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RESEARCH PAPER

# The Effect of Land Use Changes on Water Quality (Case Study: Zayandeh-Rud Basin, Isfahan, Iran)

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**ABSTRACT**
The present study aims at investigating land use changes (as one of the effective human factors on water systems) as well as its relation with water quality at spatial scales of the entire basin, sub-basin and defined buffers (10 and 15 km) in Zayandeh-Rud Basin, Isfahan, Iran. By means of supervised classification method along with maximum likelihood algorithm, it classifies the land use map into five categories, including agriculture, bare lands, urban areas, vegetation, and water. The research collects data for 11 water quality parameters in seven sampling stations of Zayandeh-Rud Basin in 2002, 2009, and 2015 from Isfahan Water and Sewerage Organization. Correlation analysis is then conducted to investigate the effect of land use changes on water quality at different spatial scales. Land use analysis in the entire basin shows that despite an increase in urban and agricultural lands from 2002 to 2015, bare lands, vegetation, and water covers have had a decreasing trend. Moreover, various land uses at different scales show some correlation with water quality parameters. The strongest correlations in this study belong to sub-basin scale. Therefore, it is recommended to use this spatial scale to investigate the relation between land use and water quality parameters.
**Keywords:** Human Factors; Surface Water; Spatial Scale; Urbanization

## INTRODUCTION

Water pollution is one of the several critical issues facing the world in both developed and developing countries (Chaudhry and Malik, 2017). Water quality is defined as a measure of water use for different purposes (drinking, industrial, agricultural, recreational, and habitat) using various parameters such as physical, chemical, and biological (Giri and Qiu, 2016). Water quality plays a central role in all aspects of living organisms on the earth, attracting the attention of a broad range of scientists, researchers, and water resource managers. Water quality varies according to location, time, weather, and sources of pollution (Giri and Qiu, 2016). Surface water is polluted by two types of sources including point sources such as wastewater treatment plants and non-point sources (NPS) such as runoff from urban areas and agricultural lands. In most cases, point sources can be easily controlled, but non-point sources are difficult to identify due to large coverage. Land use change is known as one of the factors increasing non-point pollution (Gyawali et al., 2015). Land use change is a matter of concern in recent years, specifically with fast paced urbanization (Mahmoudzadeh, 2017). Land use refers to anthropogenic use of lands and their resources, and the physical conditions of these lands result from a long-term interaction between humans and natural environment (Camara

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et al., 2019). Satellite imagery is a new dimension in land use change assessment (Tewolde and Cabral, 2011). Remote sensing techniques and free access to satellite images have increased the possibility of evaluating land use change (Maithani, 2009). Assessment of relationship between land use and water quality is of great importance to protect freshwater, which would fulfill the water demand in different sectors such as increased agricultural activities, industrial usage, municipal usage, supply of drinking water, and recreational use. Additionally, understanding the relationship between land use and water quality would help assessing the water quality in the unmonitored watershed as monitoring is expensive and time consuming. Also, this knowledge would provide guideline to watershed managers and policymakers to prioritize the future land use development in the rapidly urbanizing world (Giri and Qiu, 2016). Therefore, this requires a thorough understanding of advantage and disadvantage of techniques applied, scale of study area, focus of land use metrics, and relationship observed by different studies. Nazarnejad et al. (2019) investigated the effect of land use changes on water quality in Zarrineh-Rud basin in West Azerbaijan, Iran. The results confirmed land use change in the basin (i.e. decrease in pastures and increase in agricultural lands). Investigating water quality of Zarrineh Rud basin in this study also showed reduction in water quality as a result of land use changes. Camara et al. (2019) studied the impact of land uses on water quality in Malaysia. The results revealed that 87% of the reviewed studies indicated urban land use as a major source of water pollution, while 82% indicated agricultural land use, 77% indicated forest land use, and 44% indicated other land uses. However, the results of correlation analysis showed that agricultural and forest-related activities more affected water quality through their significant positive correlation with physical and chemical indicators of water quality, while urban development activities had a greater impact on water quality through altering hydrological processes such as runoff and erosion. Tahiru et al. (2020) investigated the effect of land use and land cover changes on water quality in the Nawuni Catchment of the White Volta Basin, Northern Region, Ghana. The results of LULCC revealed an increased expanse of grassland/farmland (4.1%), settlement (0.1%), bare land (9.4%) and closed savannah (1.2%), whilst opened savannah (14.7%) and water body (0.1%) recorded a decreasing trend. The study showed an increase in the levels of turbidity and ammonia and a decrease in total coliforms over the study period (2007 to 2017). The study also revealed a positive relationship between LULC categories and water quality parameters, implying that LULCC contribute to the change in water quality in the area. Recent rainfall reduction and drought have reduced Iranian water resources. Provinces like Isfahan are more exposed to water shortage and consequent problems, due to dry climate and lack of proper management in distribution and application of water resources. This study aimed to investigate land use changes in Zayandeh-Rud basin in 2002, 2009 and 2015 as one of the effective anthropogenic factors on water systems quality. It also investigated the relationship between water quality and land surface characteristics at different spatial scales. Selecting the appropriate spatial scale is beneficial to control the effects of land use on water quality.

