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The Impact of Land Use/Land Cover Changes on Groundwater Resources Using Remote Sensing & GIS (Case Study: Khan-Mirza Plain)

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Abstract

Hydrological status and water table fluctuations are directly related to land use and/or land cover (LULC) changes in each area. In this research, the impact of LULC changes on groundwater quantity and quality of Khan-Mirza Plain, in the northern Karun watersheds, was investigated. For this purpose, Landsat 5, 7 and 8 satellite images and ETM and OLI sensors were employed to prepare the LULC map of Khan-Mirza Plain for 2006 and 2016 using the artificial neural network algorithm. The neural network algorithm with the general accuracy of 90/29 was classified into six use classes (agriculture, rangeland, residential areas, rocky and bare lands, gardens and lowlands). Analysis of changes indicated that agricultural and residential uses were increased, respectively, by 62.5% and 3.5%. The biggest change was in conversion of the rocky and bare lands for the agricultural use. Another change was in the LULC of rocky and bare lands and rangelands: these have been converted into to the residential areas. A few piezometric wells in the plain were also used to investigate the lowering of the groundwater table during the 2006- 2016 period. The quality parameters investigated were calcium, sodium, magnesium, potassium, all soluble solids, electrical conductivity, sulfate, chlorine, bicarbonate, and water acidity (PH). Investigation of the time variation of the groundwater quality parameters further showed that potassium, water acidity, and bicarbonate followed an upward trend during the studied time. Most chemical parameters of water had the highest concentrations in the central plain area. The results, therefore, showed that increase of degradation and growth of human activities in the region had both caused changes in the LULC, subsequently intensifying the quantitative and qualitative loss of groundwater in the Khan-Mirza Plain. Therefore, the areas with irrigated agriculture, dry farming, and undeveloped agriculture have been increased. One of the main reasons for lowering of water table in 2016 was the excessive exploitation of groundwater as a result of the change in agriculture uses.

Keywords: Khan-Mirza Plain; Land Use Change; Satellite Images; Groundwater Loss; Groundwater Quality

1. Introduction

Factors such as population growth, the need for more food, improvement of health and social welfare, industrial development, and ecosystem protection have all created a growing demand for water every day. Given the population growth in Iran and the annual rate of renewable water resources, which was about 7000 cubic meters in 1956 and decreased to 2000 cubic meters in 1996, it is expected that it will have been reduced to about 800 cubic meters by 2021, which is lower than the dehydration boundary, that is 1,000 cubic meters. It is, therefore, very important to understand land use/land cover (LULC) changes because the processes related to the human contact with nature can have widespread impacts on the environment, hydrological cycle alteration, biogeochemical conditions, size and arrangement of natural ecosystems such as forests and species diversity (Pijanowski *et al*., 2002). Awareness of water table changes is, in fact, needed to understand groundwater table status and its optimal management. Assessing groundwater fluctuations is important for

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managing water resources. Understanding land use changes to identify the underlying factors and causes over a given period can be of interest to planners (Shaban, 2006). Land use can be considered to get plenty of information about earth's land features and various activities such as using the land and making plans for the future. There are different methods for assessing the impacts of land use change on groundwater hydrology. A direct way is to relate land use change and land cover to groundwater table fluctuations (Scanlon *et al*., 2005). Compared to the traditional terrestrial methods, satellite assessment method provides more land use data at a geographic location, which can save time and cost at the regional scale (Yuan *et al*., 2005). Land use maps show how people use the land for agriculture, forestry and ranching. Land use and vegetation changes due to human activities have direct impacts on the quantity and quality of groundwater (Dams *et al*., 2008). Compared to the traditional terrestrial methods, satellite-based remote sensing, which greatly facilitates data collection, provides more land use data at a geographic location, which can save time and cost at the regional scale. Remote sensing data does not have a long history in the hydrological models, but the works done in this area are significant. A lot of studies have been done to assess the impact of LULC changes on the characteristics of groundwater resources, as mentioned in the following part. Ekrami *et al*. (2011), for instance, reviewed the quantitative and qualitative changes of groundwater resources in Yazd-Ardakan Plain during the 1997-1999 period. The results indicated a downward trend in groundwater changes, such that the average annual water loss was about 0.5 m. One of the main reasons for the huge loss in the groundwater table is the frequency of drought and the irregular groundwater harvesting. Beven and Fisher (1996) have reported that collecting information about soil moisture, evaporation, transpiration, and snow cover through remote sensing technology can be very important for surveying watershed hydrology. Identification of timely and accurate land use changes can lead to a better understanding of human interaction with the land resources. Identification of these relationships leads to the management and sustainable use of these resources. Satellite data, due to their specific properties, such as wide coverage, repeatability and multispectral features, can play an effective role in the development of land cover and land use mapping.

