Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 6, No. 5, p. 241-249, 2015
http://www.innspub.net

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RESEARCH PAPER
OPEN ACCESS

# Zonation and modeling of irrigation water quality changes in Kohpayeh plain of Segzi, Iran

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**Key words:** Zonation Water quality, Kohpayeh plain, Segzi, Kriging, $GS^+$, GIS, EC, SAR.

**Abstract**

In this research, quality data of underground water in fifty wells in Kohpayeh plain – Segzi during statistical period of eleven years (from 1997 to 2007) was studied. For investigating the changes of electrical conductivity (EC) and Sodium Absorption Ratio (SAR), first, half change was calculated in $GS^+$ environment and then by considering the best empirical fitting model, zonation of these parameters was performed using Wilcox classification and Kriging method in GIS environment. The results have shown that EC and SAR data have the best fit with Guassian and exponential model; respectively they have had ascending trend. The areas Percent are out of Wilcox classification, reached of 54.33% to 67.16%. Overall, results showed that, by using the obtained maps in GIS environment, the quality of underground water for agriculture could be easily investigated, by updating the data, better water management of the area could be performed and qualitative status of underground water of the plain could be determined at any time.

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## Introduction

Determination of Quality and quantity of groundwater is a quite obvious as one of the most important and vulnerable water supplies in recent decades (Rizzo & Mouser, 2000). Groundwater is considered as an important part of the world's renewable water. Calculation of global water resources showed that groundwater resources are formed about 0.6 percent of total water resources and 60 percent of the renewable available water resources (The Department of Environment and Conservation NSW, 2007).

Due to the variable of environmental parameters from one point to another point, using classical statistics common methods will not be useful because the geographic location of samples cannot be considered. So, for quantitative description of these environment variables distribution patterns, in addition of attribute values Set, geographical location of observations should be considered simultaneously (Mahdavi, 2005).

Changes in groundwater quality and Water salinity is a major threat to development agriculture spatially in arid area. Groundwater quality is constantly changing such as surface water, but these changes are much slower than surface water (Ahmadi & Sedghamiz., 2008).

Changes maps in chemical characteristics of groundwater plays a crucial role in the decision making process and the management of groundwater exploitation (Shabani, 2008). There are various methods for studying and zoning changes in groundwater characteristics that the accuracy of each depends on Depending on local conditions and sufficient statistics and data. Of interpolation methods for mapping groundwater quality changes can indicate to geostatistical methods including Kriging, Co-Kriging, and specific methods such as Inverse distance, radial function and etc (Shabani, 2008). Selection of appropriate method to zoning and mapping changes in groundwater quality characteristics is a major step in water resources management.

Zehtabian *et al,* (00000) in a study titled spatial analysis of water quality in Gamsar basin, Iran, using Interpolation methods of the statistics and specific comparing the RMSE and other evaluation factors concluded that Geostatistical methods are more accurate than the specific methods. Of geostatistical methods, kriging method and among specific method, radial function method, the accuracy was higher for most factors.

Ebrahimi Dorche (2009) with the study of the direct evaporation of groundwater resources on quaternary deposits in Kohpayeh plain–Segzi, Iran, using Geostatistical concluded that the kriging method is useful method in groundwater studies and evaporation from the aquifer is an is an important factor in reducing groundwater quality. Ahmadi and Sedghamiz (2008) with study the depth of groundwater in different weather conditions using Krigink and Co-Kriging showed that water depth is fluctuating and the kriging method shows these changes with higher accuracy. Dick and Heuvelink Gerard (2007) used universal kriging method to determine an appropriate pattern for groundwater sampling and mapping groundwater level fluctuations. Thomas and Bennett (1987) with zoning the risk of contamination of surface water in Mount Bold Dam watershed in America result that zoning accuracy on one hand depend on carefully data providing and field study and on the other hand the methods used in GIS environment is determinate zoning resolution of water pollution sources.