## MATERIAL AND METHODS

Zayandeh-Rud basin (Gavkhoni basin) with an area of 41,485.65 $km^2$ in central plateau of Iran, is located between the longitude of 50°, 21′ and 24″ to 53°, 21′ and 34″ and the latitude of 31°, 50′ and 18″ to 33°, 43′ and 50″ (Figure 1). Zayandeh-Rud river is 350 km long and flows approximately west-east. The river which extends from Zagros Mountains in the west to Gavkhoni wetland in the east, providing irrigation water, drinking water and water supplies for important industries in Iran. Major part of Zayandeh-Rud basin is located in arid and semi-arid climate. Average monthly temperature varies from 3° Celsius in January to 29° Celsius in July. Annual rainfall changes from 1500 mm in Zagros in the west to 80 mm in desert areas in the east, with an average of 120 mm. As a result of rainfall in cold months, runoff is created in sedimentary plains. There are some screening stations located along the river to monitor river's condition (Sadat Mirahsani et al., 2017).

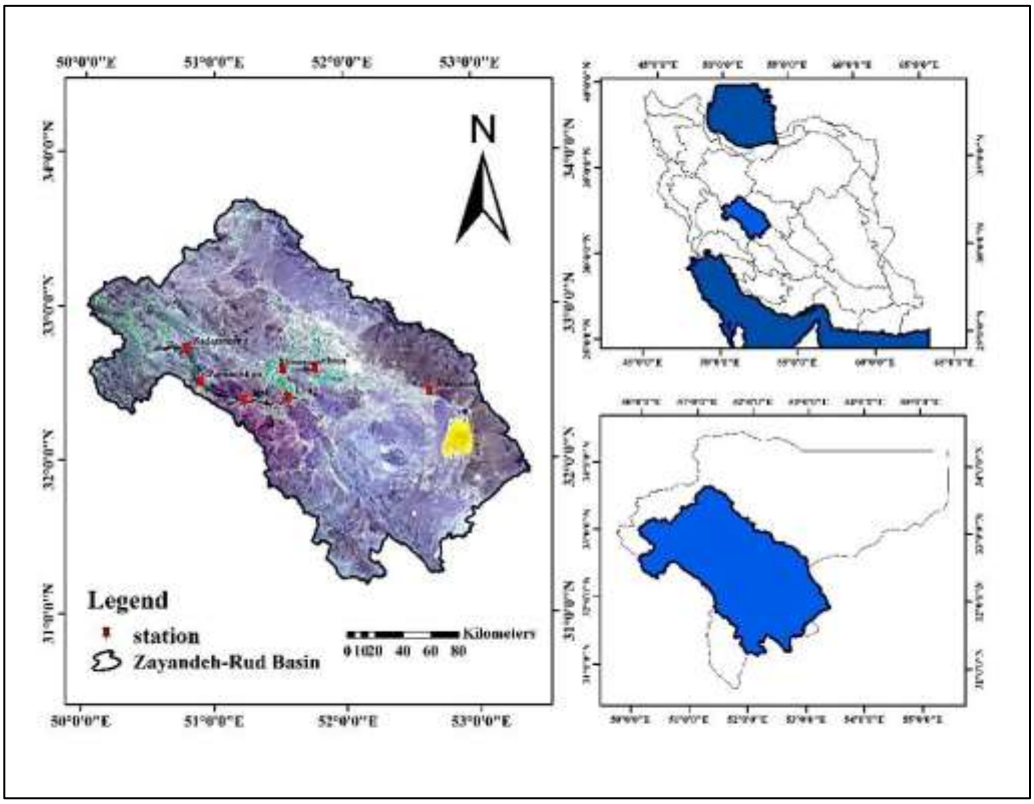


**Figure 1.** Study area

Landsat 5 TM (2009) and Landsat 8 OLI images of 2002 and 2015 were applied in this study. ENVI 5.3 and ArcGIS 10.5 software were used to pre-process, classify and interpret satellite images. Training samples were used to classify images and prepare land use maps. Using the supervised classification method, maximum likelihood algorithm, land use map of Zayandeh-Rud basin was classified into five categories: agriculture, bare lands, urban areas, vegetation, and water. Using probability rule, maximum likelihood algorithm provides more accurate results than other classification methods. Based on the rule, each pixel belongs to a class to which it has the highest probability of being a member (Alavipanah, 2016). Kappa coefficient obtained using the error matrix parameters (Equation 1) was used to evaluate the accuracy of the classification results (Rwanga and Ndambuki, 2017).

$$k = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+} * x_{+i})}{N^2 - \sum_{i=1}^{r}(x_{i+} * x_{+i})} \quad (1)$$

Where:

r = number of rows in the error matrix;

$x_{ii}$ = number of observations in row i and column i;

$x_{i+}$ = marginal total of rows i;

$x_{+i}$= marginal total of columns i;

N = total number of observations (pixels).

Finally land use map was extracted for 3 years in ArcGIS 10.5. Three spatial scales including entire basin, sub-basin, 10 and 15 km buffers (Figure 2) were used in the current study to analyze the relationship between water quality and land use. Area of each land use type at various spatial scales for each station was extracted in ArcGIS 10.5.

