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Assessment of drought and landuse changes: Impacts on groundwater quality in Shabestar basin, North of Lake Urmia

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Abstract

Management of groundwater quality is very important in arid and semi-arid areas. In this study, satellite images from TM, ETM and OLI sensors were used to evaluate the impacts of land use changes on groundwater quality for 1990, 2007 and 2015 in Shabestar basin. After processing and analyzing images, the basin was classified into five land use classes including pasture, bare land, farming, garden and residential. Motivate averages of 3, 5 and 7 years were used to determine precipitation changes trends and identifying wet and drought periods. Zoning maps of qualitative parameters including EC, SAR, TH, Cl and Na for 40 wells in a decade (2002 to 2012) were plotted using geostatistical methods to evaluate changes in groundwater quality. The obtained results from motivating average graph showed that drought was occurred during the first period 1997 to 2003 due to lack of rainfall, the worst drought was occurred in year 1999. Overall, the quality of groundwater was improving over the period. So that water quality was low in the first period (2002-2005) due to coinciding with the drought period and water quality was improving due to coinciding with wet periods in the second and third period (2006-2009 and 2010-2012). The amount of water quality parameters has increased in the southern and western parts of the region where located in the vicinity of Lake Urmia and water in these areas aren't suitable for farming and drinking. It can be due to overuse of groundwater affected by land use changes in this parts of the region.

Keywords: Precipitation; Wilcox classification; Qualitative parameters; Remote sensing; GIS

1. Introduction

In Iran, ground water resources are very important as one of the most important sources of water demand for agriculture, industry and drinking. Assessment of water quality has been particular importance in groundwater studies. Agriculture and other uses of water faced with serious limitations because of excessive increase in the concentration of ions. Agriculture allocated 95% of water consumption and more than 80% of its water requirements is provided from groundwater sources, therefore it has a major role in changing qualitative and quantitative parameters of aquifer (Ahmadi *et al.*, 2007). Excessive increase in population, due to the limitation of surface water resources and the excessive exploitation of aquifers cause irreparable damage to the country natural resources including groundwater resources (Zehtabian *et al.*, 2010). Occurrence of Severe droughts and precipitation are the most extremum climatic that can effect on groundwater potential in short and long terms (Panda *et al.*, 2007). Since the amount of precipitation reduce in drought years, so lack of rainfall and excessive exploitation of groundwater cause changes in chemical quality of groundwater. Hence, unsuitable water for farming as well as soil secondary salinization could be its consequences (Karami and Kazemi, 2012). Nowadays, changes in groundwater quality and salinization of water resources are big obstacles in Iran's agricultural development, especially in arid and semi-arid lands. Therefore, evaluation of groundwater quality

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and its relation to both land use and drought is important for sustainable use of water resources. To evaluate the effect of land use change and drought on groundwater quality, a lot of studies by different researchers have done and different results also have been obtained.

Chaidembaran *et al*. (2010) investigated the effect of land use patterns on the quality of groundwater resources in south India. Salman Mahini and Raheli Namin (2012) predicted the impact of land use change on groundwater quality in Gharehsou watershed using GIS and artificial neural network. Their results showed that urban development, population growth and agricultural chemicals, washed by irrigation and come into water resources, were the most obvious sources of pollution. Karami and Kazemi (2012) evaluated spatial monitoring of groundwater salinity on drought and wet years in Tabriz plain. They concluded that for analyzing groundwater salinity in drought and wet periond. Concluded that groundwater resources were salty, very salty and with high alkalinity in years of drought, while the water quality has been good in the wet periods. Sadeghi et al. (2015) studied the effect of land use changes on the quality of groundwater in the Zeribar basin. Satellite images, GIS and geostatistical methods were used for this purpose. Concluded that land use change from forest to agriculture has the greatest impact on qualitative characteristics of groundwater, especially in north of the region. In another study Sadeghi *et al*. (2014) investigated the effect of drought on qualitative parameters of groundwater for drinking consumption using Schoeller diagram and GWQI index in Zaribar basin. Concluded that reducing the quality of groundwater in drought years can be due to groundwater drop and confluence of salty and sweet water in the study area. Williams *et al*, (2008) studied the relationship between water quality and land use properties in Ontario region located in Canada and concluded that forest land use could increase water quality, but agriculture land use creates negative change in water quality, especially during dry times of year. Other researches including Mohammadi and Karimpour Reihan, 2008; Kumar, 2012; Naghibi, 2010; Glalyzadh, 2012; Tang and Chen, 2012; Strohschön *et al*., 2013; Zehtabian, *et al*., 2013; Pour Reza, *et al*., 2014; Nitin Mishra *et al*, 2014; Nitin Mishra and Kumar, 2015 can be cited among other studies done in this field.

Due to the special significance of the plain in providing water for agriculture in Shabestar basin, North of Lake Urmia, the goal of this study is to do a research on drought and land use changes, to find drought trend, analyze land use changes, and evaluate their effects on ground water quality.

2. Materials and Methods

2.1. The study area

Shabestar is one of the counties of East Azerbaijan province which is located in 45° 05' to 46° 09' eastern longitudes and 37° 42' to 38° 24' northern latitudes. The County covers an area of 2750 square kilometers (Fig 1). It is limited to Tabriz city and Urmia Lake from northwest and northeast respectively. The maximum and minimum height of the area is 3155 to 1280 meters above sea level. Also the minimum and maximum of temperature in the area are -14 °C in winter and +31 °C in summer, respectively. The climate of study area with the annual precipitation of 300 mm is mostly semi-arid.

