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Quantitative and qualitative analysis of groundwater affected by land use change

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Abstract

Compared to surface water, groundwater resources are the primary source of water supply in arid and semi-arid regions of Iran, hence the importance of the management of these resources . In this regard, we assessed the effects of land use changes on the qualitative and quantitative status of groundwater resources in Eshtehard region, Iran. Through processing and analyzing the satellite images, the region was divided into six different land uses, namely agricultural lands, *Haloxylon* planted area, bareland, saline lands, rangelands, and urban areas; the maps pertaining to these land uses were then prepared. The ground water table fluctuation was assessed via the quantitative data of wells in the study area during 2000-2014. IDW interpolation method was employed to study the spatial variations of parameters, such as EC, Na, SAR, and TDS; afterwards, the maps related to the qualitative and quantitative changes in groundwater were prepared. The results showed that the rangelands, bare lands, and urban areas increased, and the agricultural lands decreased during the studied period. There was more reduction in groundwater table whereas water quality dropped. Generally, water quality was reduced from west to east, and there was more decrease in groundwater table from south to north. It could be deduced that human and natural factors, particularly over exploitation of groundwater, were the main reasons for these changes.

Keywords: Land use changes; Groundwater table; Groundwater quality; GIS, ENVI; Eshtehard

1. Introduction

Water is an essential natural resource for the socio-economic development of human society and the ecosystem. Its purification and transition are difficult and costly and its replacement is impossible (Dannowski *et al*., 2014). Population growth, urban development, and cutting forest trees have caused significant changes in the terrestrial ecosystem and has raised concerns regarding the ecosystem and water resources management. Distinguishing the impacts of these changes on the quantity of water resources is still a challenge for hydrologists (Hutchins *et al*., 2018).

Recent studies have shown that land use change is one of the most critical factors affecting water quantity, and the study of land use changes to understand the elements and their causes over a period can be of interest to planners and managers (Eulenstein *et al*., 2016). It is necessary to assess the effects of land use changes on groundwater resources because compared to surface water, these resources have more advantages such as better quality and lower pollution, and they are the primary source of water supply in arid and semi-arid regions(Xu *et al*., 2014).

The world's population has faced a water crisis, which is expected to be significantly worsened by the end of this century (Erb *et al*., 2015). Problems caused by the abuse of groundwater resources and natural and anthropogenic pollutants are major challenges (Hua, 2017). This particular issue is conducive to selecting topics related to water scarcity and

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groundwater quality in different regions of the world (Luczaj and Masarik, 2015). In this connection, many studies have focused on the effects of land use changes on groundwater resources:

Using satellite images, Ranjpishe *et al*. (2018) assessed the impacts of drought and land use changes on groundwater quality in Shabestar basin, north of Lake Urmia. Their results showed that the extent of farming, residential areas, gardens and bare lands increased from 1990 to 2015 while the extent of pasture land decreased. They also concluded that 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. Zhu *et al*. (2018) investigated the effects of land use changes on groundwater resources of the lower Shiwalik hills, in Rupnagar, Punjab, India during 17 years; for this purpose, they utilized remote sensing and GIS techniques, images of IRS and LISS sensors, and groundwater quantitative and qualitative data. They concluded that the amount of groundwater increased because of natural and artificial recharge caused by land use and land cover pattern changes. Mirzo Jalilov (2018) predicted the impacts of land use changes on groundwater quantity in northern Kelantan, Malaysia during 1989-2014. Based on their results, residential areas increased by 3.9%, agricultural lands were reduced by 2.6%, and groundwater resources were lowered by 20%. Liu *et al*. (2017) evaluated the effect of land use changes on the water resources of Thai River over the past thirty years. In their research, they analyzed the impact of different land uses on river water quantity, concluding that land use change had a direct effect on water quantity. By use of satellite images, Fu Yeh *et al*. (2016) examined the impact of land use changes on groundwater resources in Gilan-e Gharb plain. Their findings showed that the depletion of groundwater increased during the studied years. Human intervention in their research was identified as the most crucial destructive factor. Using GIS software, Elmahdy *et al*. (2016) investigated the impact of land use changes on the quantity and quality of groundwater in Ajman Emirate during fifteen years. They further employed TDS, Na, and Cl parameters to obtain water quality. They revealed that water quality was reduced and water depletion increased due to the increase in the land use/ land cover classes. Chen (2008) assessed the effect of land use changes on groundwater resources using satellite images in Ansan city, Korea and concluded that the increased urban and industrial areas led to groundwater reduction.

Accordingly, land use changes affect water resources. In the future, Iran and other countries will face a more severe crisis caused by reduced water resources and failure to generate new water resources (the USA, 2015). As a result, it is essential to study the effect of land use changes on water resources (Wittenberg, 2015).

Therefore, we aimed to investigate the effect of land use changes on the quantitative and qualitative status of groundwater resources in Eshtehard region. Because of its special temperature conditions, economic progress, and urban development and its suitable agricultural conditions, this region was selected as the case study.