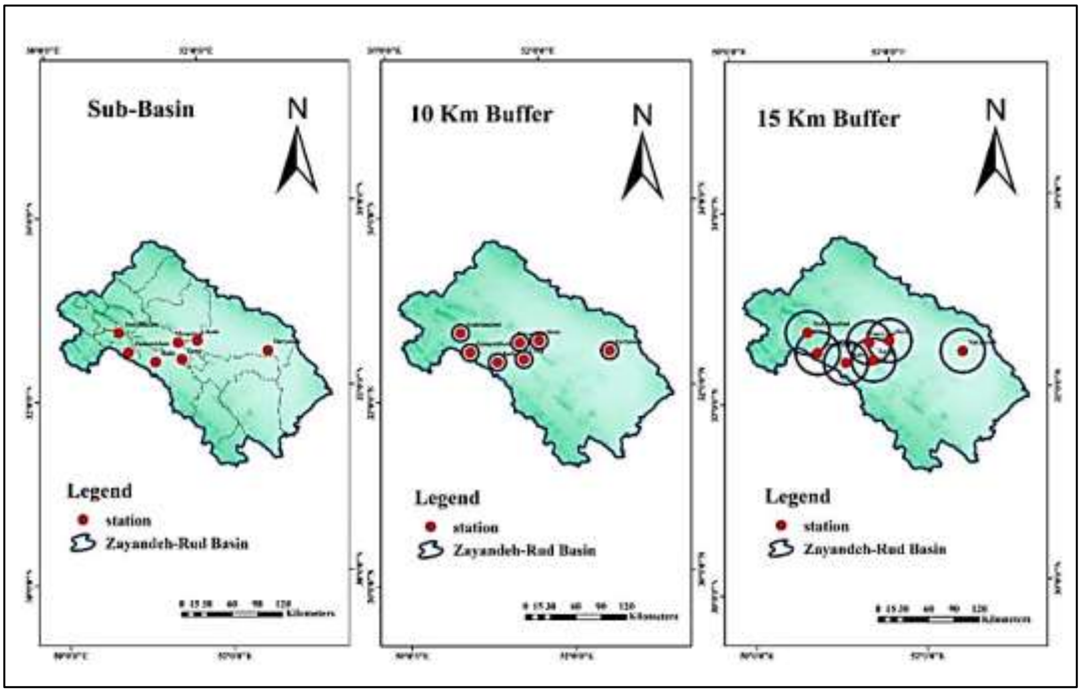


**Figure 2.** Sub-basin and 10km and 15km buffer zone in 7 monitoring stations in Zayandeh-Rud basin

Information on 11 water quality parameters including: total dissolved solids (TDS), pH, electrical conductivity (EC), sulfate ($SO_4$), chlorin (Cl), magnesium (Mg), sodium (Na), potassium (K), calcium (Ca), carbonate ($CO_3$) and bicarbonate ($HCO_3$) in seven sampling stations along Zayandeh-Rud basin in 2002, 2009 and 2015 were obtained from Isfahan Water and Wastewater Organization. The obtained data were used to investigate the effect of land use change on water quality at different spatial scales. Analyzing the correlation between water quality parameters and land use types was conducted in SPSS 22.

## RESULT AND DISCUSSION

Kappa coefficient has been used to determine land use classification accuracy (Table 1). It considers the probability of random chance in classification (Lillesand et al., 2004). The results show an acceptable level of accuracy in land use map extraction from satellite images.

**Table 1.** Kappa coefficient and overall accuracy in land use classification

| Year | Kappa Coefficient | Overall Accuracy % |
|---|---|---|
| 2002 | 0.98 | **98.54** |
| 2009 | 0.96 | **96.67** |
| 2015 | 0.97 | **97.72** |

Figure 3 shows the extracted land use maps in 2002, 2009 and 2015. Considering the maps, land use types have changed over years. Figure 4 represents changes in land use over time. During considered 13-years period (2002-2015), land use changes showed a decrease in vegetation cover and an increase in urban lands in the entire basin. Area of urban lands in Zayandeh-Rud basin has increased from 564.91 $km^2$ in 2002 to 848.13 $km^2$ in 2015. Considering land use changes in sub-basin scale confirmed an increase in urban and agricultural lands in most sub-basins. Evaluating the effect of these changes on water quality along Zayandeh-Rud confirmed water quality reduction over time. This can be directly attributed to increase in urban and agricultural lands in most sub-basins. Ding et al. (2015) argued urban land use as a main factor affecting water quality and concluded that limiting waste leachate in urban areas in dry seasons is essential to improve water quality in Dongjiang river basin. Pir Ali Zafrehe'i and Ebrahimi Dorcheh (2015) evaluated the effects of