Shakiba *et al.* (2011) have concluded that droughts in the eastern part of Kermanshah can have a significant impact on the groundwater loss. Regarding the impact of droughts on groundwater resources, the correlation coefficient of the two parameters was calculated by measuring the monthly fluctuations of the standard precipitation index (SPI) and groundwater table during 30 years. Singh *et al* (2010) also assessed the possible impacts of LULC change and land cover on groundwater resources using remote sensing and GIS methods. They used IRS and LISS sensors and groundwater quantitative and qualitative data for a period of 17 years. The results showed that the amount of groundwater was increased by natural and artificial charges due to an increase in the land use change and the land cover pattern (Singh *et al*., 2010). The results obtained by Mortezaei and Kohandel (2015) in Chaharmahal-Va-Bakhtiari plains also showed the impact of land use changes on groundwater resources, with a negative balance in all plains except Farsan, Shalamzar, and Gandoman plains. Further, Tabatabaei *et al.* (2010) assessed the impact of land use changes on groundwater quality in Shahrekord Plain, showing that the difference between nitrate and ammonium concentration and electrical conductivity in the agricultural and urban areas was significant at the 5% confidence level. They also stated that the difference between nitrate amounts in different seasons was also significant at the 1% confidence level. Rahmati *et al.* (2013) also investigated the impact of land use and lithology on the spring water quality of Piranshahr Watershed. In this study, the impact of lithology and agricultural activities, the most important factors affecting spring water quality, was evaluated; the results showed that lithology had a greater impact on the spring water quality of Piranshahr watershed than land use. To investigate the impact of land use change on groundwater resources in the Sang-Sung Desert from the aerial photographs, Chen (2002) used TM and ETM satellite images of 1978 and 1998 and the hydrologic data. Their results showed that groundwater table was dropped due to urban and industrial areas. Rahman *et al*. (2017) also investigated the impact of land use on groundwater quality changes in the Lajan Basin using Landsat 5 and 8 satellite images with TM and OLI sensors and geographic information system. The results showed no changes in the water quality due to land use changes. Also, to determine the status of groundwater circulation in Italy, Marengo *et al*. (2007) analyzed 44 wells in terms of 29 chemical and physical factors such as temperature, pH, electrical conductivity, dissolved oxygen, all suspended solids, all structures, and so on. Results revealed significant differences in the quality of water in the inhabited villages and uninhabited remote areas. Furthermore, Singh *et al*. (2010) utilized remote sensors, GIS techniques, IRS and LISS sensors, and groundwater quality and quantity data of 17 years for land use change and land cover on a groundwater resource. The results showed that the amount of groundwater was increased by using natural and artificial charge due to the changes in the land use and land cover pattern (an increase in the fallow land). By using of the Indian satellite (IRS) and preparing a map of the second type salinity, Khan *et al*. (2005) determined the extent of flooding areas. The purpose of this study was to investigate the changes in salinity and land use units in a period of 14 years using the existing satellite data. Regarding the literature, the present study was conducted to investigate the impacts of land use change on the status of groundwater resources in Khan-Mirza Plain, a sub-basin of the northern Karun watershed in Chaharmahal-Va-Bakhtiari Province.

2. Materials and Methods

2.1. Study area

The study area was Khan-Mirza Plain, with the north latitude from 31.4 to 31.6° and the east longitude from 51.02 to 51.5°. The study area in this research was Khan-Mirza Plain in Chaharmahal-Va-Bakhtiari Province. This area is surrounded by Borujen from the north, Ardal from the west, Flard district from the east, and Rig village and the Armand district of Lordegan in the south of Chaharmahal-Va-Bakhtiari. The location of plain in the province and country is shown in Fig. 1. This region has 37 villages and a population of 30 thousands. Its center is Alouni with the two villages of Khan-Mirza and Javanmardi, which are among the fertile and superior plains of the province in agriculture. The plain watershed is in the northern and north-western parts of the protected area of Sabzkouh.

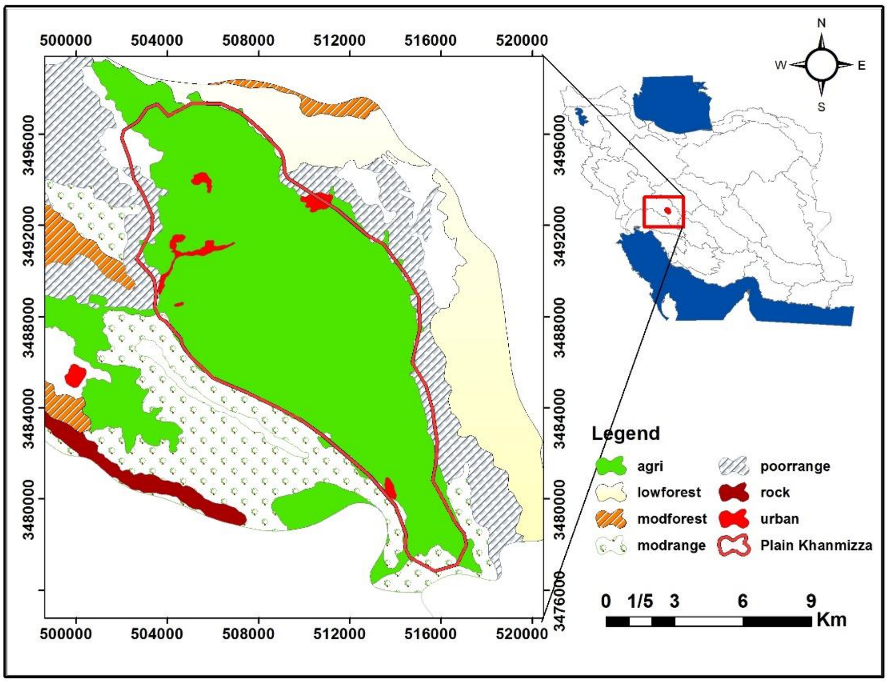


Fig. 1. The study area

In this study, Landsat images (Table 1) in the 2 periods of 2006 and 2016 and Artificial Neural Network (ANN) were used to provide LULC change maps. In the preprocessing stage, radiometric, atmospheric and geometric errors were taken into account with a series of operations on the raw data (before any visual or digital processing); therefore, identifying and detecting possible errors in the satellite data can be very important. After receiving the data, a thorough geometric and radiometric investigation was required.