Jager (1990) used statistical tools such as kriging to modeling of water quality variables and concluded that kriging is better that other geostatistical tools. Hu *et al.* using ordinary kriging method and with studying the spatial changes of table surface, EC and nitrogen concentrations concluded that determination of the risk of groundwater contamination is useful to proper management of groundwater, soil salinity and minimize nitrate pollution in groundwater. Fatani *et al.* used ordinary kriging method to zoning map of groundwater quality from view point of the amount of ammonium nitrate and bacterial contamination in Tryfa agricultural lands in the North East of Morocco. Their results showed significant changes compared with previous studies and expressed that if have not been done any long-term deterrence, development of agricultural land causes groundwater quality degradation in these areas. Ahmed (2002) used Kriging method to estimate the spatial dependence of variable water quality such as TDS and concluded that Kiging has a high potential for this aim. Krsic (1997) suggested Kriging method as the best and most powerful tool to interpolation data for mapping groundwater.

The aim of this research is determination of the irrigation water quality changes based on provided zonation maps using Krigink in Kohpayeh plain–Segzi.

## Materials and methods

### *The Study Area*

Kohpayeh plain–Segzi is located in Isfahan province in 51° 38' to 52° 38' E and 32° 20' to 32° 49' N and has an arid climate with annual average precipitation of 117 mm. Geological map of the plains (Figure . 1) shows that marls formation (Mpm) have located in north and Northwest of the study area that can be effective on groundwater quality.

### *Methodology*

At the first, Water samples of 50 wells were selected for zoning irrigation water quality in 1997 and 2007 based on EC and SAR parameters (two effective parameters in Wilcox diagram) (Figure .2).

Therefore, semi-empirical model of change was prepared using GS⁺ software, and the best fitting model was selected and finally these changes were studied using Kriging model. Since the normalized data in ordinary kriging is initial condition, Sodium Adsorption Ratio data were normal but the electrical conductivity data were normalized using Log test. Appropriate model for fitting was determined based on less RSS and $C_0/(C_0 + C)$ ration. This ration shows that how much of the total variability is justified by section effect. So that, if $\frac{c_0}{sill} \geq \frac{1}{2}$ the effect of structured component is less than unstructured. So, in conclusion it can be said that under study variable has weak spatial structure (Hasani pak, 2007).

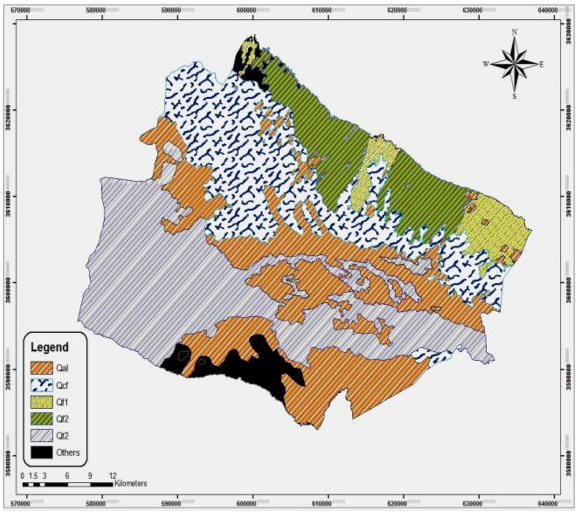


**Fig. 1.** Location of effective marl formation on groundwater salinity.

Then, according to the best fitted model and Kriging method interpolation was done using GIS and, classification of provided maps was done based on Wilcox classification (Ahmadi & Sedghamiz., 2008). Also water quality map was provided by merging EC and SAR maps based on Wilcox classification.