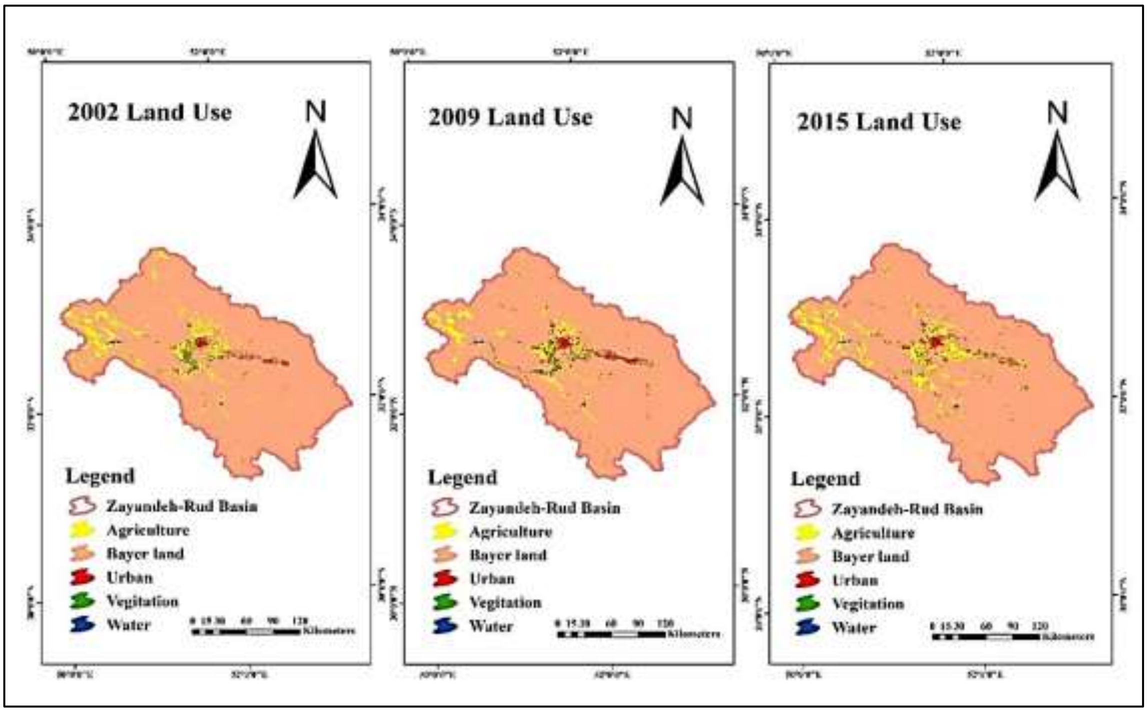


**Figure 3.** Comparison of land uses between 2002, 2009 and 2015 in Zayandeh-Rud basin

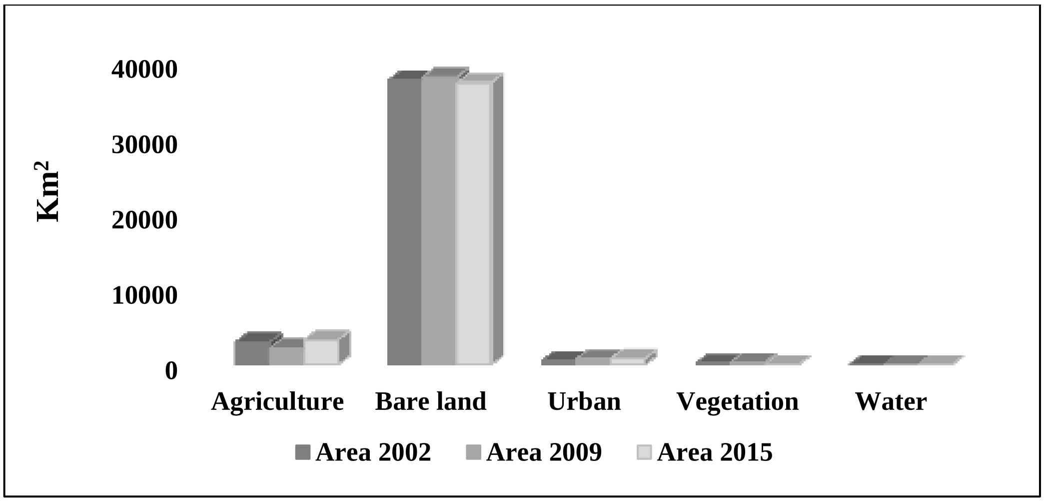


**Figure 4.** Land use changes in Zayandeh-Rud basin

drought on Zayandeh-Rud water quality and showed quality reduction over drought period. It can be concluded along land use changes, drought occurred in the region in 2013-2014 had reduced Zayandeh-Rud water quality. However, extensive land use changes (e.g. increase in urban lands from 564.91 to 848.13 $km^2$) is still the main factor.