Even if some corrections have already been applied to the data, we should be fully aware of the errors in such data. In order to evaluate the accuracy of the classified maps, a confusion matrix was prepared by adapting the classified maps with the ground reality map from the field studies; the overall accuracy and Kappa coefficient were calculated accordingly. Also, vegetation maps 1:25,000 of the forests and rangelands organization, topographic maps 1:50000 of the experts, and field observations data (60 study points) were used. Finally, the LULC maps of these two periods (2006, 2016) were prepared and compared. Processing and analysis of the satellite images were done using the ENVI 5.3 software and Google Earth software; Also, IDRISI 17, and ArcGIS10.2 were used to analyze the resulting information. Table 1 shows the characteristics of the satellite images used.

Table 1. Characteristics of the used satellite images

Satellite	Sensor	Date	Band	Row/Path
Landsat 5	TM	1996.17.10	7	38/164
Landsat 7	ETM+	2006.03.07	8	38/164
Landsat 8	OLI	2016.20.06	11	38/164

2.2. The utilized data

The data used in this study was gathered from the piezometric wells during the 2006-2016 period. Landsat 7 and 8 satellite images and ETM and OLI sensors (Table 1) were used to analyze the LULC changes based on the sensor images in the studied area for the two periods of 2006 and 2016 in the ENVI software; also, the ArcGIS software was employed to calculate the area of use and to prepare the output map. In this study, in order to investigate the chemical quality and groundwater quality changes in the Khan-Mirza Plain, 16 wells data were collected during 15 years (2001-2016), based on the distribution of agricultural, residential and industrial areas, the dispersion of wells, and the existence of the data of wells; then they were analyzed. The chemical quality parameters of water studied in this study included residual solutes, electrical conductivity, acidity, bicarbonate, chlorine, sulfate, nitrate, all anions, calcium, magnesium, sodium, potassium, all cations, all alkalinity, temporal stiffness, and total stiffness, indicating the chemical quality and the overall annual trend. It should be noted that quantitative data about the groundwater table of observation wells from 1996 to 2016 was investigated. In order to determine water quality, the statistical status of the data was first determined, and their normality was analyzed using Excel and SPSS software.

2.3. Classification of satellite images by the artificial neural network

Artificial neural networks were first designed by Rosenblatt in 1985. In this regard, for network training, the educational samples are entered into the network through the input layer; after being multiplied by the neural connectivity weights, they are entered into the middle layer. In each neuron of the middle layer, an activity function is applied to the inputs and the calculations are sent to the output layer. At this stage, the network exit is compared with the optimal value expected from the network, and the errors of different methods are moderated by changing the neural connectivity weights. Typically, algorithms such as Back Propagation are used for this purpose. This algorithm modulates network weights to reduce network error using the cost function gradient. After classification, all uses of the study area were classified into five categories (forests, rangelands, irrigated agriculture, dry farming, undeveloped agriculture and residential regions); then the authenticity of all uses was obtained. Finally, the obtained layers were transmitted to the ArcGIS software to calculate the area of use and prepare the appropriate output map.

2.4. Interpolation of groundwater quality criteria by Kriging

Zoning is a suitable method to display water quality data or information such as changing parameters in the form of a map. Data can be displayed individually with different signs or continuously with different colors on the map. In this research, the Kriging method was used for zoning the quality parameters. Kriging is a well-established and efficient interpolation method with many applications to hydrological data; it could be especially useful for groundwater table data in this study. The kriging method comprises a family of interpolators. The most common methods in hydro sciences are the Ordinary Kriging (OK) and Universal Kriging (UK). Kriging is characterized as the best linear unbiased estimator (BLUE). The kriging estimator is a weighted linear function of the data with weights that follow from the unbiasedness constraint (i.e. zero mean estimation error) and the minimum square error condition. The resulting system of linear equations is solved to determine the estimator's weights. The coefficients of the equations depend on the model semi-variogram, which is obtained by fitting the empirical semi-variogram to the theoretical models, or by means of the maximum likelihood estimation method (Kitanidis, 1997; Ahmed, 2007). The semi-variogram measures the degree of spatial correlation as a function of distance and/or direction between the data points. The semi-variogram determines the kriging weights and therefore, controls the quality of the estimates (Mouser, 2005; Ahmed, 2007). An advantage of kriging, as compared to the deterministic approaches, is that it allows the estimation of the interpolation error at the unmeasured points (Deutsch and Journel, 1992). In addition, in the absence of a nugget (e.g. measurement error), kriging is an exact interpolator at the measurement points (Delhomme, 1974; Ahmed, 2007). Optimal kriging results can be obtained if the probability distribution of the data is stationary in space (spatially homogeneous).

2.5. Groundwater table

The status of the groundwater table and its loss was studied using the piezometric wells data in the plain during the 1996 – 2016 period. The relevant information was collected from Iran Water Resources Management Agency. After sorting statistics, the piezometric surface hydrograph of the mentioned period was plotted using the Excel software.

2.6. Processing quality parameters

In this research, the Mann Kendall nonparametric test was used to examine the quality parameters. This method can be used to identify data changes and their types; time is considered to determine the jumping-off points and the time series trend. Mann Kendall non-parametric test was originally developed by Mann and then applied by Kendall based on the data rank in a time series. To study time and spatial distribution and to present the pattern of the impact of LULC changes on the water quality of the wells studied in this area, the chemical parameters zoning map was developed in the GIS software for the periods of 2006 and 2016 and then analyzed.