2. Materials and Methods

2.1. Study area

Eshtehard is one of the ancient cities of Iran located in Alborz province. Its area is 769.743 $km^{2,}$ and its population is approximately 25,000 people. Eshtehard is situated behind Alborz and Zagros mountains and does not receive the main rainfall in these regions. Annual precipitation of the study area is 196.4 mm with maximum and minimum of 266.5 and 109.8 mm, respectively. Eshtehard includes two units, two types, and 11 facies of geomorphology. Water erosion and lack of vegetation are the main constraints on the north and west of the region. Agricultural lands exist in the southern parts of the region and may have salinity and wind erosion limitations. The area of the study region in Eshtehard is 247.28 km^2 located on 50° 29' 60" to 50° 44' 56" eastern longitude and 35° 43' 01" to 35° 47' 18" northern latitude (Fig. 1).

2.2. Methodology

To determine the changes in the study area, we used the TM, ETM^+, and OLI sensors data of Landsat satellite. Table 1 shows the details of the used images. After provision and correction, these images, related to the years 2000, 2008, and 2014, were analyzed using ENVI software.

Some studies have been done to select precise classification methods. Based on the Shojaeian *et al*. (2015) and Comte *et al*. (2016) results, Maximum Likelihood Method is the one of the most optimal methods for classification, hence this method was used for classification.

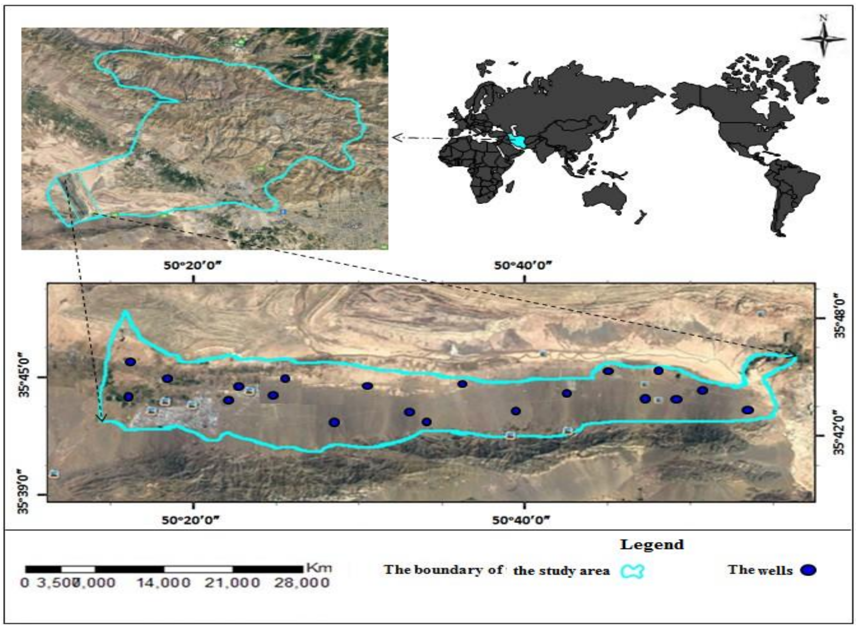

Fig. 1. Location of the study area in Iran, Alborz Province, Eshtehard County

As far as images and study area are concerned, land uses, including agricultural lands, *Haloxylon* planted region, bare area, saline lands, rangelands, and urban areas were selected, and their training points were recorded using GPS. To enhance the accuracy of the training points, their modification was performed using unsupervised classification method. The training samples were matched with the unsupervised image, and the same pixels between unsupervised classes and training points were then determined. Next, these pixels were assigned to the relevant land uses in order to increase the classification accuracy. Consequently, land use maps were prepared for all three years, and their accuracy was assessed by calculating the overall efficiency and Kappa coefficient.

The quantitative data of the wells of the study area were used to investigate the groundwater table condition and its depletion during 2000-2014. Primarily, the location of each well was specified with regards to the existing information and field visits (Fig. 1); after that, the data were sorted, and figures related to their average were designed in the EXCEL software. Finally, the IMDPA model (Iranian Model of Desertification Potential Assessment) was used to generate the zoning map of water table depletion.

Figure 2 shows the framework of the research.

