997	18.904	9.684	1.415

Table 7: Area of different groups of water based on Wilcox classification, 2006

Status	*Good*	*Medium*	*Inappropriate*
Area (hectare)	40305.835	87792.903	17073.454
Area (percent)	27.764	60.475	11.761

Table 8: Area of different groups of water based on Wilcox classification, 2013

Status	*Good*	*Medium*	*Inappropriate*	*Uninvited*
Area (hectare)	28372.25	39139.1819	48752.03219	28907.7617
Area (percent)	19.54399	26.9607026	33.58243523	19.9128732

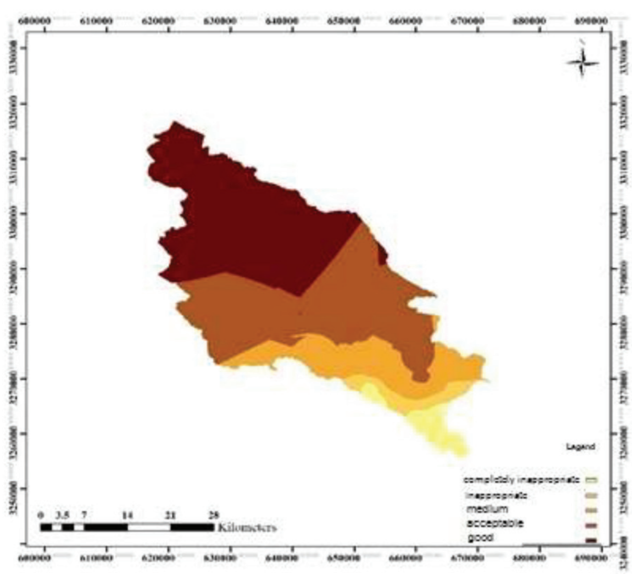

Figure 4: Groundwater quality according to Schuler classification in 2006.

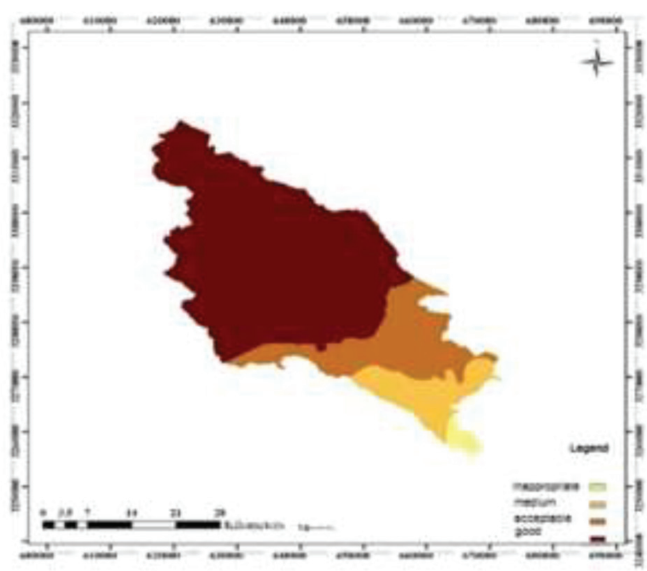

Figure 5: Groundwater quality according to Schuler classification in 2013.

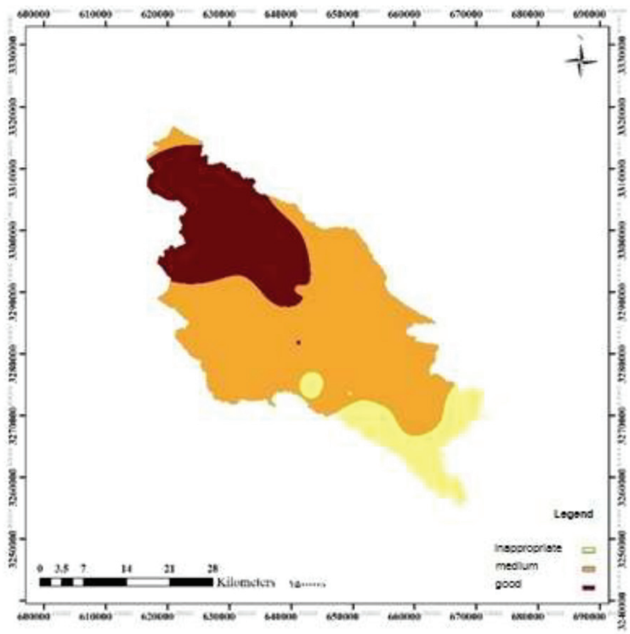

Figure 6: Groundwater quality based on Wilcox classification, year 2006.