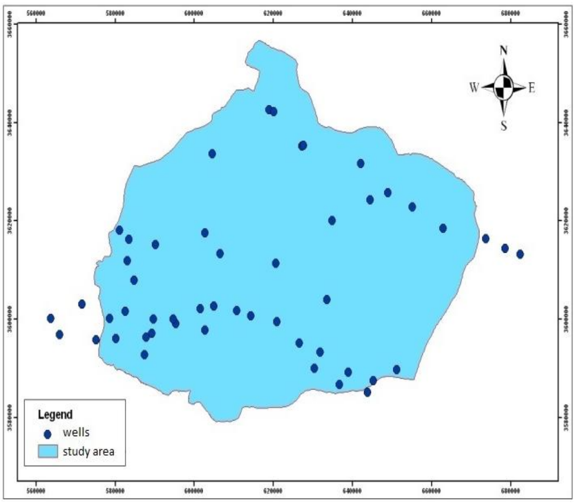


**Fig. 2.** Location of sampled wells

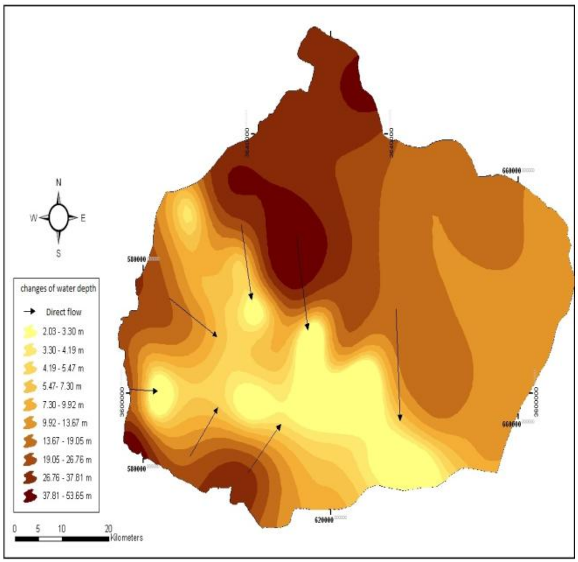


**Fig. 3.** Map of groundwater direction.

## Results

### *Water flow, EC, and SAR changes*

The results of descriptive statistics of sampled wells have been shown in table1.Changes in water flow in the study area are north and northwest to the south and east. So that in south parts of the study area and especially east, water is near the surface (Figure 3).

The results of relative frequency graph in $GS^+$ software (Figure .4) showed that Log converter is appropriate for normalization of EC data and SAR data normalization is not necessary.

Table2 shows fitted variogram parameters of EC and SAR data. According to RSS and $C/(C_0 + C)$ Gaussian model was the best model for EC and was selected as fitted model to express EC spatial changes. For SAR data, Spherical and Exponential models were determined as the best fitted model in 1997 and 2007 respectively.

Semi-empirical changes model of EC and SAR with their appropriate model related to 1997 and 2007 in $GS^+$ environment has been shown in Figure 5. For all four provided variograms with increasing distance, variance was increased indicated that spatial integration between electrical conductivity and sodium adsorption ratio data has been maintained.

Figure .6 shows the zonation maps of EC and SAR in GIS environment. The results indicate that EC and SAR condition is inappropriate in the study area and these two parameters have had ascending trend during these 11 years. On the other hand most area of the study area has classified in inappropriate classes.