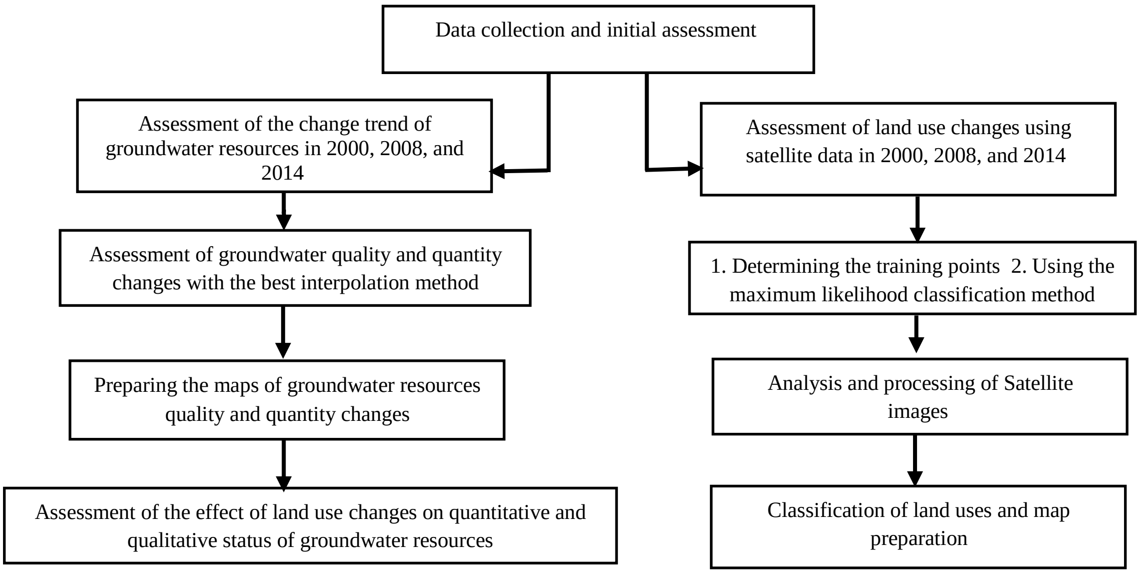

Fig. 2. Flowchart of the research

Table 1. Images used in the research

Correction level	Basis	Years	Pass	Row	Sensor
L1T	WGS84	2000	165	35	TM
L1T	WGS84	2008	165	35	ETM+
L1T	WGS84	2014	165	35	TM

3. Results

Investigation of the radiometric quality showed that all images had a good quality with no error. As mentioned above, the Maximum Likelihood Method was used to evaluate the classification accuracy, Table 2.

Table 2. Results of the evaluation of classification accuracy in 2000, 2008, and 2014

Year	Kappa coefficient	Overall accuracy
2000	0.9788	99.2640
2008	1	100
2014	0.9667	98.8992

3.1. Land use maps and monitoring land use changes

Figure 3 shows the results of the visual interpretation of satellite images. Table 3 and Figure 4 show the area of all land uses and the change procedure, respectively. According to the results, the total area of different land uses in the study region was 247.28 Km^2. The most surface was related to the rangeland in all three years: 71.56% in 2000, 71.66% in 2008, and 72.4% in 2014. As seen, rangeland surface increased around 0.26 Km^2 during these years. Following rangeland, the largest area was related to agricultural use, which decreased about 8.23 Km^2 in 2008 compared to 2000. In 2000, the smallest surface belonged to saline lands, but in 2008 and 2014, it was related to *Haloxylon* planted areas. During these three years, rangelands, urban areas, and bare lands increased by 1.8, 1.57, and 1.98 Km^2, respectively. The reduction pattern of agricultural lands continued until 2014, so that its surface decreased by 8.63 Km^2. According to these changes, it can be inferred that agricultural lands were reduced and urban areas increased during these three years.

Table 3. Area of different land uses

Class	2000		2008		2014	
	Area (Km^2)	Area (%)	Area (Km^2)	Area (%)	Area (Km^2)	Area (%)
Agricultural land	37.60	15.20	29.37	11.18	20.74	8.38
Urban area	13.71	5.54	14.36	5.80	15.93	6.45
Rangeland	176.94	71.56	177.2	71.66	179.01	72.4
Saline land	8.26	3.34	9.58	3.87	11.27	4.55
Haloxylon planted area	0	0	1.55	0.63	3.13	1.26
Bareland	10.77	4.36	15.22	6.16	17.2	6.96
Total	247.28	100	247.28	100	247.28	100

3.2. Groundwater quality

Groundwater quality was evaluated using IDW (Inverse Distance Weighted) method. Figures 5, 6, 7, and 8 show the maps of spatial variations associated with electrical conductivity, sodium absorption ratio, sodium, and total dissolved solid in years 2000, 2008 and 2014, respectively. According to the findings, groundwater quality in the study area worsened during these years. Generally, for all indicators, the western parts of the region with agricultural lands had a better condition compared to the eastern parts, which were unsuitable for agriculture. Furthemore, the southern parts of the region had more suitable conditions in comparison with the northern parts. These results are shown in Tables 4, 5, 6, and 7, indicating the areas related to EC, SAR, Na, and TDS.

Based on Tables 6 and 7 and the Schoeller diagram, most of the regions had an acceptable and moderate condition for drinking; these conditions, on the other hand, were gradually replaced with inappropriate, entirely improper, and non-drinkable status.