3. Results

3.1. LULC change detection

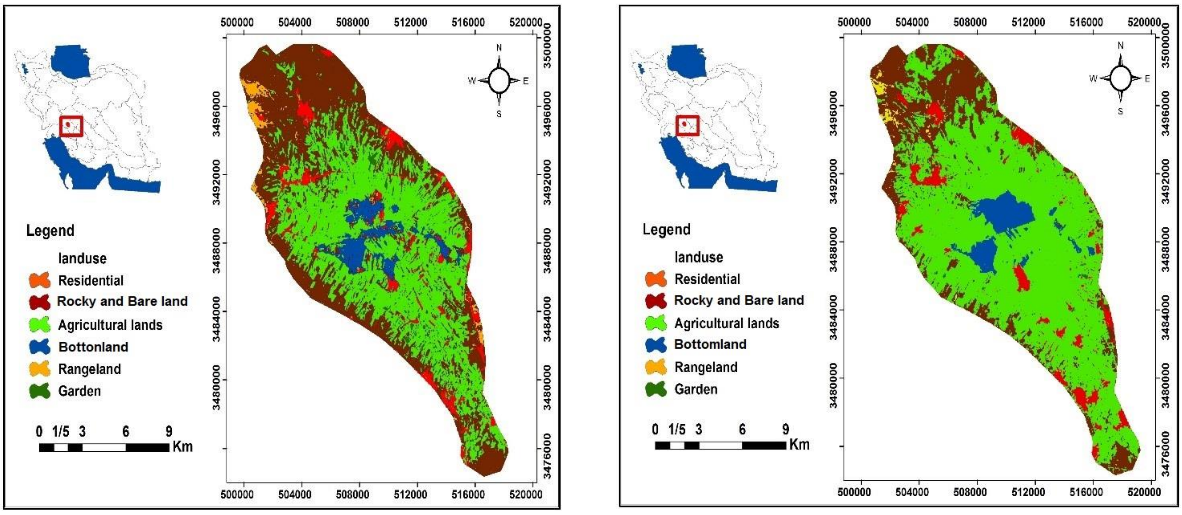
Following the classification of LULC, the confusion matrix of the classifying artificial neural network algorithm was provided. The results are presented in Table (2).

Table 2. Confusion matrix of the classifying artificial neural network algorithm

LULC **type**	Garden	Rangelands	Lowlands	Agriculture	Rocky and Bare lands	Residential lands	Commission’s error (user’s accuracy)
Garden	26.9	0.0	0.0	1.2	0.0	0.0	0.7
Rangeland	0.0	25.2	0.0	0.0	35.0	0.0	5.5
Lowlands	0.0	0.0	100.0	0.0	0.0	0.0	14.7
Agriculture	73.1	0.0	0.0	97.1	0.4	4.3	54.8
Rocky and Bare lands	0.0	74.8	0.0	0.0	64.4	3.1	11.3
Residential lands	0.0	0.0	0.0	1.7	0.2	92.6	13.0
Omission’s error (Producer’s accuracy)	73.1	74.8	0.0	2.9	35.6	7.5	100.0
Overall accuracy: 90.29 percent	total kappa coefficient: 0.848						

Table (2) shows the confusion matrix of the classifying artificial neural network algorithm for 2016. As shown in Table 2, lowlands, agricultural and residential lands with 0, 2.9, and 7.5% error had the least error among the existing users. The overall accuracy of the artificial neural network algorithm was 90.29%, and the total kappa coefficient was 0.848.

In Figure 2, the LULC map of the region is presented with the supervised classification method and the artificial neural network algorithm in 2006 and 2016. The results of LULC classification in 2006 indicated that the minimum LULC was 2% for the garden and the maximum was 49% for agriculture. The results also showed that changes in the agricultural, garden and residential uses followed an upward trend, involving the reduction of rocky and bare lands, rangelands and lowlands in the region. Figure 3 presents different uses and LULC assigned percentages for 2006 and 2016.



LULC classification map for 2006 LULC classification map for 2016

Fig. 2. LULC classification using the artificial neural network algorithm, for 2006 and 2016

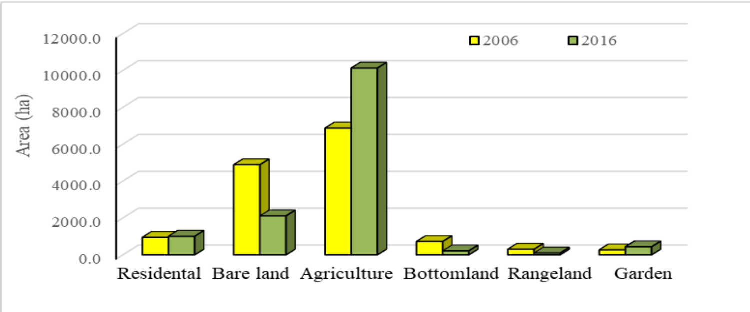


Fig. 3. LULC for 2006 and 2016

3.2. LULC changes

In this study, after determining the areas under investigation, two classified images were compared using the CROSSTAB command in the IDRISI17 software. Comparisons of the 2006-2016 classifications are presented in Table 3. One of the most noticeable changes in this comparison is the conversion of rocky lands and bare lands to the agriculture lands. This table represents the number of use changes of different classes in hectares. Two classification maps were compared in two comparative matrices based on the LULC in 2016 and 2006 and the LULC changes were investigated over a 10-year period. The rows in this table show the LULC units in 2006, and the columns represent the LULC units in 2016, as derived from the information classification.