**Table 1.** Descriptive statistics of sampled wells.

| Row | Longitude | Latitude | Depth water (1979) | Depth water (2007) | Row | Longitude | Latitude | Depth water (1979) | Depth water (2007) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 580752 | 3594198 | 86.23 | 4.2 | 26 | 636615 | 3585955 | 6.4 | 3 |
| 2 | 596055 | 3607245 | 5 | 21.6 | 27 | 592365 | 3629528 | 9 | 27.1 |
| 3 | 590270 | 3622287 | 5.7 | 9.7 | 28 | 590542 | 3615534 | 6.9 | 8.9 |
| 4 | 647937 | 3595825 | 44.12 | 13.12 | 29 | 640412 | 3591926 | 4.4 | 9.3 |
| 5 | 570441 | 3599152 | 99.17 | 1.4 | 30 | 597405 | 3587308 | 75.29 | 19.32 |
| 6 | 607362 | 3614405 | 11 | 21.11 | 31 | 583871 | 3611455 | 8.21 | 69.2 |
| 7 | 630380 | 3609525 | 9.12 | 9.13 | 32 | 584237 | 3607671 | 7.16 | 9.12 |
| 8 | 602004 | 3595333 | 19.8 | 5.4 | 33 | 616385 | 3610977 | 6.5 | 4.2 |
| 9 | 617858 | 3595182 | 6 | 3 | 34 | 570801 | 3596815 | 6.9 | 2.5 |
| 10 | 610693 | 3602287 | 8.4 | 17.4 | 35 | 577338 | 3618860 | 3.3 | 81.28 |
| 11 | 576254 | 3600560 | 26 | 7.23 | 36 | 562715 | 3598349 | 11.46 | 5.38 |
| 12 | 587921 | 3591375 | 16 | 9.13 | 37 | 604351 | 3583024 | 46.23 | 11.25 |
| 13 | 602012 | 3585131 | 9.29 | 8.31 | 38 | 626638 | 3595608 | 8.4 | 1.3 |
| 14 | 600657 | 3602123 | 37.6 | 2.3 | 39 | 620576 | 3611430 | 37.13 | 8.13 |
| 15 | 587427 | 3610338 | 5.18 | 16.17 | 40 | 568581 | 3593891 | 24.61 | 54.54 |
| 16 | 579009 | 3604139 | 9.1 | 9.8 | 41 | 609262 | 3619528 | 36.48 | 48.5 |
| 17 | 613479 | 3613689 | 6.19 | 17.21 | 42 | 625479 | 3605139 | 9.4 | 6.4 |
| 18 | 596737 | 3614732 | 7.7 | 5.8 | 43 | 653763 | 3583690 | 6.7 | 82.2 |
| 19 | 604549 | 3601611 | 5.4 | 22.3 | 44 | 623597 | 3607113 | 7.13 | 86.13 |
| 20 | 610086 | 3609851 | 7.8 | 2.9 | 45 | 565362 | 3597259 | 17.37 | 15.29 |
| 21 | 560695 | 3598325 | 3.41 | 7.4 | 46 | 642640 | 3597593 | 2.16 | 8.15 |
| 22 | 604181 | 3608512 | 66.12 | 9.14 | 47 | 635844 | 3603267 | 6.14 | 8.14 |
| 23 | 599683 | 3616901 | 5.5 | 9.5 | 48 | 613114 | 3597197 | 8.3 | 5.2 |
| 24 | 584129 | 3596551 | 8.6 | 2.3 | 49 | 653786 | 3588712 | 7.9 | 9 |
| 25 | 594455 | 3621143 | 4.8 | 9 | 50 | 602182 | 3620188 | 7 | 5.7 |

*Zonation and modeling of Irrigation Water quality changes results*

The results of Wilcox classification using GIS software showed that for EC factor 75.22 and 80.02 percent of the total area was classified in impermissible class IN 1997 and 2007, respectively ($C_4$: EC is more 4000 mμ/cm). While, for SAR, just 16.79 and 39.93 percent of the study area was classified in impermissible class ($C_4$) in 1997 and 2007 respectively, and the rest of the study area was classified in $C_3$ In both years. All in all the result of EC and SAR indicate that the groundwater quality for irrigation is inappropriate (Figure .5).

**Table 2.** The best fitted model to Semi-empirical changes model.

| Factor | Model | Nugget ($C_o$) | SILL ($C_o$+C) | Range (m) | $C_o/(C_o+C)$ | $R^2$ | RSS |
|---|---|---|---|---|---|---|---|
| EC(1997) | Gaussian | 0.28 | 0.76 | 35800 | 0.63 | 0.81 | 0.058 |
| EC(2007) | Gaussian | 0.35 | 1.32 | 39700 | 0.73 | 0.91 | 0.1 |
| SAR(1997) | Spherical | 6.86 | 15.5 | 55000 | 0.55 | 0.5 | 58.3 |
| SAR(2007) | Exponential | 9.09 | 20.96 | 24900 | 0.57 | 0.67 | 35.4 |

**Table 3.** The results of groundwater quality classification for agriculture (1997).

| Class C | Class S | Willcox | Area | Percent |
|---|---|---|---|---|
| C3 | S3 | C3S3 | 117657 | 25 |
| C4 | S4 | C4S4 | 99139 | 21 |
| >C4 | S4 | >C4,S4 | 79730 | 17 |
| >C4 | S3 | >C4,S3 | 178231 | 38 |

The area of inappropriate groundwater classes have been more over 11 years. The results of quality classification based on Wilcox classification (irrigation water) in GIS environment showed that the study area was classified in C3S3, C4S3, > C4, S3 and >C4, S4 in 1979 and in 2007 also classified in $C_3S_4$ and $C_4S_4$. Also, 54.33 percent of the study area was out of Wilcox classification and is unsuitable for irrigation. Due to the increase of electrical conductivity and sodium adsorption ratio parameters in the study area, about 67.16 percent of the study was unsuitable for irrigation in 2007 (Table3, 4 and Figure 7).