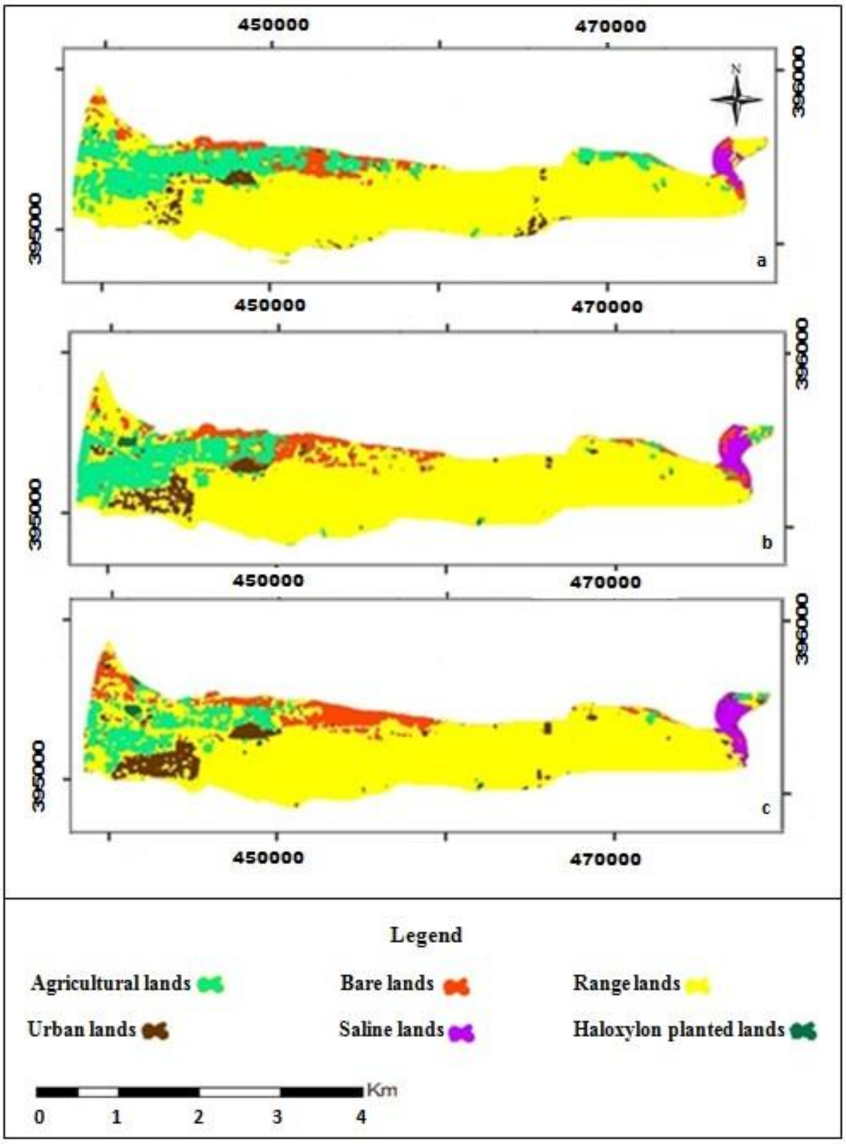

Fig. 3. Maps of Land Use Changes, a: 2000, b: 2008, c: 2014

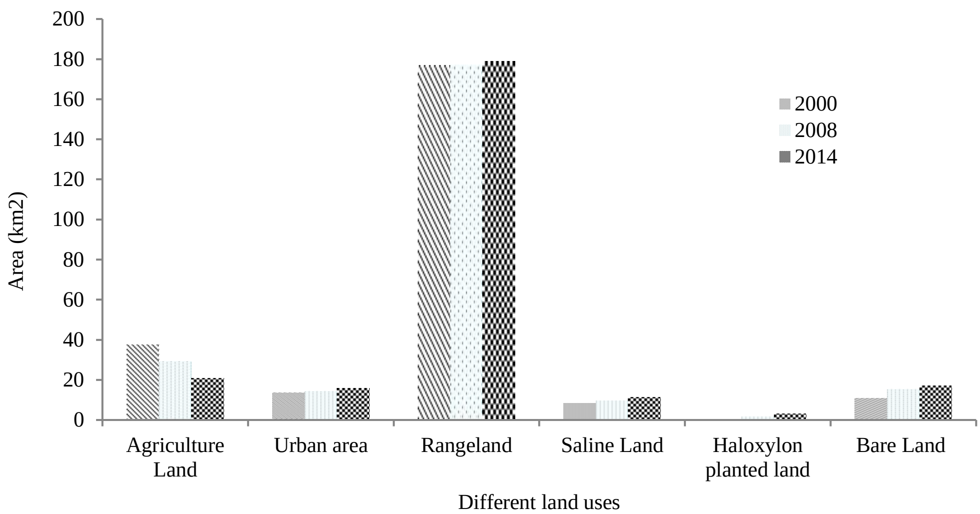

Fig. 4. The area of different uses during the period of 2000-2014

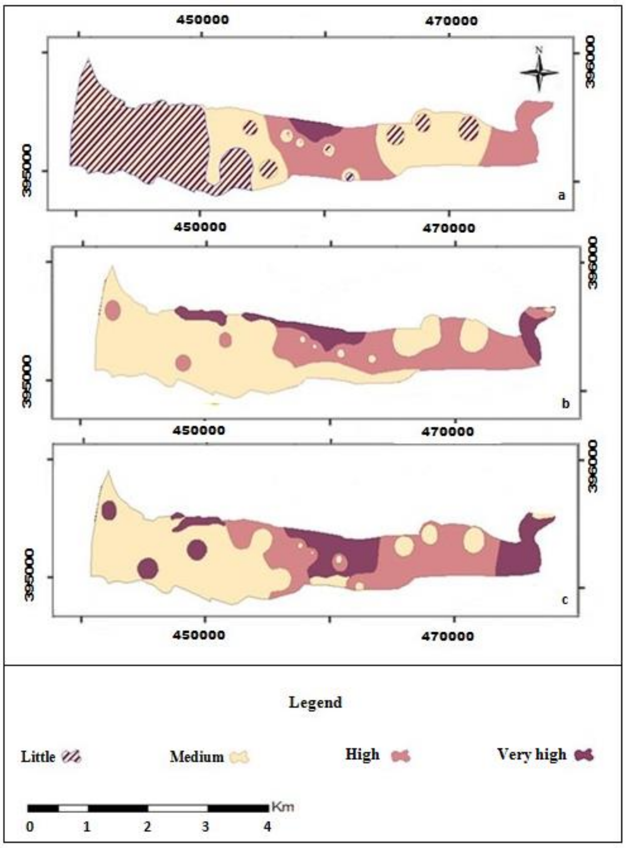

Fig. 5. Spatial variations of EC, a. 2000, b. 2008, c. 2014

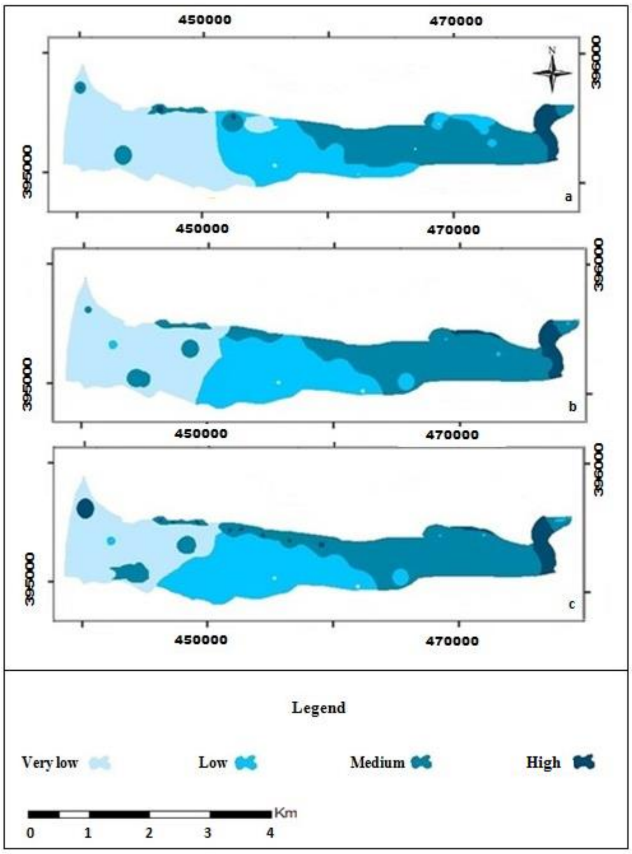

Fig. 6. Spatial variations of SAR, a. 2000, b. 2008, c. 2014