Table 3. LULC changes for different classes during the 2006-2016 period (in hectares)

		2016					
	LULC	Residential lands	Rocky and bare lands	Agriculture	Lowlands	Rangelands	Gardens
2006	Residential lands	887.7	-	-	-	-	-
	Rocky and bare lands	65.7	2062.5	1673.0	4.5	-	58.9
	Agriculture	11.2	8.1	8397.8	-	4.4	21.0
	Lowlands	-	18.2	11.2	210.4	15.2	5.6
	Rangelands	40.8	4.2	28.0	-	76.6	42.1
	Gardens	1.4	21.0	21.5	-	1.4	307.9

The results of LULC changes for different classes in 2006 and 2016 are presented in Table (3). The most common LULC changes belonged to the rocky and bare lands, which had been changed for the agriculture uses; this was such that 1673 hectares of rocky and bare lands had been changed into agricultural lands in 2016; the other change changed was related to rocky and bare lands, and rangelands, which had been changed to the residential areas, such that 65.6 hectares of rocky and bare lands and 40.8 hectares of rangelands had been changed for the residential use.

3.3. Piezometric surface

The status of piezometric surface changes is represented in Fig. 4. As shown, in the recent years, the level of groundwater in the region has been decreasing. In general, an increase in the annual loss of the studied area indicates an increase in water harvesting from groundwater resources and an increase in degradation; if continued, the aquifer may be put into trouble. Figure (4) shows piezimetric surface changes and the lowering of the groundwater in all wells studied in Khan-Mirza Plain during the 1971-2016 period. It could be seen that water table had been reduced since 2012, with a tension in the plain aquifer and the 15-meter reduction of the plain water table in 5 years. The highest level of groundwater table reduction in the plain occurred in the 2012- 2013 period, with a 7.5-meter reduction in the aquifer only in one year; this suggests severe pressure on the groundwater resources. In general, the trend of water table changes indicated that during the study, the groundwater table in the area had been reduced, with its lowest level in 2016. Finally, an increase in the annual loss in the studied area, especially in the recent years, could be indicative of an increase in water harvesting from groundwater resources and the growth of degradation; if continued, this could cause serious problems in the aquifer.

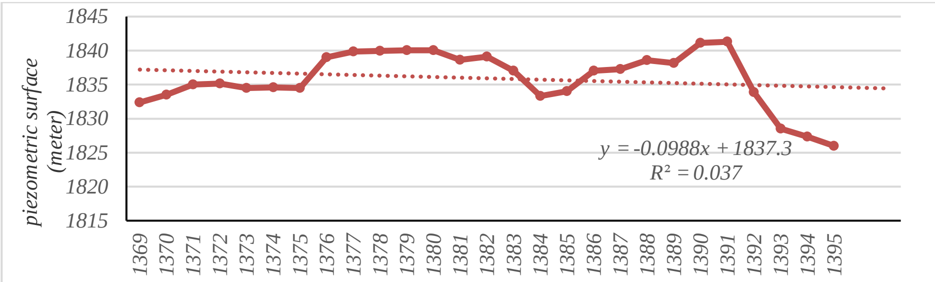
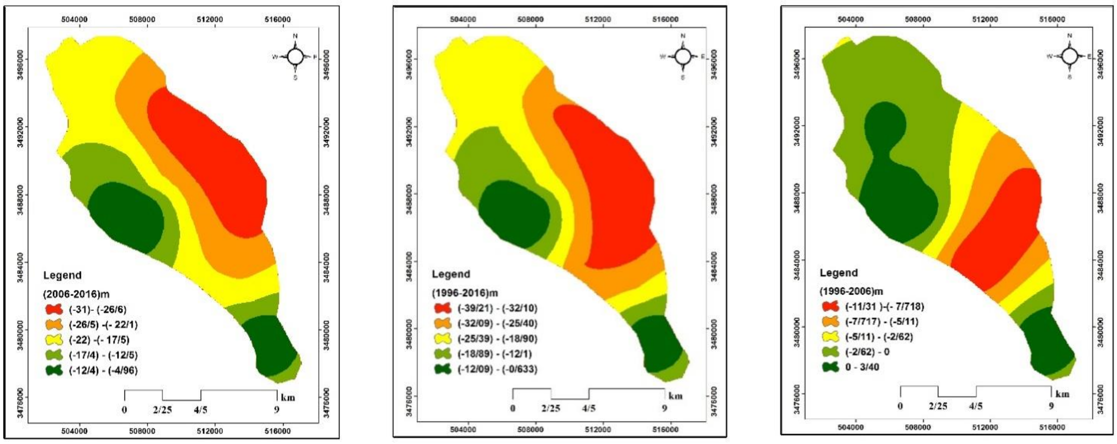


Fig. 4. Changes in the piezometric surface

The status of groundwater loss is given in figure 5. According to the statistics of the observation wells (from 1996 to 2016), after determining the amount of water loss in 15 observation wells, the amount of loss during 10 years was investigated and the zoning of the loss of the studied region was done using the Kriging method. As known, the critical points with a greater water loss were more in the central and eastern parts of the plain. The level of groundwater loss was between 5 and 31 meters from 2006 to 2016. The greatest amount of groundwater loss belonged to the eastern part of the aquifer. The level of groundwater loss over the 1996-2014 period was from 0.6 to 39.2 meters. The greatest amount of groundwater loss of this period was in the eastern part of the aquifer. The loss from 1986 to 1996 was increased by 3.4 m and decreased by 11.3 m. The greatest loss of groundwater of this period was recorded in the central parts of the aquifer. Water table was increased only in the south and west of the aquifer; however, in most areas of the plain, there was a loss in groundwater.