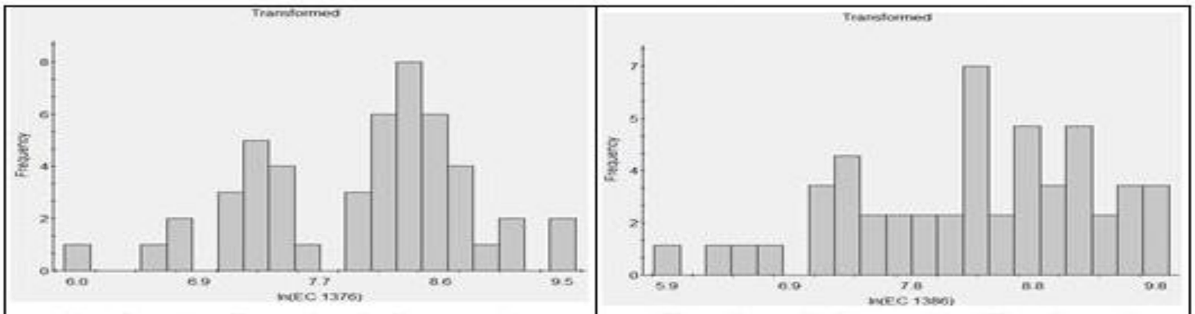
**Table 4.** The results of groundwater quality classification for agriculture (2007).

| Class C | Class S | Willcox | Area | Prcent |
|---|---|---|---|---|
| C3 | S1 | C3S3 | 90617 | 19 |
| C3 | S2 | C3S4 | 3985 | 1 |
| C4 | S1 | C4S3 | 55036 | 12 |
| C4 | S2 | C4S4 | 6262 | 1 |
| >C4 | S1 | >C4,S3 | 139515 | 29 |
| >C4 | S2 | >C4,S4 | 179341 | 38 |

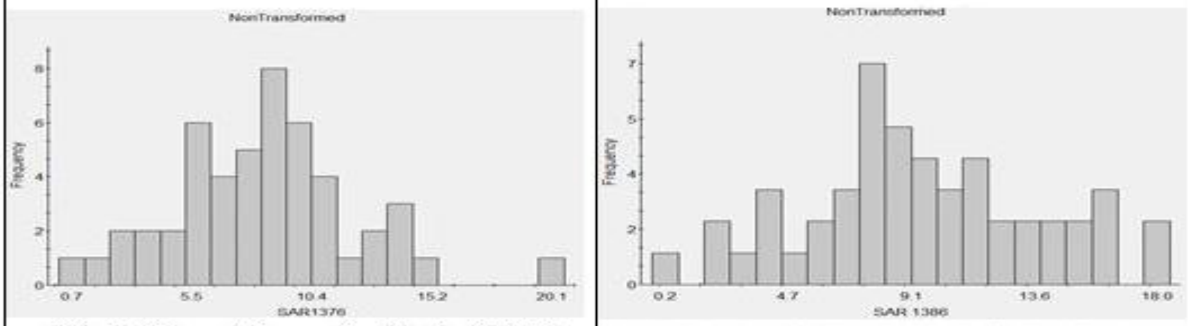
Figure 8 shows irrigation water quality changes from 1997 to 2007. This change is that each class has changed to a worse class and water quality is generally more unsuitable.

## Discussion and conclusion

The results showed that the electrical conductivity was more that 4000 mμ/cm in most part of the study area (75.22) in 1979 that the cause is probably due to the marl formations in the north part of the region. In 2007, this rate is higher than the maximum Wilcox classification in more part of the study area (80.07) that shows increased salinity. The cause of this increased salinity is related to shallow groundwater and high evaporation in the study area that leading to soil and water degradation.