2.2. Methodology

2.2.1. Land use Changes

Compilation interpretation method were used to preparing land use change maps. First, radiometric and geometric quality of satellite images were evaluated. To achieve this objective, available TM 1990, ETM 2007 and OLI 2015 satellite sensor imagery were selected and also data from field visit was used as more information. The processing and analysis of satellite imagery was conducted in ENVI 5.1 software. In order to prepare a land use changes map, supervised classification method and maximum likelihood method was used. After classification, all the land uses of study area were divided into six classes including pasture, bare land, farming, garden, residential and water body. Finally, these layers were transferred to Arc GIS 10.1 for calculating the area of land uses and creating appropriate output map.

2.2.2. Geostatistics methods

Information and data of groundwater quality resources and piezometers and precipitation of study area for period (2002-2012) was taken from the database of Iran Water Resources Management Company. In order to evaluate changes in groundwater quality, zoning maps of qualitative parameters including for 40 piezometric wells in a decade (2002 to 2012) were plotted. Figure 2 shows geographical location of studied piezometric wells.

In this study kriging geostatistical method was used. To perform this procedure GS+ software was utilized to identify the best model and ArcGIS 10.2 was used to draw zoning map. Each quality parameters were assessed by GS+ software after calculation the best fit model for each parameter were identified and the model used to draw zoning map of parameters. After reviewing the errors in each of the kriging models the model which has the lowest estimated error were selected as appropriate interpolation method to predict the spatial variability of each of the quality parameters.

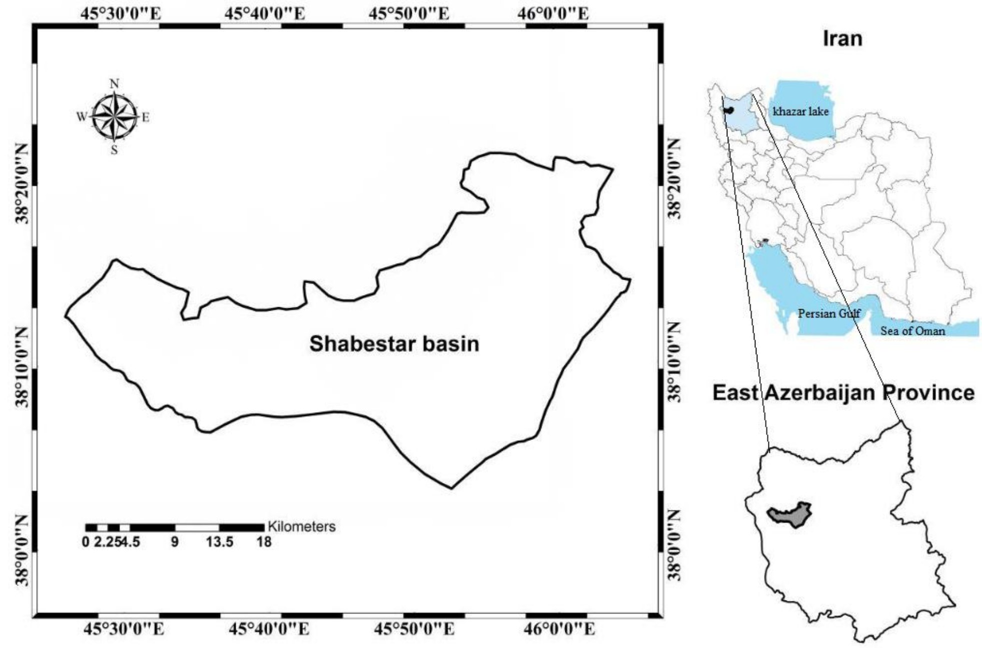

Fig. 1. Geographical location of the study area

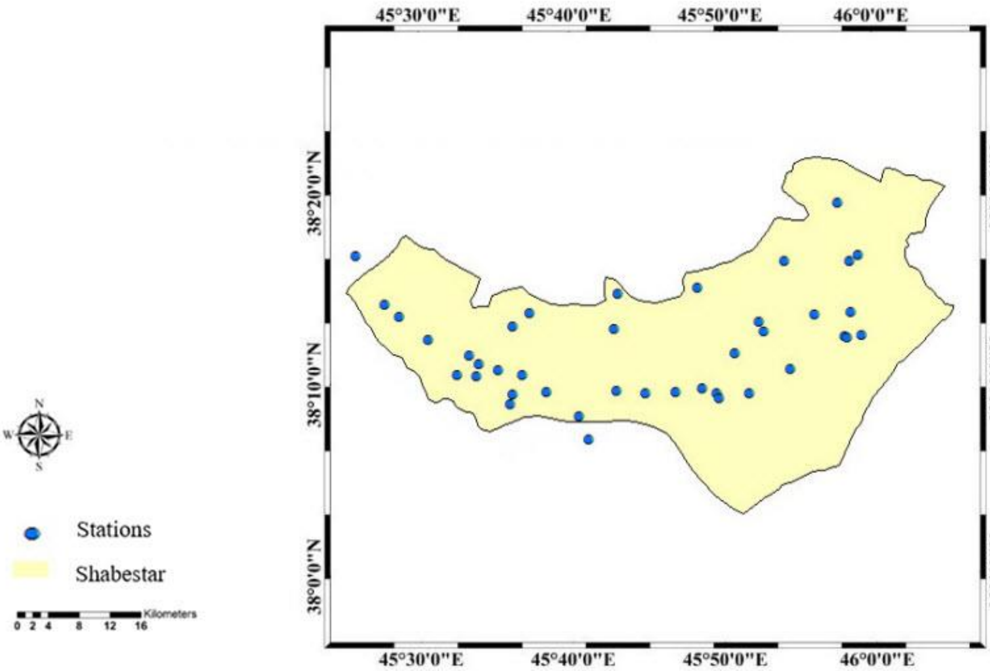

Fig. 2. Geographical location of the studied piezometric wells

2.2.3. Drought

Motivating averages 3, 5 and 7 years were used to determine precipitation changes trends and identifying wet and drought periods.