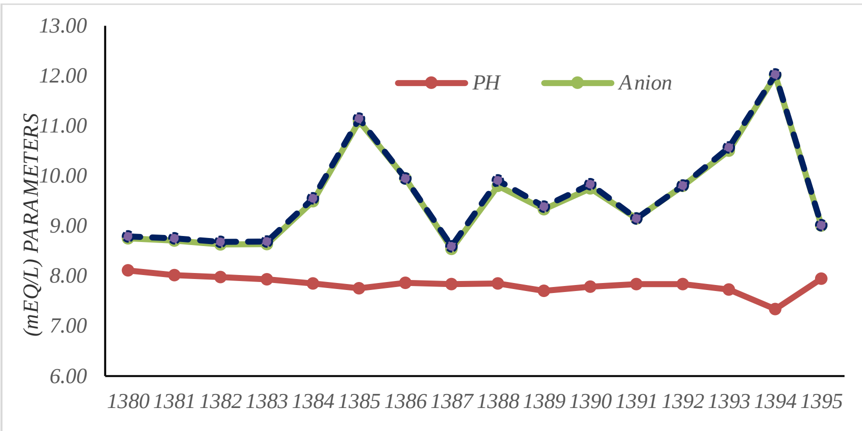
The 2006-2016 period The 1996-2016 period The 1996-2006 period

Fig. 5. Lowering of groundwater in the last three decades

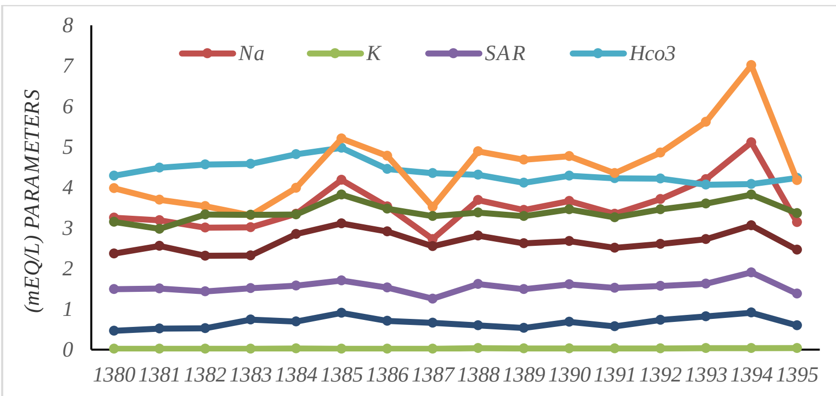
The results of the qualitative survey are given below. As shown in the table, most quality parameters followed a significant trend. Absorbable sodium, sodium percentage, sulfate, magnesium and, cations were not significant and did not change much during the studied period. Finally, the study of the changes in the distribution maps of the quality parameters of the wells in the 10-year period showed that the parameters of potassium, chlorine, sodium, calcium, anion, total dissolved solids, stiffness, and electrical conductivity followed an upward trend at the 95% confidence level, decreasing the quality of water in the region. The general characteristics of water chemical parameters are given in the following table. (+) shows significance at the confidence level of 90% and a Z factor absolute value is greater than 1.67. At the 95% confidence level, Z was greater than 1.96 Z. So, if Z factor absolute value is greater than 1.96, it is significant at the 95% confidence level, as indicated by (*) in Table (4) (the larger the number of *, the higher the significance at the higher confidence levels).

Table 4. Trend of water quality parameters

Parameter	Start	End	Z factor	significance	Line slope age
Sodium	2001	2016	1.940	+	0.052
potassium	2001	2016	3.920	***	0.001
Sodium percentage	2001	2016	-0.230	No trend	-0.004
Electrical conductivity	2001	2016	1.760	+	6.110
Sodium Absorption Ratio	2001	2016	1.310	No trend	0.007
Stiffness	2001	2016	1.760	+	2.224
Total dissolved solids	2001	2016	1.760	+	3.951
Alkalinity	2001	2016	-2.750	**	-0.022
Total anion	2001	2016	1.670	+	0.094
Bicarbonate	2001	2016	-2.930	**	-0.035
Chlorine	2001	2016	2.120	*	0.111
Sulfate	2001	2016	1.580	No trend	0.011
Magnesium	2001	2016	0.770	No trend	0.014
Calcium	2001	2016	1.850	+	0.020
Total cation	2001	2016	1.490	No trend	0.093



(a)



(b)

Fig. 6 (a,b). Groundwater quality parameters

3.4. Zoning quality parameters in the 2006 period

Figure 7 shows the zoning map of the quality parameters using the Kriging method. As can be clearly seen in the figure, most of the quality parameters of the central parts of the plain had the greatest value and the least value was recorded for the northern parts of the plain. Generally, dissolved solids concentrations could be caused by human resources such as evacuation of domestic wastewater and agricultural wastewater, and natural factors such as the dissolution of geological formations. The pH of the natural water is mainly due to the lithology of the region, carbon dioxide, and other atmospheric gases dissolved in water. Based on the pH parameter, plain is not in a good condition, and the greatest value was for the southern plains, where pH was more than 7.7. In regard to the parameters of electrical conductivity and absorbable sodium, the central parts of the plain were in a moderate condition and the northern parts were in a more favorable condition. The most important anions in the region were found to be bicarbonates, chlorides, and phosphates, with different amounts of water due to the region conditions. Also, important cations in the groundwater of Khan-Mirza Plain included calcium, magnesium, and potassium. As can be clearly seen, the cations and anions values in 2006 were similar with low content in almost all parts, except in the central parts of the plain.