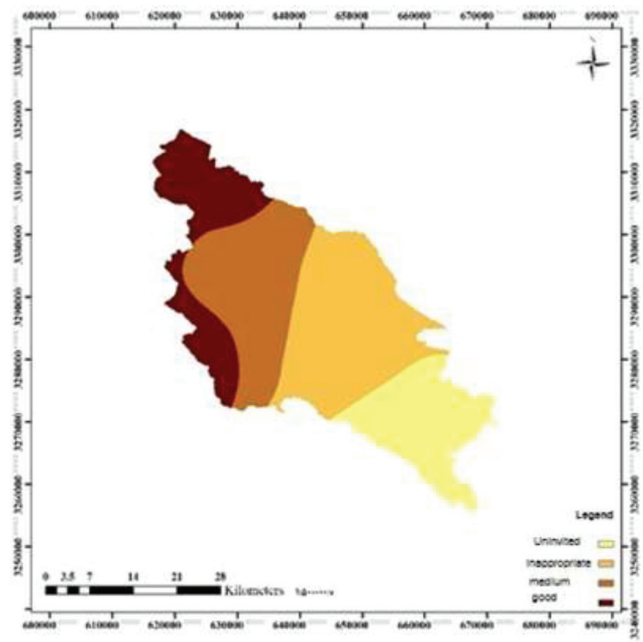

Figure 7: Groundwater quality based on Wilcox classification, year 2013.

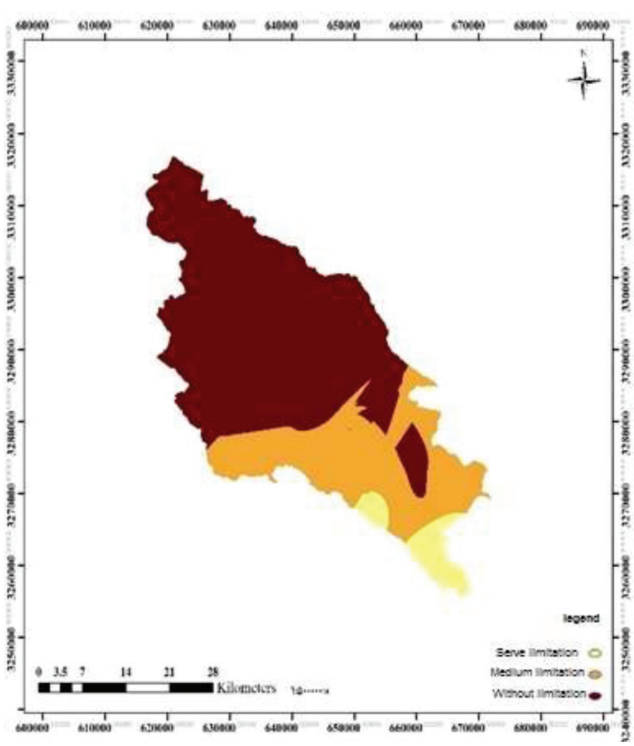

Figure 8: Groundwater quality based on FAO classification, 2006.

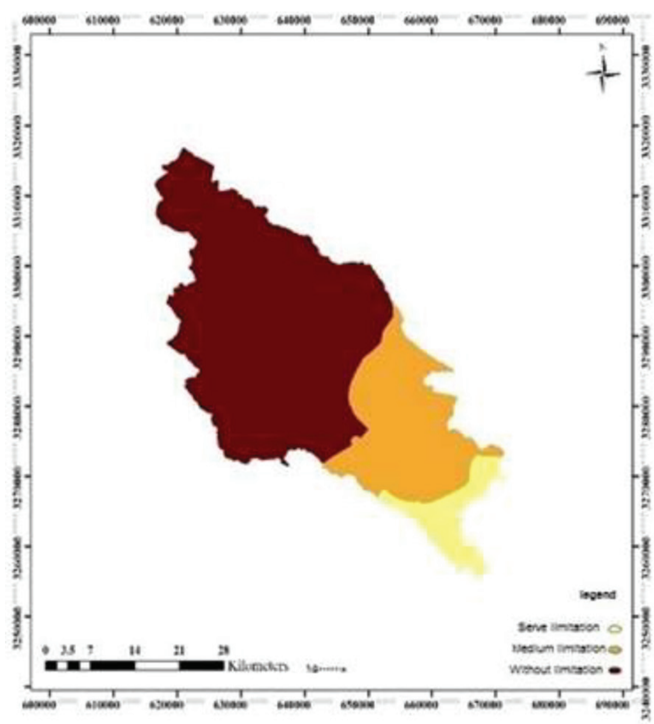

Figure 9: Groundwater quality based on FAO classification, 2013.