3. Results and Discussion

3.1. Land use changes

Figure 3 shows obtained results from visual interpretation of satellite images. Most changes have occurred in the time period of 1990 to 2007. According to table 1, the extent of farming, residential, gardens and bare lands since 1990 to 2007 have increased about 4221, 1587, 718 and 4337 hectares, respectively. At this period pasture land was decreased about 10312 ha and water body was totally removed. Increasing the amount of precipitation and digging deep and semi-deep wells in the region were lead to increase the extent of farming and gardens land use. Also from 2007 to 2015 the extent of farming, residential, gardens and bare lands were increased about 709, 293, 310 and 553 hectares and pasture land was decreased about 1866 ha.

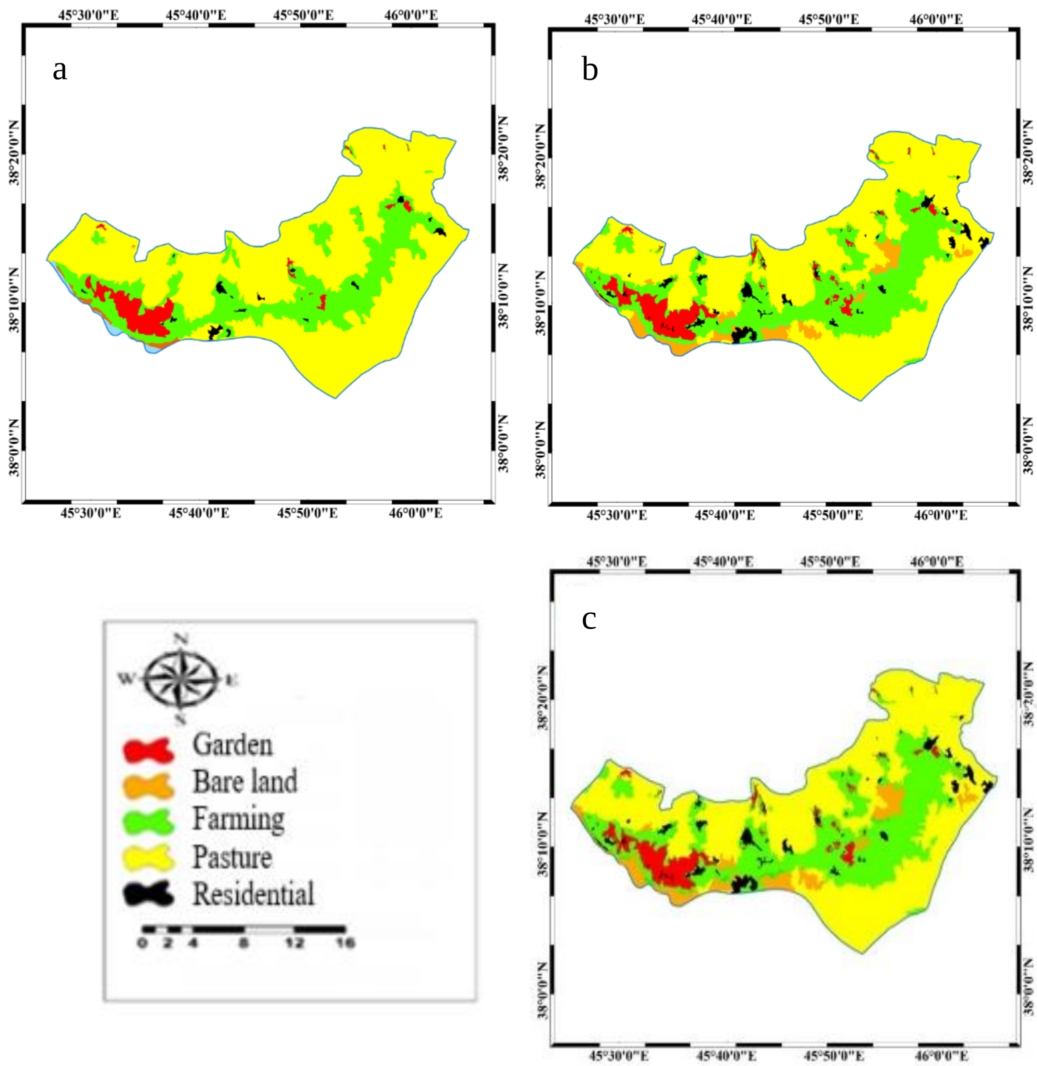

Fig3. Map of land use changes, a. 1990; b. 2007; c. 2015

Table 1. Area of different land use in observation area

2015 (hectare)	2007 (hectare)	1990 (hectare)	Land use type
26390.24	25680.71	21459.68	Farming
2707.25	2413.88	826.85	Residential
0.00	0.00	550.42	Water body
4558.89	4248.69	3530.38	Gardens
5473.63	4920.63	583.59	Bare land
49042.2	50908.29	61221.28	Pasture

3.2. Water quality parameters

According to Figure 4 and Table 1, groundwater quality has been improved in terms of EC during the period which represents the amount of EC has reduced. The amount of EC increased in southern and western parts of the area in the vicinity of Lake Urmia and water quality was unsuitable for agriculture. The Eastern part of the region located at unsuitable condition in terms of EC, so that water quality was poor in all three study periods. According to Table 2, moderate quality class has allocated more surface area of the region in the first period. Most of the area has water with good quality, in the second and third period. Also in the second and third period the amount of water with unsuitable quality have increased in southern and western parts of the region than first period.