Considering changes in water quality of Zayandeh-Rud basin in seven stations shows a reduction in water quality in a 13-years period (2002-2015) (Figure 5). EC, TDS and Cl have had an upward trend in all stations during 13-years (2002-2015), with Varzaneh station experiencing the largest increase. The lowest concentration of Cl belongs to Zaman Khan station (0.36 mg/L) in 2002 and the highest concentration belongs to Varzaneh station (580 mg/L) in 2015, which could be attributed to chloride fertilizers. Chloride-containing fertilizers such as potassium chloride could increase chloride in water sources (Smart et al., 2001). World health organization (WHO) standard for EC in water is 400 µm/cm (Oudi, 1994). Chom, Leng, Mosayian and Varzaneh stations in 2002 and Chom, Kale, Leng and Varzaneh stations in 2015 did not meet the required standard. Water with less than 500 mg/L TDS has good quality for drinking. Water with TDS between 500 to 1,000 mg/L is desirable and with more than 1,500 mg/L TDS is not drinkable (Oudi, 1994). Based on the mentioned standard, Zaman Khan, Kale and Sadetanzimi stations met desirable drinking standards in 2002 and 2009 while Varzaneh station was in a bad condition for drinking. Water with high level of TDS, impacts the color, odour, and taste dramatically. It may be extremely unpalatable. In addition to the taste, water with high level of TDS may not be suitable owing to the excessive scaling caused by it in water pipes, heaters, boilers, and household appliances. In 2015, Zaman Khan, Kale and Sadetanzimi stations had good quality for drinking, but Varzaneh station with TDS of 36,075 mg/L was not drinkable. Presence of large industries such as steel industries, located in Isfahan and upstream Zayandeh-Rud basin causes transfer and accumulation of pollution in lower stations. Therefore, Varzaneh station as the last station in the study area is more exposed to various pollutants. Water acidity of Zayandeh-Rud basin is almost uniform during the study period and has been alkaline (pH of 7.5-8.1) in all stations. The acidity of natural waters is mainly related to geology and hydrology of the region and presence of carbon dioxide and other atmospheric gases in water (Blocksom et al., 2002). Anions such as bicarbonate and sulfate in Zayandeh-Rud basin have different concentrations in various stations due to unique characteristics of each station. The results confirmed bicarbonate as dominant anion in water samples. Bicarbonate concentration varies between 2.09 and 4.67 mg/L during the study period in Zayandeh-Rud basin. Factors such as biodegradation of organic matter, weathering of silicate and carbonate minerals can lead to high concentrations of $HCO_3$ in water (Kim et al., 2017). The maximum and minimum sulfate concentrations recorded in the study area were related to Varzaneh station (65.49 mg/L) in 2009 and sadetanzimi station (0.31 mg/L) in 2015, respectively. Infiltration of domestic sewage into water sources and oxidation of sulfurous organic matters could increase sulfate in aquatic environments (Olias et al., 2004). Cations presented in Zayandeh-Rud water include Na, Ca, K and Mg. Na concentration varied from 0.12 to 464 mg/L, with minimum and maximum concentrations recorded in Sadetanzimi and Varzaneh stations, respectively. Sodium are entered into aquatic environments through a variety of effluents (domestic and agricultural wastewater) (Church and Granato, 2006). According to drinking water quality Standard, there is no maximum acceptable value for both potassium and calcium. This is due to the concentration of potassium and calcium in drinking water is well below to give any human health concern (Wang Jing et al., 2019). Analyzing K concentration in the study area showed maximum and minimum concentration belonged to Varzaneh station in 2009 and Zaman Khan station in 2015. Prasanna et al. (2010) believe that clay minerals along with agricultural fertilizers and household wastes are the main sources of potassium. Therefore, managing agricultural activities could have extensive effect in controlling water quality of Zayandeh-Rud basin. Ca and Mg concentrations have changed from 2.2 mg/L (Zaman Khan station in 2002) to 58 mg/L (Varzaneh station in 2015) and 0.57 mg/L (Kale station in 2002) to 86 mg/L (Varzaneh station in 2015), respectively. The presence of Mg in water is mainly due to carbonate minerals such as calcite and dolomite (Al-hadithi, 2012). High level of Ca in water can be associated with a variety of domestic and industrial wastewater. Therefore, there is a need to wisely manage wastewater from industrial and urban activities. Due to urban development and population growth in small areas and in a dense manner, it is necessary to pay more attention to effluents from industrial activities and consumption of urban residents.