Investigation of Changes in Water Quality Status Based on FAO Classification in 2006 and 2013

Finally, by coating the TDS, EC, HCO_3, Na and Cl layers with GIS software, the qualitative water status of the area for green area use was calculated based on FAO classification in the years 2006 and 2013, and the area of each of the groups was calculated and the process of qualitative changes and the waters of the whole area were compared according to the five top criteria.

Table 9: Area of different groups of water for green space use based on FAO classification, 2006

Status	*Serve limitation*	*Medium limitation*	*Without limitation*
Area (hectare)	7172.122	40438.578	97556.494
Area (percent)	4.9405	27.856	67.202

Table 10: Area of different groups of water for green space use based on FAO classification, 2013

Status	*Serve limitation*	*Medium limitation*	*Without limitation*
Area (hectare)	10142.249	36163.906	98862.308
Area (percent)	6.986	24.911	68.101

Table 11: Results of Agricultural Water Quality Survey with GIS 2006

Status	*Good*	*Medium*	*Inappropriate*
Area (hectare)	40305.835	87792.903	17073.454
Area (hectare)	27.764	60.475	11.761

Table 12: Results of Agricultural Water Quality Study, Chemistry, 2013

C4				*C3*				*C2*			
S4	*S3*	*S2*	*S1*	*S4*	*S3*	*S2*	*S1*	*S4*	*S3*	*S2*	*S1*
0	0	10.53	10.53	0	0	0	52.63	0	0	0	26.32

Validation

First, in reviewing the quality of water according to the Schuler and Wilcox indicators, the results of the work with my results and outputs, which were performed in the Chemistry software, were compared, and the results are very close and realistic.

Conclusion

The results of statistical analysis of the data in the GS plus environment showed that the majority of water quality parameters have high skewness. Thus they were normalized using logarithmic transitions. This may be due to inadequate number of samples or their inappropriate distribution. Also, the high variability of environmental factors and the many factors affecting these factors can cause most environmental parameters not to be followed to normal distribution. The results of variogram analysis in 2006 and 2013 showed that all water quality parameters follow the Gaussian model. Because it is in this model most of the parameters have the least RSS and the highest correlation (R^2). Also, the results of evaluating different interpolation methods using the elimination validation technique for each of the parameters studied in 2006 indicated that for calcium, bicarbonate, sodium and the rate of sodium and sulfate adsorption, the Kriging method and for conductivity and electrical conductivity and electrical parameters, for total soluble and magnesium concentrations the IDW-2 method, and the IDW-1 method for chlorine has the least MAE and MBE.

For 2013, the parameters of bicarbonate, calcium, total soluble and magnesium concentration the IDW-2 method was the best method and for sodium parameters, the rate of sodium and sulfate adsorption Kriging method and for electrical and chlorine conductivity parameters LPI method were the best. Qualitative analysis of the parameters showed that the southern and southeastern parts of Shiraz plain has the poorest type of water quality, which requires more management and improvement and one of the main reasons is the plain topography, in which the surface water level is very high and by water the surface of the plain is fed.

In the next step, maps of qualitative parameters were prepared based on the Schuler charts for drinking purposes based on the classifications in the GIS environment. The results in 2006: 71.546 percent of the total area of drinking water was in the good category for drinking, but the amount of this class reached 69.997% people in 2013. Appropriate class changes from 21.169% in 2006 to 18.904% in 2013, changes in the average class water quality from 5.953% in 2006 to 9.684% in 2013 and inappropriate drinking class changes from 1.417% in 2006 to 1.415% in 2013 and 0.006% of the total area of the region in 2006 is completely unpleasant which reaches zero in 2013. However, in classification water quality in the Shiraz plain in term of agriculture, the water quality of this plain was compared with the Wilcox indexes and finally, the layers were overlapped to produce the water quality classification.

Due to the fact that the sodium adsorption parameter is the same for 2006 and 2013, it is added to the electrical conductivity layers and does not have any effect; actually the electrical conductivity layers determine water quality as agricultural use. In the FAO classification, the final results from the overlapping of required layers to classify the results were as follows: the trend of groundwater quality changes in Shiraz plain, from the FAO index of 97.293% of the total area in the unrestricted floor area for irrigation green space, 27.857% in the middle limit category and 4.641% in the severe restriction category for irrigation of green space in 2006 to 68.102% in the unrestricted floor, 24.912% in the middle class and 6.987% in the floor has been severely restricted for green area irrigation in 2013.