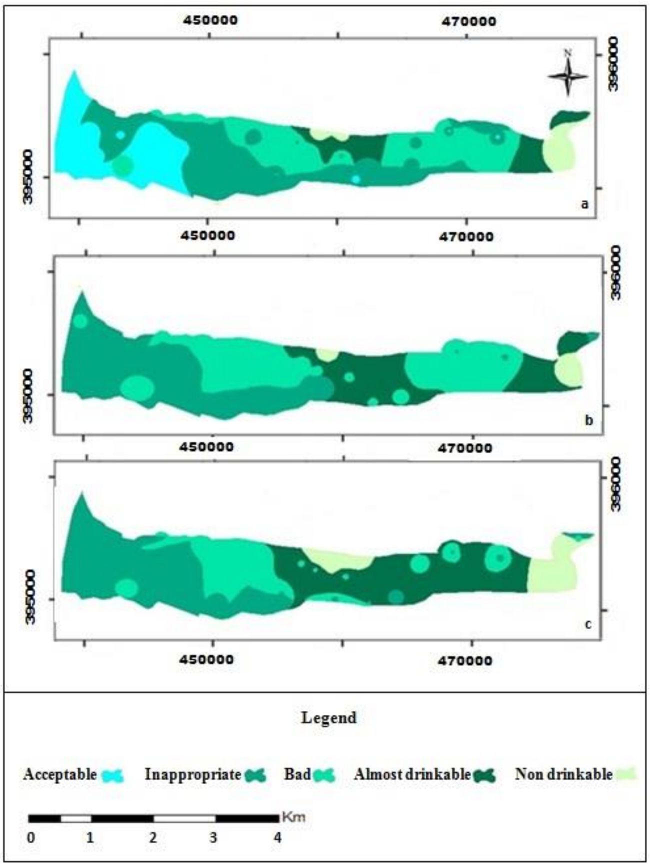

Fig. 7. Spatial variations of Na, a. 2000, b. 2008, c. 2014

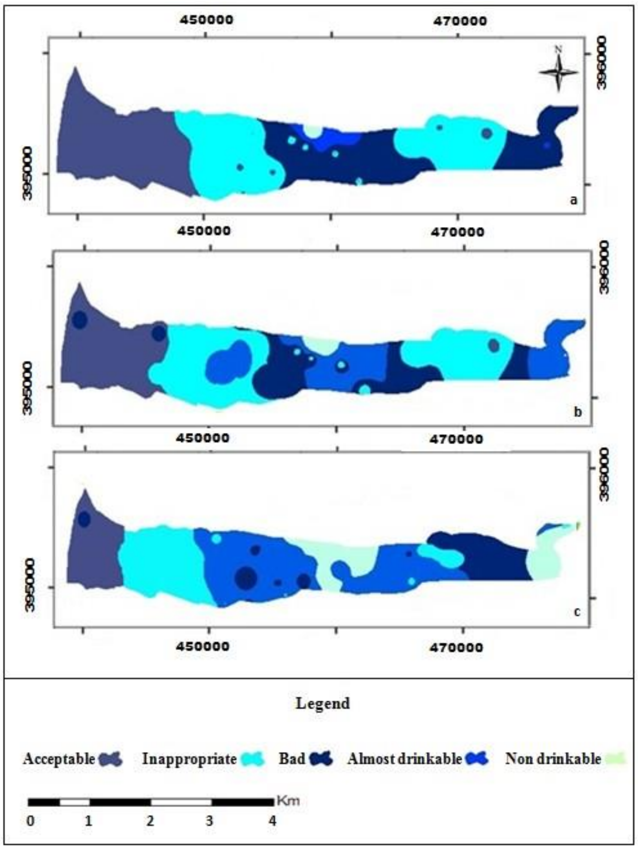

Fig. 8. Spatial variations of TDS, a. 2000, b. 2008, c. 2014

Table 4. Areas allocated to EC classes in the study area

EC classification (µ mho/cm)	Area (%), 2000	Area (%), 2008	Area (%), 2014
250-750	45.39	0	0
750-2250	29.06	60.09	52.61
2250-5000	23.23	29.39	36.52
>5000	2.32	10.52	10.87