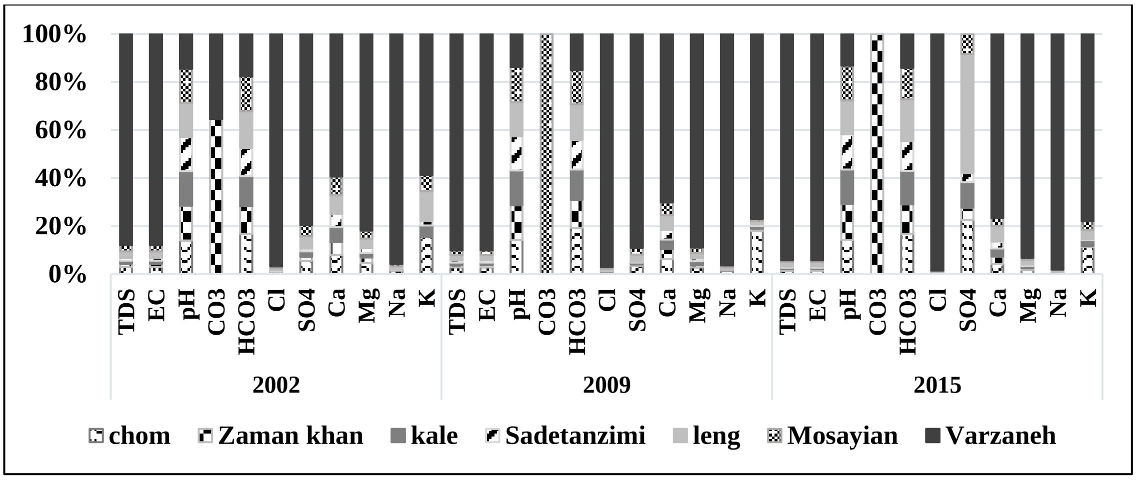


**Figure 5.** Surface water quality trend in Zayandeh-Rud basin

Table 2 shows the correlation between types of land use and surface water quality at different spatial scales. The results confirmed a significant positive correlation between bare lands and all quality parameters except pH, $CO_3$ and $HCO_3$ at the basin and 15 km buffer scales. Urban areas and vegetation covers have significant positive correlation with $HCO_3$ at the scale of the entire basin, while only urban lands are correlated with $HCO_3$ at 15 km buffer scale. Urban lands also show a positive correlation with $HCO_3$ at 10 km buffer scale. Agricultural and bare lands have positive relationship with all water quality parameters, except pH at sub-basin spatial scale. Moreover, at this scale, positive relationship is confirmed between urban areas and all considered water quality parameters except pH and $CO_3$. As most of the water quality parameters are related to agricultural, bare and urban lands at the sub-basin scale in this study, this scale is recommended for research aim to investigate the relationship between land use and water quality. Other studies also showed that land use changes close to a river provide more precise prediction of water quality compared to an entire basin. Gyawali et al. (2015) examined the effect of land use changes on water quality at basin, sub-basin and buffers (200 m, 500 m and 1000 m) scales in U-tapao river basin. The results showed that there is a positive and significant relationship between water quality and land use at the sub-basin scale compared to the entire basin and buffer scales. Zhou et al. (2012) extracted land use pattern in Dong Yang river basin, China in 1990 and 2006, using remote sensing data. Moreover, considering the relationship between land use and several water quality variables in various scales (basin, sub-basin and buffers (500 m, 1000-1500 m, 2000-2500 m and 3000-5000 m)), they found considerable changes in water quality of the river in recent decades. They also found that land use had major effects on the flow and water quality of the Dong Yang river at different spatial scales. Although the major variables