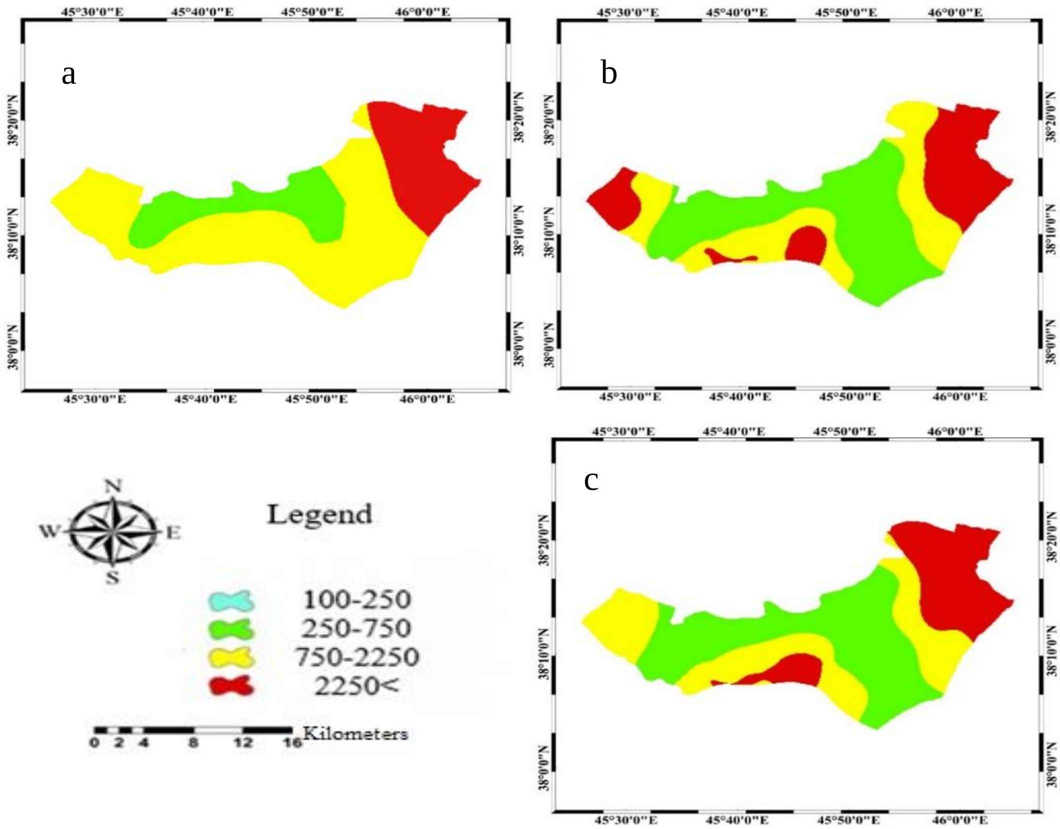

Fig. 4. Spatial variations of electrical conductivity of groundwater a. 2002-2005, b. 2006-2009, c: 2010-2012

Table 2. The area assigned to classes of electrical conductivity

Classification of electrical conductivity	Wilcox Classification	Area (%) 2002-2005	Area (%) 2006-2009	Area (%) 2010-2012
<250	Very good C_1	0	0	0
250-750	Good C_2	18	43	42
750-2250	Moderate C_3	61	31	33
2250<	Not suitable C_4	21	26	25

Figure 5 shows zoning maps of SAR which in all three studied periods, most area has water with low SAR (0-10 class) in terms of farming. Water quality has improved in the second period compared to the first and third period so that more surface area of the region has good water quality. Water quality has decreased in southern and western parts of the region during the studied period. Most classes of SAR in all three studied periods was taken between 0-18 and have good quality. The worst quality in all three study period was related to eastern part. The amount of SAR has increased from north to south and from west to east of the region. According to Table 3 almost 80% of the region was taken into 0-18 class in all three study periods. More surface area was taken in this class in the second period compared to the first and third period and the amount of farming water with moderate quality has decreased.