Table 5. Areas allocated to SAR classes in the study area

SAR classification	Area (%), 2000	Area (%), 2008	Area (%), 2014
0-10	40.89	40.65	40.08
10-18	24.13	24.8	25.2
18-26	27.54	26.79	26.85
>26	7.44	7.76	7.87

Table 6. Areas allocated to Na classes in the study area

Na classification	Schoeller classification	Area (%), 2000	Area (%), 2008	Area (%), 2014
115-230	Acceptable	21.14	0	0
230-460	inappropriate	35.54	33.3	32.39
460-920	Bad	29.16	39.68	23.57
920-1840	Almost drinkable	10.67	22.76	33.34
>1840	Non-drinkable	3.49	4.26	10.7

Table 7. Areas allocated to TDS classes in the study area

TDS classification	Schoeller classification	Area (%), 2000	Area (%), 2008	Area (%), 2014
500-1000	Acceptable	23.72	32.6	29.92
1000-2000	inappropriate	35.7	35.71	35.27
2000-4000	Bad	28.45	28.21	28.2
4000-8000	Almost drinkable	2.54	2.85	5.65
>8000	Non-drinkable	0.59	0.63	0.96

3.3. Groundwater level variations

Figure 10 shows the change pattern of groundwater level depletion in Eshtehard during the 13 years. According to Figure 9, groundwater depletion increased from 2001 to 2008, decreased from 2008 to 2011, and increased once again from 2011 to 2013.

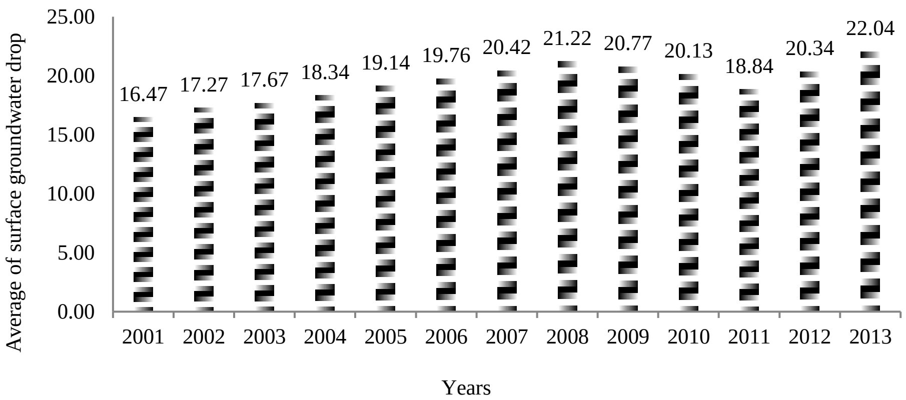

Fig. 9. The trend of temporal changes in groundwater quantity

Table 8 and Figure 10 show the classes of groundwater table depletion in the study area. Based on the results, low and moderate classes of water quantity decreased by 0.19% and 14.61% from 2000 to 2008, respectively. However, high and very high depletion increased by 46.29% and 10.5%, respectively. Moreover, from 2008 to 2014, the low, moderate, and high drop decreased by 3.07%, 25.34%, and 60.14%, respectively and the very high class increased by 65.46%. It is evident that during these three periods, groundwater level depletion in the eastern parts of the region was lower than the western parts. In addition, groundwater reduction in the southern parts of the area was more than the northern regions. In 2014, there was a very sharp decline in groundwater level in all parts of the study area.

Ground water level reduction in the study area indicates the overexploitation of groundwater and increased degradation, entailing many problems for the study area.

Table 8. The area allocated to groundwater reduction classes in the study area using IMDPA model

Groundwater reduction	Schoeller classification	Area (%), 2000	Area (%), 2008	Area (%), 2014
<20	Low	3.26	3.07	0.72
20-30	Moderate	39.95	25.34	2.17
30-50	High	46.29	60.14	20.2
>50	Very High	10.5	11.45	76.91