3.5. Zoning quality parameters in the 2016 period

The following map shows the zoning of the quality parameters in 2016. As can be seen, the status of the parameters was completely different from 2006 as their values had changed. The greatest values of most quality parameters were in the central parts of the plain; also, the northern and southern parts were in a good condition, except the parameters of electrical conductivity and bicarbonate. The map of zoning cations and anions in the plain had a condition completely similar to that in 2006, such that most of these parameters were in the central parts of the plain.

4. Discussion and Conclusion

Use change is one of the important factors determining the quantity and quality of surface and subsurface water resources. Quantitative and qualitative changes in water resources will continue both during and after use change. With an increase in agricultural levels in the studied area, the demand for water in the agricultural part has been increased significantly, as compared to the wells used for exploitation. Such an increase could be observed in the quantitative study of the plain because the level of groundwater loss was reduced between 5 and 31 meters from 2006 to 2016. The greatest level of groundwater loss belonged to the eastern part of the aquifer. Comparing the 10- year groundwater loss from 2006 to 2016 and from 1996 to 2006 showed that the loss was more latter than in the former; so this can be considered as one of the main factors leading to use changes. In the recent years, the level of groundwater table in the region has been decreasing. In general, an increase in the annual rate of decline in the studied area indicates an increase in water harvesting from the groundwater sources; according to the hydrograph of the aquifer of Khan-Mirza Plain, it can be observed that from 2012 onwards, the water table has been constantly decreasing and the aquifer status of this e plain is facing tension, as it has been reduced by about 15 meters from the surface of the plain over a period of 5 years. The highest level of groundwater table reduction in the plain occurred in the 2012-2013 period; during this year, 7.5 meters of water table was decreased. In general, the trend of changes in the surface water table indicates that during the study period, the level of groundwater in the mentioned area has been reduced, with the year 2016 representing the lowest water table. Reduction of the groundwater table in the studied area has been synchronous with the LULC changes. The results of the classification of satellite images also revealed that there has been an increase of agriculture, gardens, and residential classes between 2006 and 2016, while there has been a decrease of rocky and bare lands, rangelands, and lowlands in the study area. Also, areas with irrigated agriculture, dry farming, and undeveloped agriculture have been increased. Undoubtedly, an important factor affecting the aquifer status of Khan-Mirza Plain can be use changes. One of the reasons for the groundwater table loss in the studied area is the growth of the irrigated lands, causing an increase in groundwater harvesting. The studies done on the qualitative changes of groundwater and also, the investigation of the most important factors contaminating these resources show that the major changes occurring in the existing use can be an increase in the agricultural and residential use, and a decrease of lowlands, rocky lands and the bare lands. The most common changes belonged to the class of rocky and bare lands, as they had been changed for the agricultural use; so the greatest change was related to an increase in the cultivated area, which was increased by 8762.2 in hectares. Rocky and bare lands, rangeland and lowlands followed a downward trend, reaching to 15.1%, 1.5% and 0.7%, from 42.7%, 18.7%, 23.5%, respectively, in 1996; the increase of salt concentration in groundwater and agricultural lands reduced groundwater table, causing the desertification of the agricultural lands and rangelands in the region.