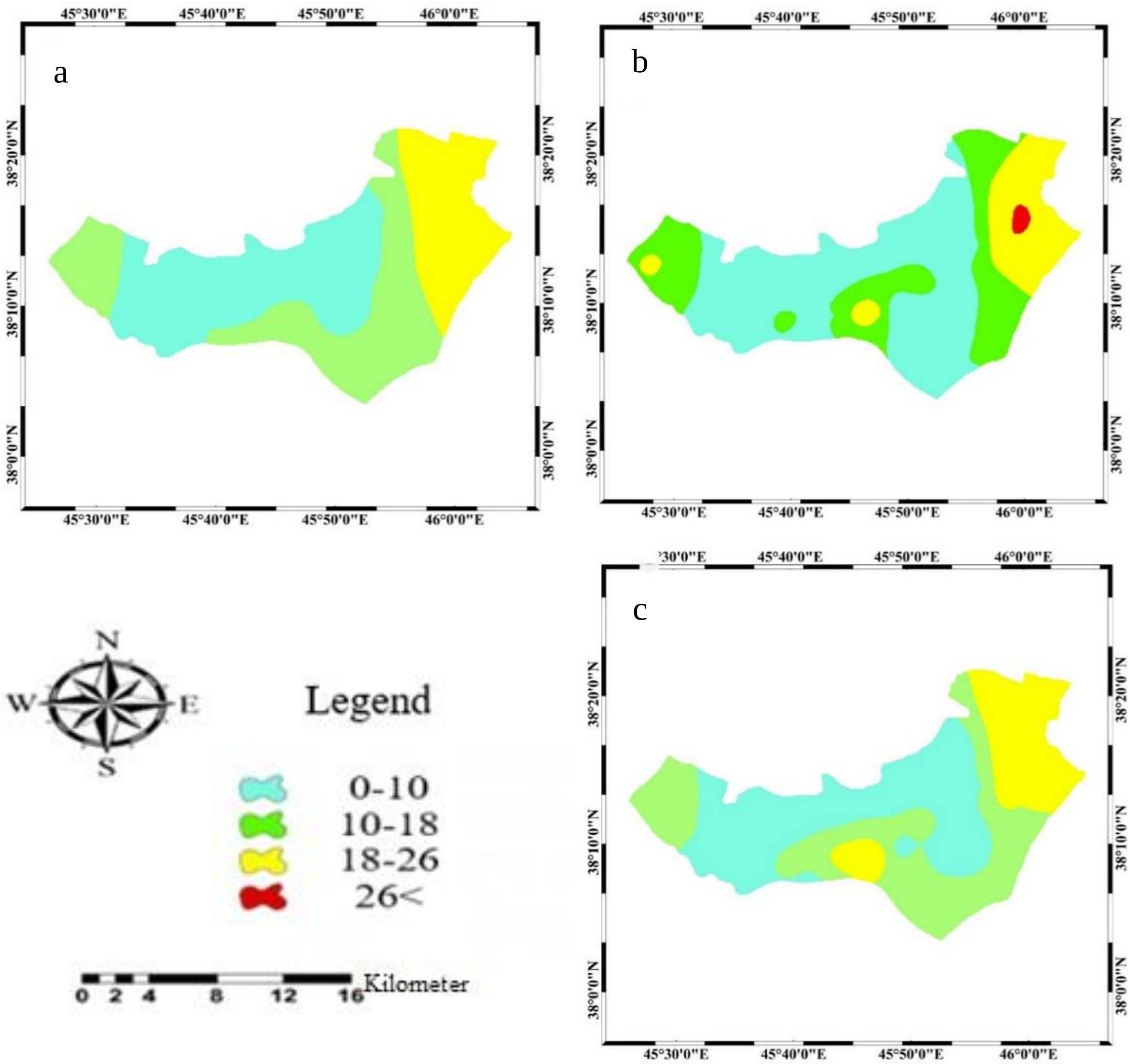

Fig. 5. Spatial variations of sodium absorption ratio of groundwater: a. 2002-2005, b. 2006-2009, c: 2010-2012

Table 3. The area assigned to classes of SAR

Classification of SAR	Wilcox Classification	Area (%) 2002-2005	Area (%) 2006-2009	Area (%) 2010-2012
0-10	Very good	14	54	42
10-18	Good	27	28	37
18-26	Moderate	22	17	21
26<	Unsuitable	0	1	0

According to Figure 6, the biggest part of the area has good quality in terms of TH in all three study periods. However, the amount of TH has increased in southern and western parts of studied area. The amount of TH has increased from north to south and from west to east of the region which according to table 4 in all three study periods most of area was taken into 0-50 (soft class). The amount of TH has been slightly increased in the second and third period in the southern and western parts of the region.