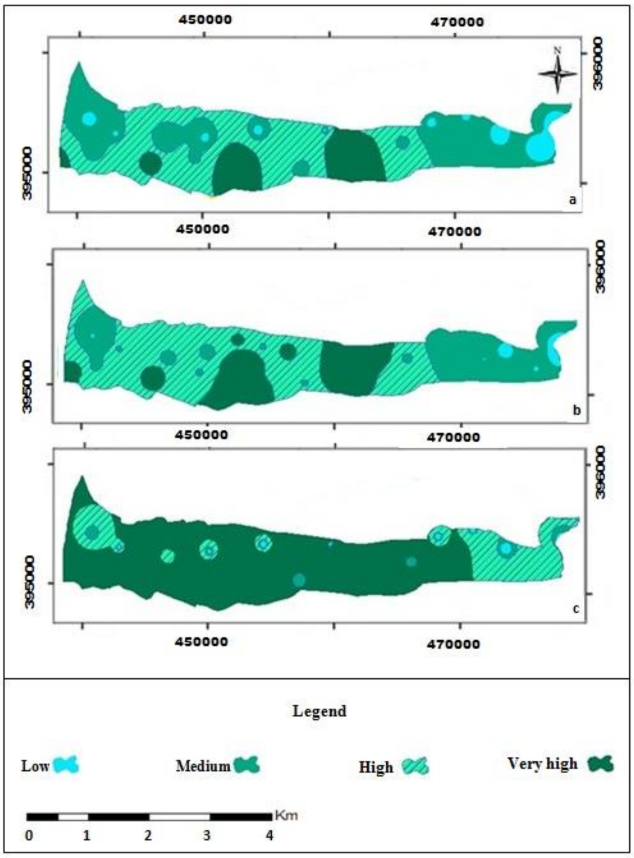

Fig. 10. Spatial changes in groundwater quantity, a: 2000, b: 2008, c: 2014

4. Discussion

The results showed that urban areas increased significantly during these years in the study area. In the western parts of the study area, where agricultural lands and gardens exist, population increase caused the overexploitation of groundwater, pumping of more water from the wells, and new well excavations. These factors led to groundwater surface reduction. Also, the decrease in rainfall and high temperature and the increase in drought caused farmers to abandon their lands. In the southern parts of the region, groundwater utilization further increased due to the growth of urban and rural areas. On the other hand, human activities and improper management resulted in land use changes, thereby reducing groundwater surface in the study area. Similarly, Liu *et al*. (2017) evaluated the effect of climate and land use changes on water resources in the Taoer River. Human activities caused a reduction of about 8.23 km^2 in agricultural lands. These changes led to the overexploitation of groundwater resources by farmers and a decrease in ground water surface during the periods of 2000-2008 and 2011-2013. According to the results, the quality of groundwater resources decreased during these years. There was an appropriate condition for agriculture in the western parts of the region in 2000. In the following years, the quality of groundwater resources was reduced due to an increase in industrial and urban areas and the inappropriate management of irrigation systems. This is consistent with Deshmukh and Aher (2016) who investigated the effect of land use changes on groundwater quality from Sangamner Area, Maharashtra, India. Moreover, the quality of groundwater resources in the central parts of the region decreased during these years owing to the increase in rural and urban areas, overexploitation of groundwater, construction of industrial centers, droughts, geological formations, and salty river. With the rise in the rural regions in the southern parts of the area, groundwater quality worsened during these years. In addition, the steep slope of these parts and the consequent flood and erosion caused a decrease in ground water quality. During these years, there were inappropriate conditions in the eastern parts of the region due to the existence of salty lands and bare lands. The main reason for the presence of saline lands in these parts is the Saline River, which passes through salty lands and Marl formations and affects groundwater resources. In addition, the water of river is unsuitable for agriculture and drinking. According to the results of Schoeller classification based on Na and TDS indicators, only the groundwater related to one section of the northern parts with barren lands, and eastern parts of the region owing to the salty river, had a low quality and was non-drinkable.

Totally, the results of this study are consistent with studies such as Neal (2010) who stated that land use changes impacted the groundwater quality. To manage the rural environments, Ozturk (2013) determined the reduction of groundwater quality in rural watershed. Abiye *et al*.(2018) investigated the effects of land use changes on groundwater quality in the Johannesburg region; Rossiter *et al*.(2014) studied the chemical quality of drinking water and indicated that high turbidity, low acidity, and high concentration of NO_3, Al, and Cl were the main problems associated with different countries.

5. Conclusion

In this research, one part of Eshtehard region in Alborz province was selected based on field observations. Landsat satellite images related to TM and ETM^+ sensors were used to assess the changes in the years 2000, 2008, and 2014. Also, the data related to water quantity was used to investigate the groundwater level changes. Afterwards, the maps of groundwater reduction and the average of groundwater reduction were drawn for all three years, and the zoning maps were finally prepared. The results showed that the surface of rangelands, bare lands, and urban areas increased while the surface of agricultural lands was reduced during the studied years. Furthemore, the reduction in groundwater table was improved and water quality was reduced. The similarity of our results to other studies indicate the accuracy of the present research.

According to the results, the reduced groundwater quality and quantity in the study area was due to the land use changes and also the inappropriate management. In fact, groundwater utilization increased due to the growth of urban and rural areas. Therefore, overexploitation and decrease in groundwater level resulted in the further destruction of soil and water resources.

In conclusion, land use changes had important effects on groundwater quality and quantity in Eshtehard region over the study period. Therefore, it can be claimed that land use change is an important parameter reducing groundwater quality and quantity; however, it is also necessary to consider the climate change and its impact on water resources.

References

Abiye, T., K. Masindi, H. Mengistub, M. Demliec, 2018. Understanding the groundwater-level fluctuations for better management of groundwater resource: a case in the Johannesburg region. Groundwater for Sustainable Development, 7; 1-7.

Chen, X.W., 2008. Using remote sensing and GIS to analyze land cover change and its impact on regional sustainable development. International journal of remote sensing, 23; 107-124.