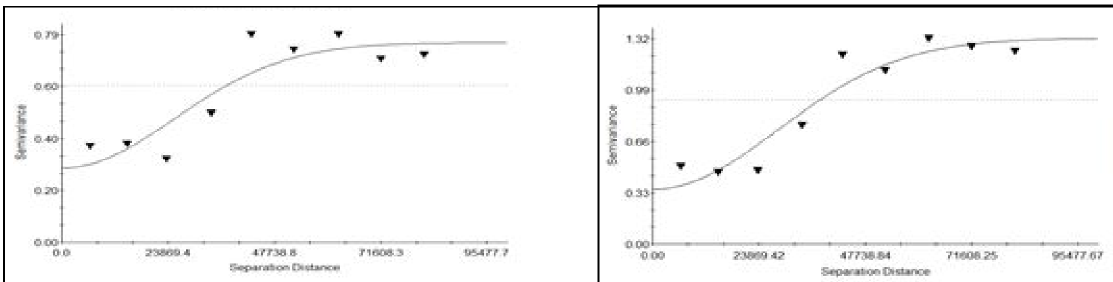


(a). Electrical Conductivity (1997) (b). Electrical Conductivity (2007)

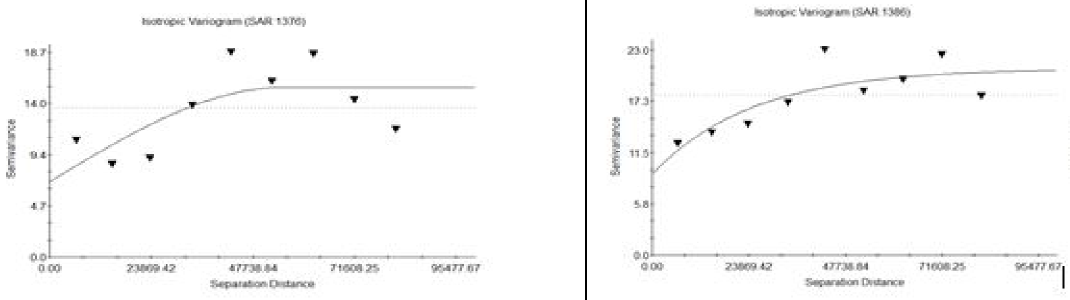


(C). Sodium Adsorption Ratio (1997) (d). Sodium Adsorption Ratio (2007)

**Fig. 4.** The graph of frequency in GS⁺ environment for studying the best way to normalize the data.



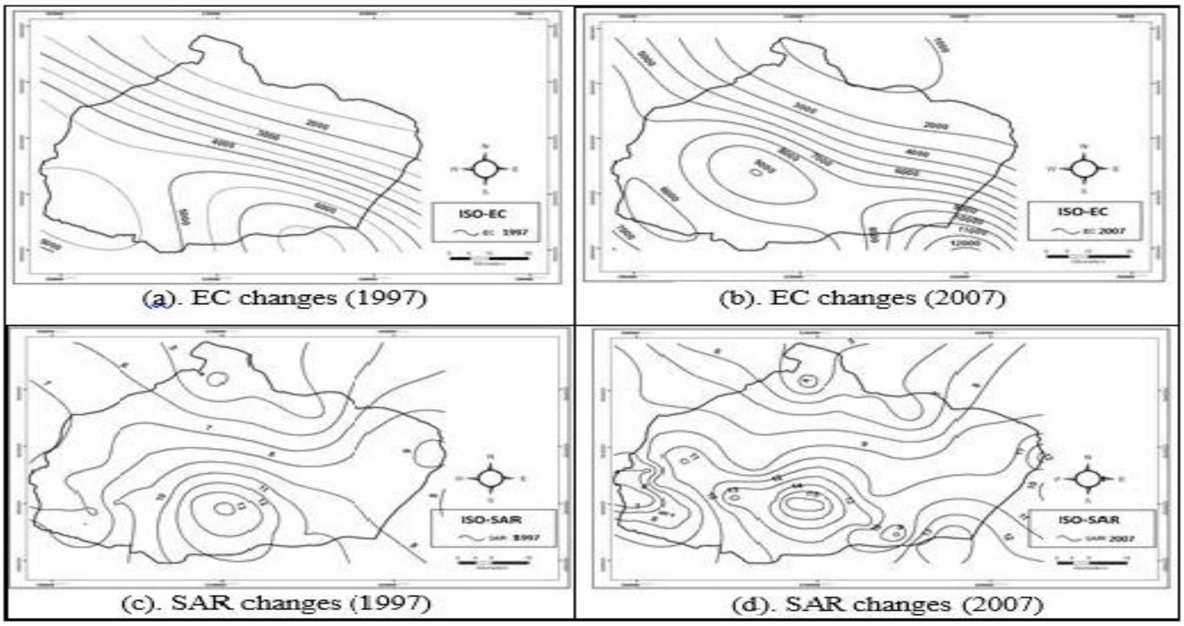
(a). Semi-empirical changes model of EC (1997) (b). Semi-empirical changes model of EC (2007)