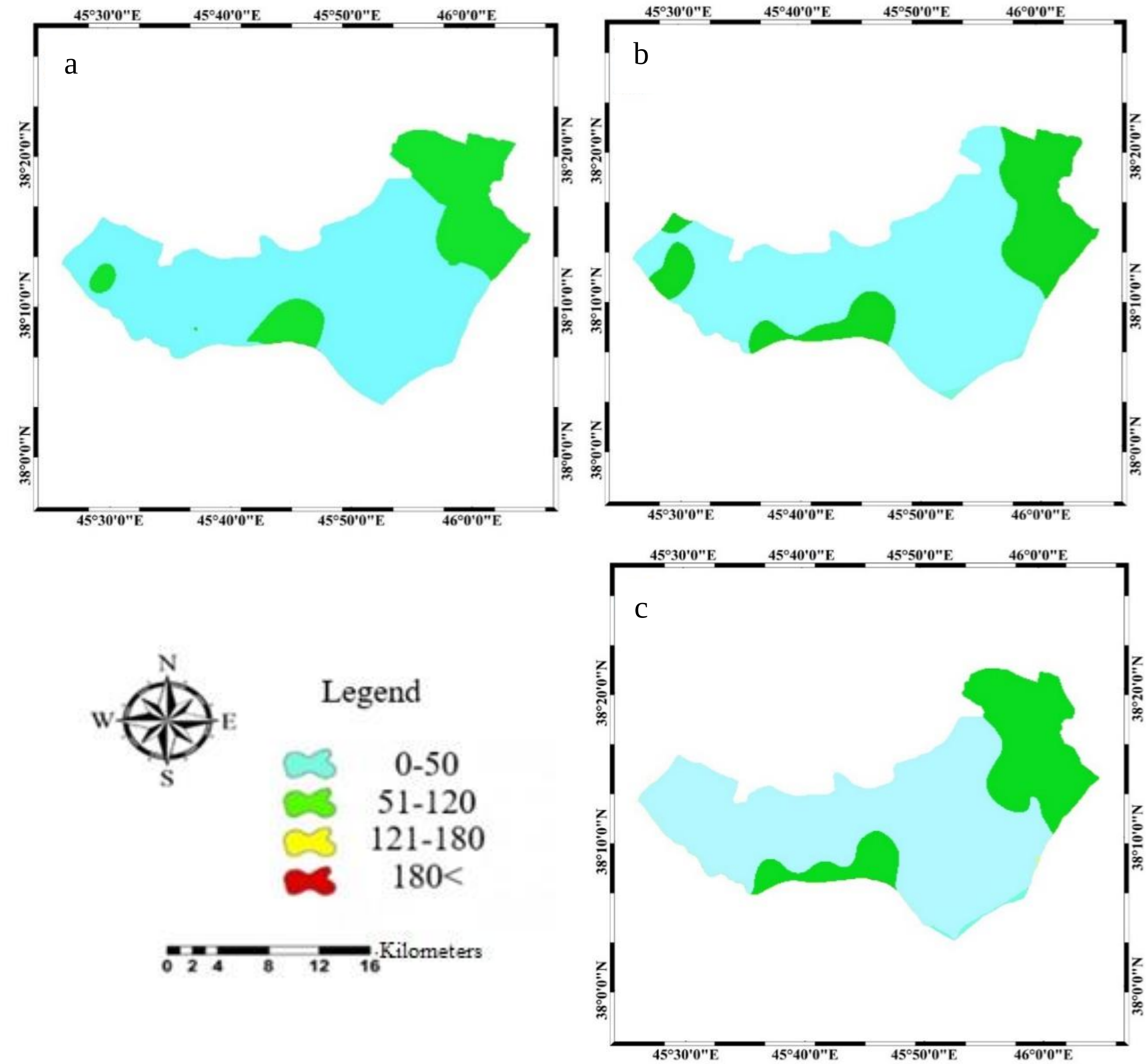

Fig. 6. Spatial variations of Total hardness of groundwater: a: 2002-2005, b: 2006-2009, c: 2010-2012

Table 4. The area assigned to total hardness levels in the study area

Classification of Total Hardness	Classes	Area (%) 2002-2005	Area (%) 2006-2009	Area (%) 2010-2012
Soft	0-50	76	73	71
Medium	51-120	24	27	29

According to Figure 7, in the first and second period, greater area of the region has good water quality and in the third period the largest area has moderate quality. The amount of Cl had an increasing trend in the southern and western parts of the region which located in the vicinity of the Lake. Water in these parts was unsuitable in terms of drinking. The eastern part of the region located at unsuitable condition in terms of Cl, so that water quality was unsuitable and quite unsuitable in all three studied periods. Table 5 shows the amount of Cl in Groundwater of the study area. In the first and second period about 55% of the area has water with good and acceptable quality, but in the third period 43% of the area has suitable quality and 57% has moderate and absolutely unsuitable water quality. It represents the increasing trend of Cl in western and southern parts of the region during this period.

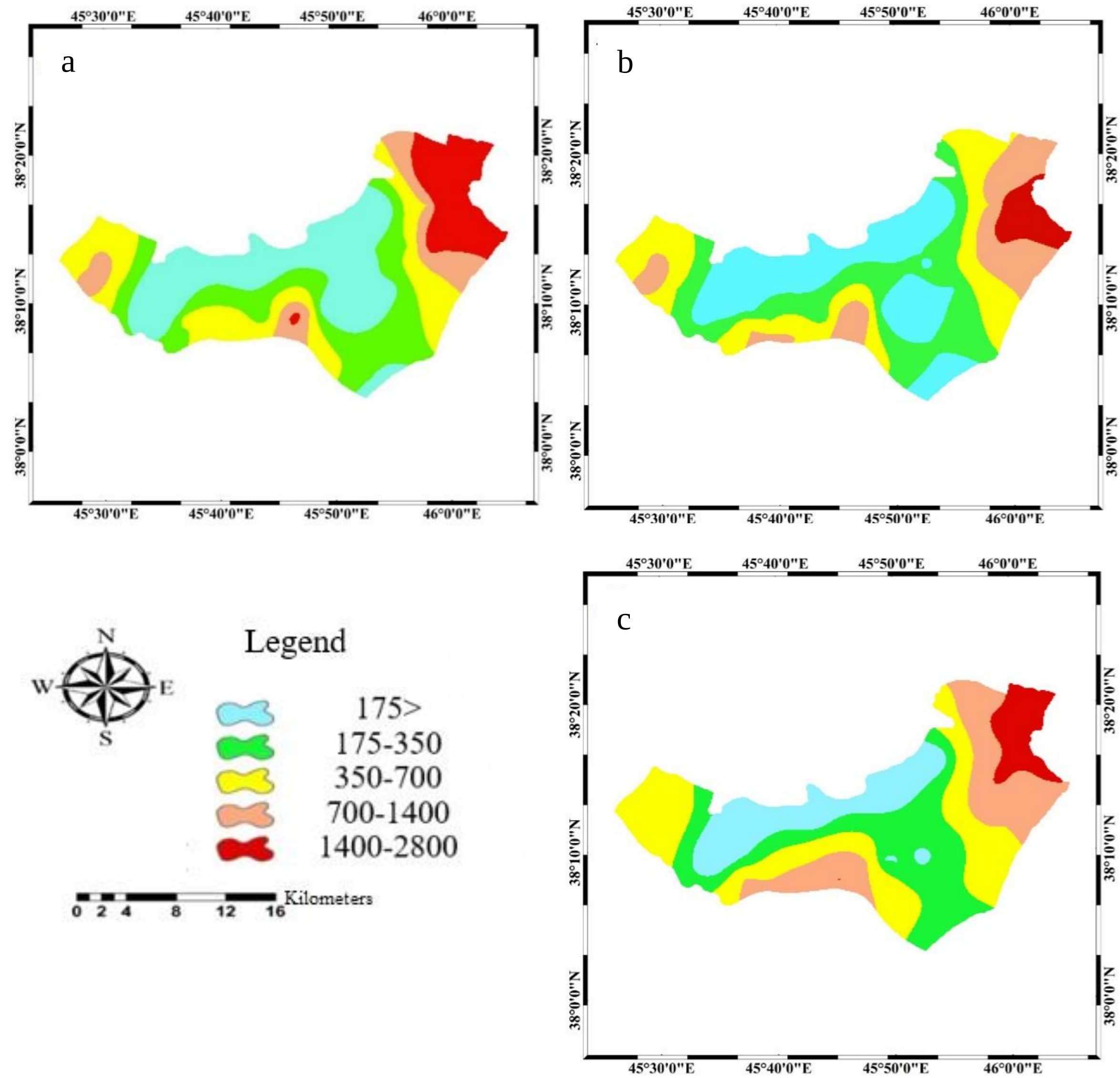

Fig. 7. Spatial variations of chlorine of groundwater: a: 2002-2005, b: 2006-2009, c: 2010-2012