References

Ayers, R.S. and D.W. Westcot (1985). Water quality for agriculture. Food and Agriculture Organization of the United Nations, Rome.

Bamdad Machiani, S., Khaledian, M.R., Rezaei, M. and Kh. Tajdari (2014). Evaluation of groundwater quality in Gilan province for agricultural and industrial uses. *J. Irrigation Drain*., **8(2):** 246-256.

Baalousha, H. (2010). Assessment of a groundwater quality monitoring network using vulnerability mapping and geostatistics: A case study from Heretaunga Plains. New Zealand.

Dasgupta, D. and S. Forrest (1995). Tool breakage detection in milling operations using a negative-selection algorithm. Technical Report CS95-5, Department of Computer Science, University of New Mexico.

Ghobadi, M.H. (2010). Groundwater. Bu Ali Sina University Press.

Gong, G., Mattevada, S. and S.E. O'Bryant (2014). Comparison of the accuracy of kriging and IDW interpolations in estimating groundwater arsenic concentrations in Texas. *Environmental Research*, **130:** 59-69.

Hoseinsarbazy, A. and K. Esmaili (2014). Investigation of groundwater resource quality change on agriculture and technology (Case study: The plain of Neyshabour). *J. Irrigation Drain.*, **8(1):** 72-83.

Habibi, A., Ahmadi, A. and M. Fatahi (2009). Modeling the Spatial Variability of Some Chemical Properties of Groundwater Using Geostatistical Methods. *Journal of Islamic Guidance Science and Engineering*, **3(7):** 23-34.

Hosni Pak, E. (1998). Geo statistical ground. First Edition. Tehran University Press, Tehran.

Johnston, K. et al. (2001). Using ArcGIS geostatistical analyst, Esri Redlands.

Khayy Siyuki, A., Hossein Nia and M. Sarbazi (2011). Neyshabour plain underground water quality zonation by using land statistics and identification of unconventional waters. 11th National Irrigation and Evaporation Seminar, Shahid Bahonar University, Kerman.

Kanani, S. (2007). River Basin Salinity Estimate Using Artificial Neural Network. M.Sc. dissertation, University of Tarbiat Moalem.

Kumar, N. (1997). A view on freshwater environment. *Ecol. Env. and Cons*., **3:** 3-4.

Mohammadi, M., Qala Ney, M. and K. Ebrahimi (2011). Time and Spatial Changes in Qazvin Plain Underground water Quality. *Iranian Journal of Water Research*, **8:** 51-42.

Mann, H.B. (1945). Nonparametric tests against trend. *Econometrica*, **13:** 245-259.

Oliver, M. (2010). An overview of geostatistics and precision agriculture. *In:* Geostatistical applications for precision agriculture. Springer.

Rezayi, M., Devangar, N., Tajajari, A. and B. Aboulpour (2010). Investigation of spatial variations of some of the quality indices of groundwater in Guilan province using land statistics. *Water and Soil Journal*, **25(4):** 932-941.

Reghunath, R., Murthy, T.R.S. and B.R. Raghavan (2002). The utility of multivariate statistical techniques in hydrochemical studies: An example from Karnataka, India. *Water Res.*, **36:** 2437-2442.

Sheikh Goodarzi, M., Mousavi, S. and N. Khorasani (2012). Simulation of spatial variations in groundwater qualitative properties by geostatistical methods (Case study: Tehran-Karaj Plain). *Journal of Natural Resources of Iran*, **65(1):** 83-93.

Shokuhi, R., Hosinzadeh, E., Roshanaei, G., Alipour, M. and S. Hoseinzadeh (2012). Evaluation of Aydughmush dam reservoir water quality by national sanitation foundation water quality index (NSFWQI) and water quality parameter changes. *J. Health and Environ*., **4(4):** 439-450.

Sun, Y. et al. (2009). Comparison of interpolation methods for depth to groundwater and its temporal and spatial variations in the Minqin oasis of northwest China. *Environmental Modelling & Software*, **24(10):** 1163-1170.

von Wolfersdorf, J. et al. (1998). A data reduction procedure for transient heat transfer measurements in long internal cooling channels. *Journal of Heat Transfer*, **120(2):** 314-321.

Zolali, M. and Gh. Barani (2012). Investigating the Process of Changing Groundwater Quality in Mashhad Plain Using Hydrochemical Software. 6th National Conference on Environmental Engineering.

Zahtabian Gh, Janfza, A., Mohammad-Askari, H. and M. Nematollahi (2010). Modeling the distribution of some characteristics of groundwater (A Case Study in Garmsar Watershed). *Journal of Range and Desert*, **17(1):** 61-73.