**Table 2.** Correlation between land use and water quality parameters

| | | **Agriculture** | **Bare land** | **Urban** | **Vegetation** | **Water** |
|---|---|---|---|---|---|---|
| Entire basin | TDS | -0.150 | 0.729** | -0.107 | -0.264 | **-0.148** |
| | EC | -0.150 | 0.729** | -0.107 | -0.264 | **-0.148** |
| | pH | -0.205 | -0.414 | -0.157 | 0.061 | **-.069** |
| | $CO_3$ | -0.008 | -0.198 | -0.231 | -0.161 | **-0.141** |
| | $HCO_3$ | 0.349 | 0.015 | 0.679** | 0.501* | **-0.404** |
| | Cl | -0.145 | 0.704** | -0.112 | -0.259 | **-0.139** |
| | $SO_4$ | -0.146 | 0.592** | -0.039 | -0.197 | **-0.138** |
| | Ca | -0.151 | 0.736** | -0.098 | -0.259 | **-0.159** |
| | Mg | -0.142 | 0.716** | -0.105 | -0.259 | **-0.146** |
| | Na | -0.151 | 0.725** | -0.110 | -0.265 | **-0.145** |
| | K | -0.002 | 0.637** | 0.000 | -0.214 | **-0.167** |
| Sub-basin | TDS | 0.674* | 0.732** | 0.927** | 0.193 | **-0.566** |
| | EC | 0.674* | 0.732** | 0.927** | 0.193 | **-0.566** |
| | pH | -0.592* | -0.643* | -0.489 | 0.085 | **0.032** |
| | $CO_3$ | -0.367 | -0.466 | -0.361 | -0.029 | **0.132** |
| | $HCO_3$ | 0.439 | 0.615* | 0.824** | 0.064 | **-0.621*** |
| | Cl | 0.710** | 0.675* | 0.917** | 0.218 | **-0.612*** |
| | $SO_4$ | 0.525 | 0.617* | 0.763** | 0.359 | **-0.379** |
| | Ca | 0.552 | 0.638* | 0.865** | 0.349 | **-0.507** |
| | Mg | 0.584* | 0.628* | 0.876** | 0.257 | **-0.661*** |
| | Na | 0.649* | 0.742** | 0.895** | 0.210 | **-0.520** |
| | K | 0.864** | 0.803** | 0.815** | -0.336 | **-0.386** |
| 10 km buffer | TDS | -0.127 | 0.172 | 0.075 | -0.261 | **-0.170** |
| | EC | -0.127 | 0.172 | 0.075 | -0.261 | **-0.170** |
| | pH | -0.128 | 0.018 | -0.167 | 0.178 | **0.023** |
| | $CO_3$ | 0.037 | -0.036 | -0.164 | -0.022 | **-0.172** |
| | $HCO_3$ | 0.257 | -0.357 | 0.624** | 0.140 | **-0.336** |
| | Cl | -0.120 | 0.170 | 0.058 | -0.255 | **-0.159** |
| | $SO_4$ | -0.159 | 0.132 | 0.180 | -0.194 | **-0.161** |
| | Ca | -0.122 | 0.162 | 0.100 | -0.257 | **-0.183** |
| | Mg | -0.116 | 0.163 | 0.077 | -0.255 | **-0.167** |
| | Na | -0.130 | 0.175 | 0.068 | -0.261 | **-0.166** |
| | K | -0.006 | 0.083 | 0.129 | -0.260 | **-0.192** |
| 15 km buffer | TDS | -0.371 | 0.603** | -0.128 | -0.291 | **-0.167** |