Table 5. Levels of area assigned to Cl classes in the study area

Chlorine Classes	Scholar Class	Area (%) 2002-2005	Area (%) 2006-2009	Area (%) 2010-2012
<175	Very good	21	29	17
175-350	Good	24	26	26
350-700	Moderate	21	24	30
700-1400	Unsuitable	11	16	20
1400-2800	Quite Unsuitable	13	5	7

According to Figure 8, in all three periods more surface area of the region has good quality in terms of drinking water. Water quality in west and south parts of the region has an increasing trend in the amount of Na during the studied periods. The eastern part of the region has unsuitable water quality in all three periods so that the amount of Na has a decreasing trend and water quality was improving in this part. The amount of Na has an increasing trend from north to south and west to east in groundwater content of the region. Table 6 shows the amount of Na in groundwater of the study area in all three periods. In all three study periods almost 80% of the region has good and moderate water quality. The percent of area with moderate and good quality in second period is more than first and third period. Water with unsuitable quality in second and third periods are less than first period.

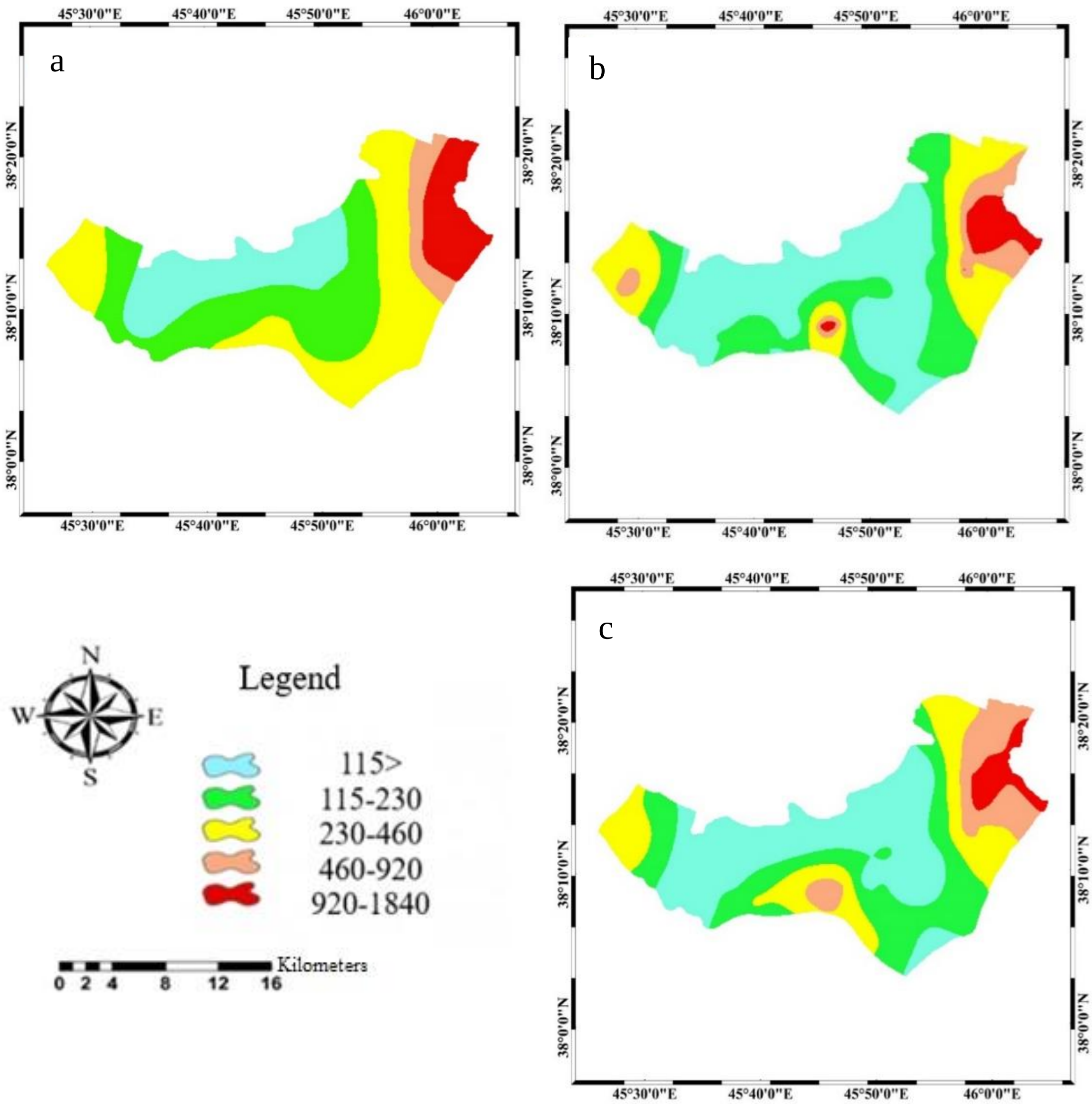

Fig. 8. Spatial variations of sodium of groundwater A: the years (2002-2005), B: the year (2006-2009), C: the year (2010-2012)

Table 6. Levels of area assigned to sodium classes in study area

chlorine classes	Scholar class	Area (%) 2002-2005	Area (%) 2006-2009	Area (%) 2010-2012
<115	Very good	21	44	38
115-230	Good	32	26	27
230-260	Moderate	31	18	19
460-920	Unsuitable	6	7	11
920-1840	Quite unsuitable	10	5	5

3.3. Motivating average

Motivate average of the study area is shown in Figure 6. Based on the obtained charts and with regard to the average rainfall 309.83 mm in the study area, wet years were occurred in 1991 to 1996 and 2008 to 2012. The impact of drought on dropping groundwater level has increased from 1998 to 2003 because of reduction in the amount of rainfall.