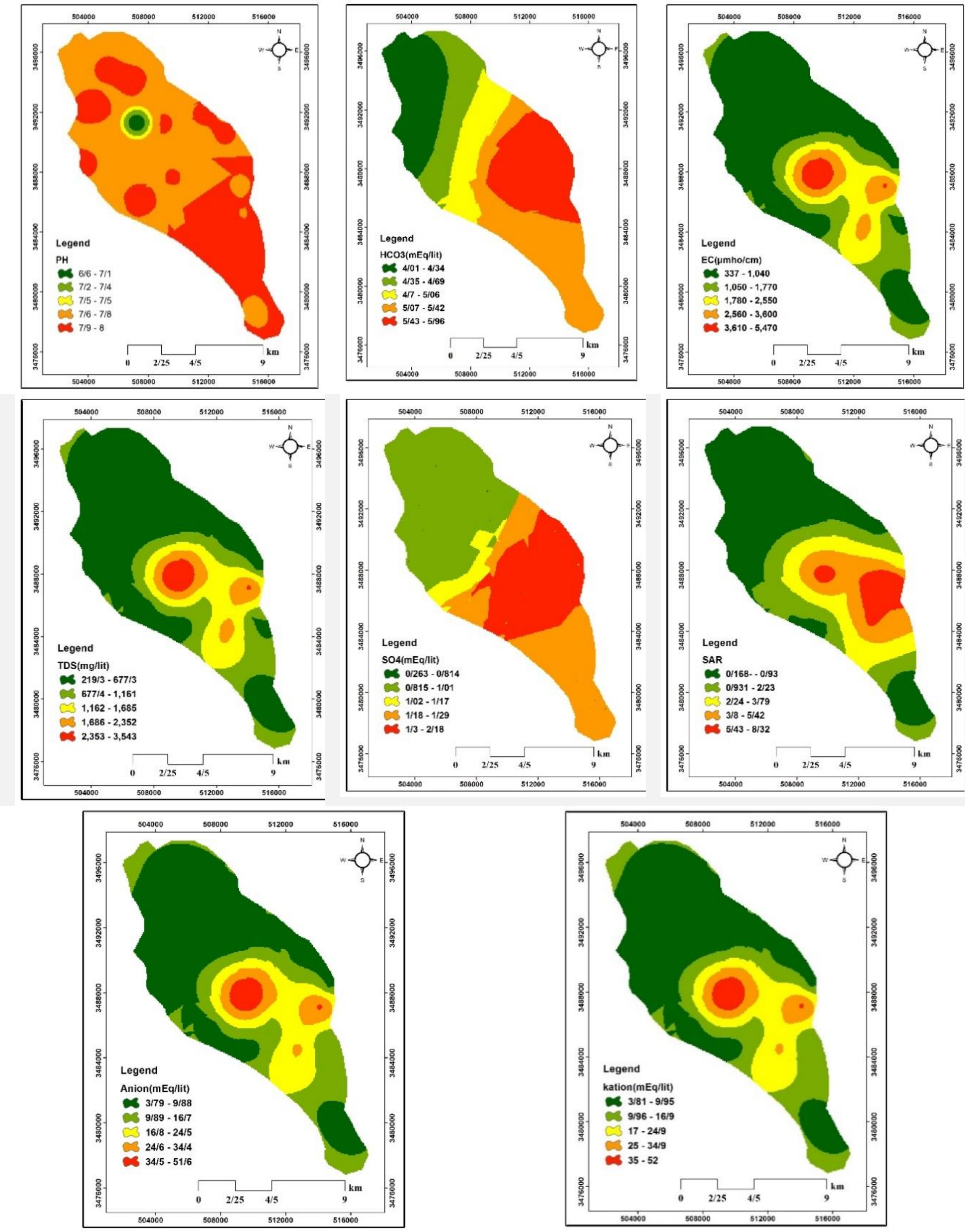


Fig. 7. Zoning quality parameters of 2006

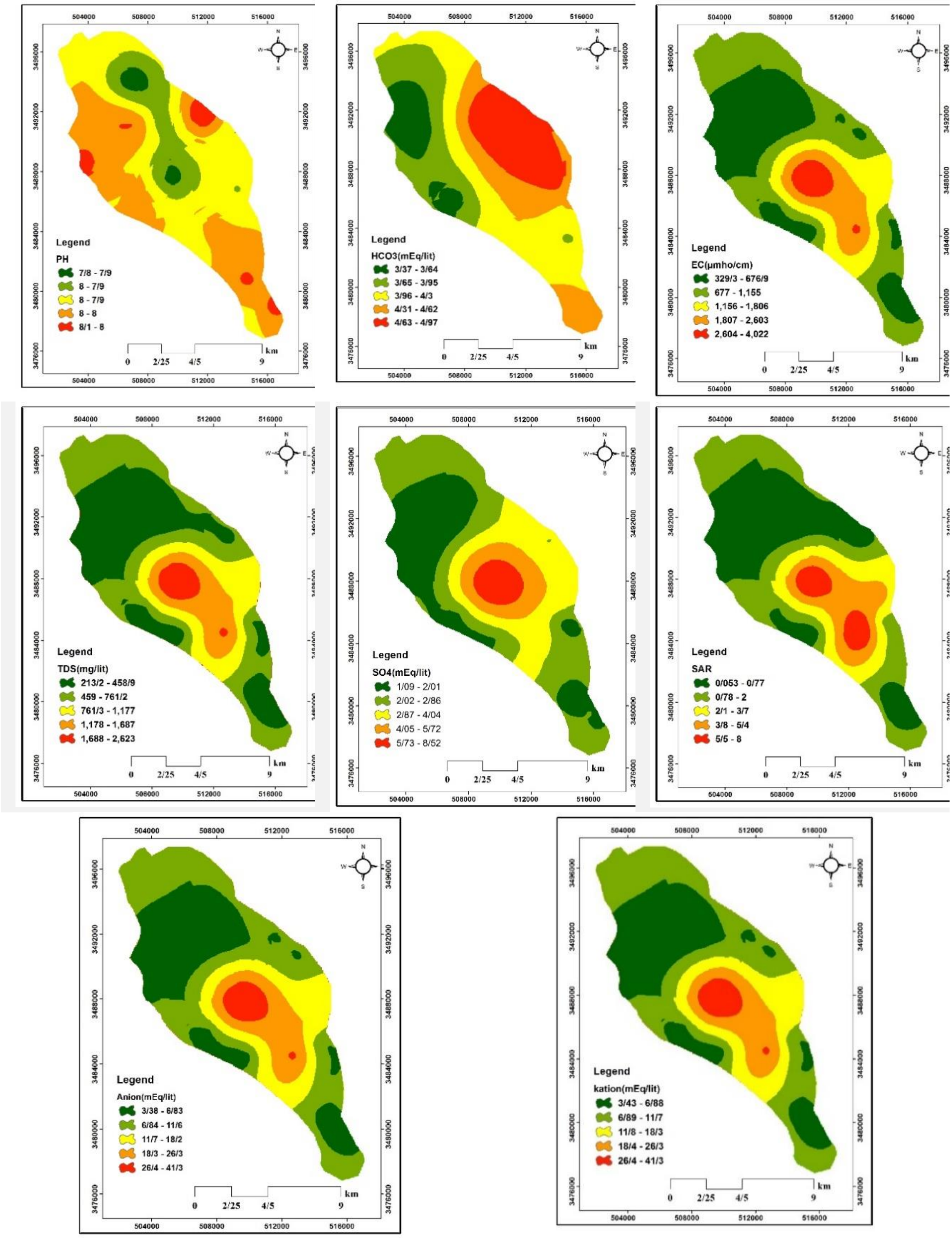


Fig. 8. Zoning the quality parameters of the 2016 period

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