(c). Semi-empirical changes model of EC 1997) (d). Semi-empirical changes model of SAR (2007)

**Fig. 5.** Semi-fitted empirical changes model of EC and SAR.

Studying the trend of EC chances in GS+ environment shows that the concentration of this parameter is increasing from the north and northeast to the south and southwest attributed to the following reasons: (a): Marl is caused groundwater salinity in the north part of the region; (b): Groundwater flow direction if from the north and northeast to the south and southwest; (c): Depth of groundwater level declines to the south and southwest regions, even reaching the earth's surface in some years, that causes groundwater evaporation and increased salinity in this area (Ebrahimi Dorche, 2009). About SAR, this increasing trend is from north to the south and southeast. Water quality zoning map based on Wilcox classification in GIS environment shows that water quality for irrigation is more unsuitable in east and southeast, extended to center, north and northwest over the time. Also, the results of water quality zoning for agricultural is more corresponded with the results of SAR changes. The reason for this is that EC concentration is above Wilcox classification in most part of the region that caused electrical conductivity has almost the same effect in the study area.



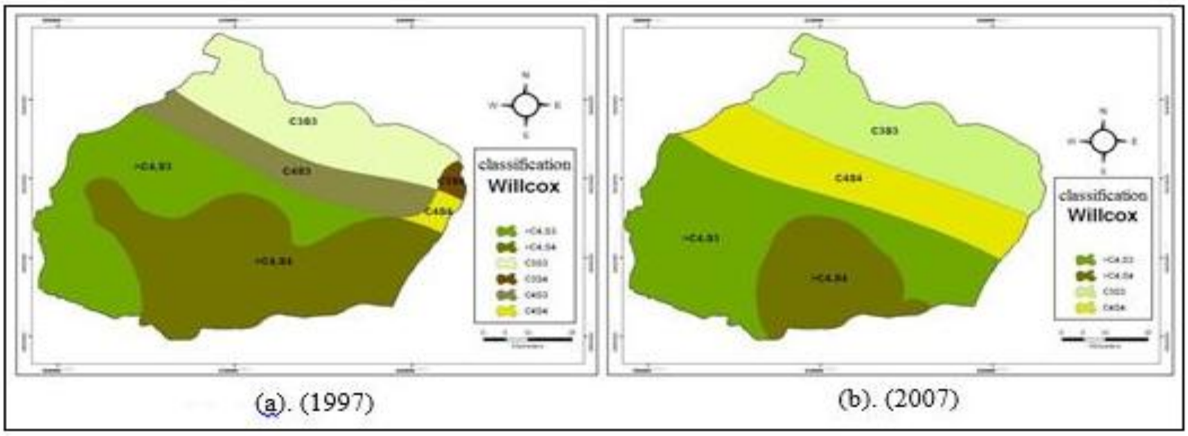
(a). EC changes (1997)

(b). EC changes (2007)

(c). SAR changes (1997)

(d). SAR changes (2007)

**Fig. 6.** Zonation map of EC and SAR changes.



(a). (1997)

(b). (2007)

**Fig. 7.** Zoning map of irrigation water quality based on Wilcox classification.

This study corresponded with the results of Jager (1990) has endorsed high performance of Kriging model in groundwater quality studies. Also the result showed that qualitative and quantitative status of groundwater in terms of drinking and agricultural easily can be studied using GIS and geostatistical methods Consistent with the results of Hu *et al*, (2005) and Ahmed (2002). All in all, using geostatistical methods such as Kriging can have a greater control on management of groundwater quality especially in arid and semi-arid area that because of lack of surface water resources groundwater is more important.