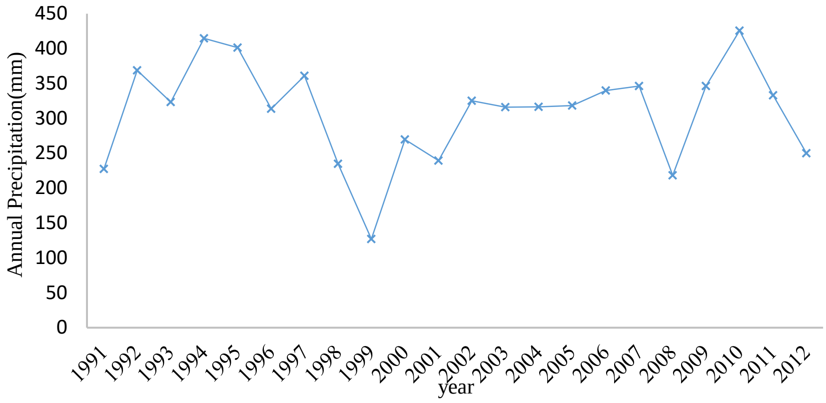

Fig. 9. Plot of annual rainfall during the studied period (1991 to 2012)

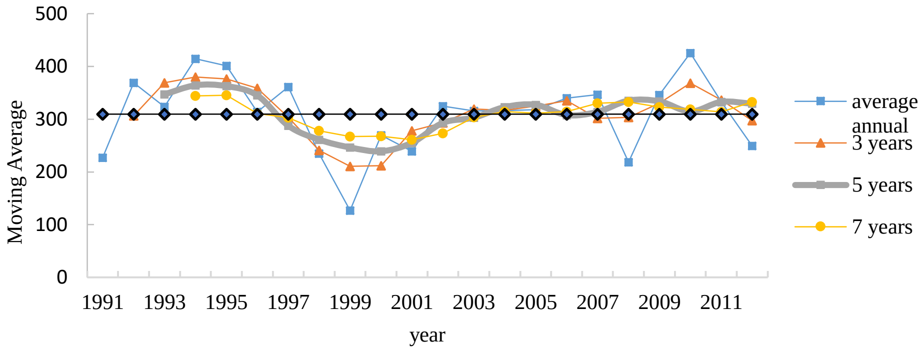

Fig.10. Moving average chart of 3, 5, 7 years during the studied period (1991 to 2012)

The obtained results show that due to land use changes and increasing in the extent of farming lands which coinciding with the drought period (1998 to 2002), Water quality has more decreased in western, central and southern parts than northern parts of the region. Another reason for this issue is water level drop caused by overuse of groundwater for watering gardens (Ranjpishe *et al*, 2016). Dropping water table was lead to intrusion of saltwater into aquifers of Lake Urmia, especially in the southern and central parts of the region and a large number of wells have been unused. Asghari Moghaddam and Mohammadi (2003), Jafari and Eftekhari (2012) were found similar results on examining the intrusion of lake's saltwater into aquifers of Shabestar plain. Our results also were similar with Sadeghi *et al.* (2014, 2015) in Lake Zaribar, Iran and Chaidembaran *et al* (2010) in South India that examined the relationship between water quality and land use properties. Overall, the quality of groundwater was improving in whole region over the study period. So that water quality was low in the first period (2002-2005) due to coinciding with the drought period and water quality was improving due to coinciding with wet periods in the second and third period (2006-2009 and 2010-2013). Karami and Kazemi, (2012) evaluated spatial monitoring of groundwater salinity on drought and wet years in Tabriz Plain, they also found similar results.

4. Conclusion

With the growing population and the need for food production man has done many things for providing his necessities. For example, exploitation rate has increased and more range lands have changed to farm land. Looking to increase agricultural lands various strategies have been used to harvest more crops per unit. Digging the deep and semi-deep wells and excessive pumping which lead to drawdown the water table and decrease water quality. Using various chemicals such as fertilizers, herbicides and insecticides which led to land degradation. Today, the use of these materials is a common practice in agriculture for more harvesting, avoid waste by pest plants before the harvesting. The use of chemical materials in agriculture is followed groundwater and surface water pollution. Since more pesticides are stable organic compounds with regard to factors such as temperature, precipitation, soil characteristics and properties of chemical substances they could pass different soli layers with different and pollute surface and groundwater resources.

So through land use changes, increase the area under cultivation, mismanagement and wrong methods of irrigation, the quantity and quality of groundwater will be reduced and unsustainable farming on ahead.

In conclusion, land use changes have important effects on reducing the water quality of wells in Shabestar basin in the period of study. This happened because of the severe changes in the watershed land uses, especially the increase of residential and barren lands from 583.59 and 526.85 to 5473.63 and 2707.25 hectares between 1990 and 2015, respectably. But we shouldn't also neglect the aridity that occurred in the period of 1997 to 2003. Therefore, we can claim that the most important parameter that caused the water quality to reduce is land use changes but aridity could have intensified this reduction.

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