| | EC | -0.371 | 0.603** | -0.128 | -0.291 | **-0.167** |
| | pH | -0.147 | -0.278 | -0.100 | 0.148 | **0.013** |
| | $CO_3$ | -0.206 | -0.211 | -0.150 | -0.038 | **-0.170** |
| | $HCO_3$ | 0.286 | -0.136 | 0.575** | 0.243 | **-0.338** |
| | Cl | -0.358 | 0.582** | -0.132 | -0.284 | **-0.157** |
| | $SO_4$ | -0.323 | 0.502* | -0.051 | -0.214 | **-0.159** |
| | Ca | -0.368 | 0.609** | -0.113 | -0.286 | **-0.180** |
| | Mg | -0.363 | 0.589** | -0.121 | -0.284 | **-0.165** |
| | Na | -0.371 | 0.601** | -0.132 | -0.291 | **-0.164** |
| | K | -0.227 | 0.476* | -0.029 | -0.269 | **-0.190** |

** .Correlation is significant at 0.01 level, *.Correlation is significant at 0.05 level (including Cl, EC, $NO_3$) were related to land use at all three spatial scales, the correlation was stronger at sub-basin compared to total basin and buffer scales. The relationship between urban lands and water quality in this study might be associated with point and non-point pollution sources in urban areas (Sliva and Williams, 2001).

## CONCLUSION

Surface water is one of the most important parameters in the environment and therefore reduction of its quantity and quality is a vital issue. Results of the present study showed that water quality parameters such as $HCO_3$, EC, TDS and Cl could be applied to investigate the relationship between water quality and land use. In other words, there are significant relationships between water parameters and various land use types at different spatial scales. The present study also confirmed sub-basin as the most suitable scale for investigating the relationship between land use and water quality. The results showed reduction in water quality in Zayandeh-Rud basin as a result of reduced vegetation covers and increased urban lands. Due to the proved effect of land use on water quality in Zayandeh-Rud basin in this study, it is necessary to adopt correct and comprehensive programs to control land use change in order to maintain the ecological balance of the region.

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## CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

## LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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