Comtea, J., R. Cassidy, J. Obando, N. Robins, K. Ibrahim, S. Melchioly, I. Mjemah, H. Shauri, A. Bourhanej, I. Mohamed, C. Noe, B. Mweg, M. Makokha, J. Join, J. Davies, 2016. Challenges in groundwater resource management in coastal aquifers of East Africa: Investigations and lessons learnt in the Comoros Islands, Kenya, and Tanzania. Journal of Hydrology: Regional Studies, 5; 179–199.

Dannowski, R., R. Schindler, N. Cremer, F. Eulenstein, 2014. Methods of In Situ Groundwater Quality Monitoring: Basis for the Efficiency Survey of Agricultural Groundwater Conservation Measures. Novel Measurement and Assessment Tools for Monitoring and Management of Land and Water Resources in Agricultural Landscapes of Central Asia. Environmental Science and Engineering, 275-288.

Deshmukh, K.K. and Aher, S.P., 2016. Impact of Land-Use Changes on Groundwater Quality from Sangamner Area, Maharashtra, India. In Crystallizing Ideas–The Role of Chemistry (pp. 209-226). Springer, Cham.

Elmahdy, S.I., M.M. Mohamed, 2016. Land use change impact on groundwater quantity and quality. A case study of Ajman Emirate, the United Arab Emirates, using remote sensing and GIS. Arabian Journal of Geoscience, 9; 722, 1-22.

Erb, K., E. Ronk, V. Koundinya, J. Luczaj, 2015. Groundwater Quality Changes in a Karst Aquifer of Northeastern Wisconsin, USA: Reduction of Brown Water Incidence and Bacterial Contamination Resulting from Implementation of Regional Task Force Recommendations. Resources, 4; 655–672.

Eulenstein, F., M. Tauschke, U. Schindler, L. Müller, M.A. Lana, R. Schindler, W.H. Mayer, H. Drechsler, N. Cremer, 2016. Agricultural Land Use Systems and Groundwater Quality: Impact Assessment Using Nutrient Balances for Evaluation, Monitoring and

Conservation of Natural Resources. Agriculture and Agricultural Science Procedia, 11; 49 – 58.
Hua, A.K., 2017. Land use changes in Detection of water quality of the Malacca River a case study of public perception. International Journal of Scientific Research in Science and Technology, 3; 111–116.
Hutchins, M.G., C. Abesser, C. Prudhomme, J.A. Elliott, J.P. Bloomfield, M.M. Mansour, 2018. Combined impacts of future land-use and climate stressors on water resources and quality in groundwater and surface water bodies of the upper Thames river basin, UK. Science of the Total Environment, 631; 662–686.
Liu, J., C. Zhang, L. Kou, Q. Zhou, 2017. Effect of climate and Land use changes in water resources in the Taoer River. Journal of Biodiversity and Environmental Sciences, 2; 12–16.
Luczaj, J., K. Masarik, 2015. Groundwater Quantity and Quality Issues in a Water-Rich Region: Examples from Wisconsin, USA. Resources, 4; 323–357.
Mirzo Jalilov, S., 2018. Value of Clean Water Resources: Estimating the Water Quality Improvement in Metro Manila, Philippines. Resources, 71; 1-15.
Neal, C., H.P. Jarvie, P.J.A. Withers, B.A. Whitton, M. Neal, 2010. The strategic significance of wastewater sources to pollutant phosphorus levels in English rivers and environmental management for rural, agricultural and urban catchments. Science of the Total Environment, 408; 1485–1500.
Ozturk, M., N. Copty, A.K. Saysel, 2013. Modeling the impact of land use change on the hydrology of a rural watershed. Journal of Hydrology, 497; 97-109.
Ranjpisheh, M., Karimpour Reihan, M., Zehtabian, G.R. and Khosravi, H., 2018. Assessment of drought and land use changes: Impacts on groundwater quality in Shabestar basin, North of Lake Urmia. Desert, 23(1), pp.9-19.
Rossiter, M.A., P.A. Owusu, E. Awuha, A.M. MacDonal, A.I. Schafer, 2014. Chemical drinking quality in Ghana. Science of the total Environment, 408; 2378-2386.
Shojaeian, A.S., L. Mokhtari Chalcheh, E. Keshtkar, A. Soleimani Rad, 2015. Comparison of Parametric and NonParametric Methods for Land Cover classification by using Satellite Landsat 8. Journal of Geographical Sciences, 93; 53–64.
USA, 2015. Today—Pumped Dry: The Global Crisis of Vanishing Groundwater. Accessed on 16 December 2015.
Wittenberg, H., 2015. Groundwater Abstraction for Irrigation and Its Impacts on Low Flows in a Watershed in Northwest Germany. Resources, 4; 566–576.
Xu, D., Ch. Li, X. Song, H. Ren, 2014. The dynamics of desertification in the farming-pastoral region of North China over the past ten years and their relationship to climate change and human activity. Catena. 499; 520–53.
Yeh, H.F., Y. Cheng, H. Lin, C. Lee, 2016. Mapping groundwater recharge potential zone using a GIS approach in Hualian River, Taiwan. Journal of sustainable Environmental Sciences, 26; 33-43.
Zhu, X., J. Wu, H. Nie, F. Guo, J. Wu, K. Chen, K. Liao, H. Xu, X. Zeng, 2018. Quantitative assessment of the impact of an inter-basin surface-water transfer project on the groundwater flow and groundwater-dependent eco-environment in an oasis in arid northwestern China. Hydrogeology Journal, 26; 1475-1485.