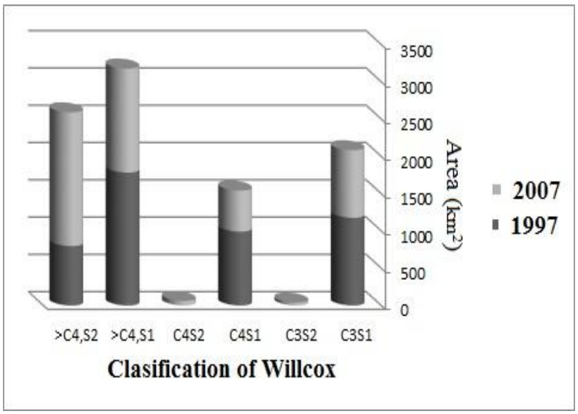


**Fig. 8.** Water quality changes and class area in 1997 and 2007.

**Refrences**

**Ebrahimi KH.** 2009. Investigation of quaternary deposits from view of dircert evaporation from groundwater, segzi plain. MSc thesis, university of Tehran.

**Hasani pak AA.** 2007. GEOSTATISTIC. Pubilish of university of Tehran. 302 p.

**Zehtabian GH, Mohammad askari H.** 2007. Investigation and spatial analysis of groundwater quality, garmsar watershed. University of Tehran.

**Shabani M.** 2008. Determination the best geostatistic approach in providing of change map of PH and TDS. Arsanjan. Iran.

**Mahdavi M.** 2005 Applied hydrology, publication of university of Tehran.

**Ahmadi SH, Sedghamiz A.** 2008. Application and evaluation of kriging and cokriging methods on groundwater depth mapping. Environ Monit Assess **138**, 357–368.

**Ahmed S.** 2002. Groundwater monitoring network design: Application of geostatistics with a few case studies from a granitic aquifer in a semi-arid region. In: Groundwater Hydrology, M.M. Sherif, V.P. Singh and M. Al-Rashed (Eds.), Balkema, Tokyo, Japan **2,** 37-57.

**Dick JB, Heuvelink Gerard BM.** 2007. Optimization of sample patterns for universal krijing of environmental variables. Geoderma **138,** 86-95.

**Fetouani S, Sbaa M, Vanclooster M, Bendra B.** 2008. Assessing groundwater quality in the irrigated plain of Triffa (Nnorth-east Morocco). Journal of Agricultural Water Management **95,** 133-142.

**Hu K, Huang Y, Li H, Li B, Chen D, Edlin White R.** 2005. Spatial variability of shallow groundwater level, electrical conductivity and nitrate concentration, and risk assessment of nitrate contamination in North China Plan, Environment International **31,** 896-903.

**Jager N.** 1990. Hydrology and Groundwater simulation. Lewis Publisher.

**Kresic N.** 1997. Hydrogeology and Groundwater Modeling. Lewis Publishers.

**Taghizadeh Mehrjerdi R, Zareian M, Mahmodi SH, Heidari A.** 2008. Spatial distribution of groundwater quality with geostatistics (Case study: Yazd-Ardakan plain).World Applied Science Journal **4(1),** 9-17.

**Kitanidis PK.** 1993; Geostatistics, Chapter 20 in Handbook of Hydrology, Edited by D. R. Maidment, 20.1-20.39 p. MacGraw-Hill, New York, 1993.

**Thomas D, Bennet D.** 1987. A study of Land characteristics, use and management in relation to water quality in the catchment of Mount Bold reservoir, Journal of Water, Air and Soil pollution **124,** 198- 162.

**Rizzo DM, Mouser JM.** 2000. Evaluation of Geostatistics for Combined Hydrochemistry and Microbial Community Fingerprinting at a Waste Disposal Site. 1-11 p.

**The Department of Environment and Conservation NSW.** 2007. Guidelines for the Assessment and Management of groundwater Contamination, Published by: Department of Environment and Conservation NSW, Website:www.environment.nsw.gov.au