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Assessing land-cover/land-use change and its impacts on surface water quality in the Ziarat Catchment, Golestan Province-Iran

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Abstract: This paper outlines a study aimed to assess the long-term association between land-cover/land-use change and water quality changes occurred in the Ziarat Catchment, upstream of the Ghara-soo River basin, Golestan Province northeast, of Iran. To assess the significance of trends in the time series of water quality variables, non-parametric trend tests (the Mann-Kendall and the seasonal Kendall) or parametric trend tests (linear regression and ANCOVA) were performed after removing variance due to discharge. The water quality and quantity data available for the analysis in this study belong to the observed period from 1974 to 2008 in a river gauge station located at the outlet of the catchment. The analysis revealed that with the exception of pH (no trend) and sulfate (negative trend), all other water quality variables including electrical conductivity, total dissolved solids, hardness, sodium, potassium, calcium, magnesium, chloride, sodium adsorption ratio and bicarbonate demonstrate statistically significant positive trends (P-value<0.05).Using the seasonal Kendall test, the negative trends have been detected for rainfall and mean discharge time series. To determine the likely responsible factor(s) for water quality changes, an investigation has been conducted on land-cover/land-use changes. A series of significant land-cover/land-use change were identified from 1967 to 2010, within five time intervals, referring to satellite images and also aerial photographic interpretation and based on RS and GIS standard techniques. The spatial analysis shows that within four decades about 980 ha of forests in the catchment have been converted to other classes of land cover/landuse (about 67% to croplands and/or rangelands, 8.5% to residential areas, 13% to bare lands, and 11.5 % to roads). The results of this research suggest that land-cover/land-use change is one of the key factors causing water quality changes in the study area. The findings of this research assists policy makers and catchment managers in developing catchment management plans to protect and restore water quality conditions more effectively.

Keywords*:* Water quality; Land-use change; Trend analysis; The Ziarat catchment.

1 INTRODUCTION

Freshwater is a valuable natural resource whose quantity and quality is essential for sustainable development [Vörösmarty et al. 2005]. The quality of water has recently become as important as its quantity because water quality directly affects human and ecological health and the use of water resources.

Surface water bodies are the potential recipients of the contaminations contained in surface runoff from their catchments [Chin, 2006]. Therefore, surface water

quality management is extremely important. Surface water quality monitoring and the analyses of its temporal variations are necessary to allow the detection and understanding of the effects of natural influences and anthropogenic disturbances on surface water quality [Groppo et al., 2008]. It can also be helpful for better management of water resources and controlling current and future pollution of receiving water bodies [Walling and Fang, 2003].
Trend analysis of water quality data is an important environmental diagnosis of a catchment, allowing evaluations of how the water body responds during a period of several years, in qualitative terms, to the increase of anthropogenic interventions [Maasdam and Claassen, 1998; Larsen et al., 1999; Park and Park, 2000; Groppo et al., 2008]. The purpose of trend testing is to determine if the values of a random variable generally increases (or decreases) during an intended time period in statistical terms [Helsel and Hirsch, 2002]. The presence of trends in water chemistry provides an indication of environmental changes and gives insight into contributing factors such as changes in land use and management [Potts et al., 2003; Zare Garizi et al.].

Through remote sensing and statistical analysis, this research investigates the associations between land-use changes and water-quality trends in the Ziarat catchment.

2 MATERIALS AND METHODS

2.1 Study area

The Ziarat River is one of the tributaries of the Ghara-soo River in the Golestan province, Iran. The catchment has an area of about 9700 hectares which lies between latitude of 36°46'56" and 37°37'01" N and longitude of 54°31'12" and 54°24'48" E northeast of Iran (Figure 1). The catchment has an altitude ranging from 670 to 3086 m, a mean slope of 41.5 %. The mean annual precipitation is about 750 mm. The underlying geology is mainly limestone formations, alluvial deposits near the streams and quaternary sedimentary formations and schists, in the lowlands of the study area. Occurrence of debris flow is one of the main attributes of the river system in this catchment. The Ziarat catchment, mainly the lower part, has experienced unprecedented urban growth over the past three decades. This is in particular the case for the village of Ziarat as an important tourist destination in Golestan Province.

2.2 Data

Two types of data were used in this study: water quality data and land use data.
The water quality data set of the Ziarat monitoring station (located at the outlet of the catchment) was obtained from the Golestan Province Regional Water Agency that takes samples of surface water every month and analyzes the samples using standard methods. The selected parameters for the assessment of surface water quality characteristics were river discharge (Q), Electrical Conductivity (EC), Total Dissolved Solids (TDS), pH, Total Hardness (TH), sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), chlorides (Cl^-), sulfate (SO_4^{2-}), and bicarbonates (HCO_3^-). The water quality data available for the analysis in this study belongs to the observation period of 1974 – 2008.
The land use data were generated from aerial photographs (1967) and four Landsat multi-spectral images taken over a span of 22 years (Table 1).

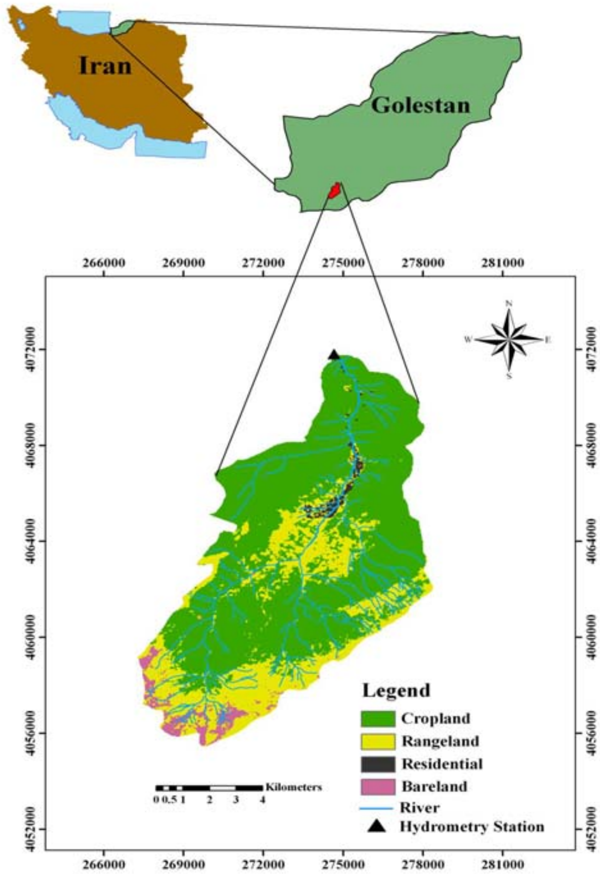

Figure 1: Location of the Ziarat catchment

Table 1: Landsat Data used over the study period

Landsat Number	Sensor	Acquisition Date
Landsat 5	TM	September 5, 1988
Landsat 5	TM	June 23, 1992
Landsat 7	ETM+	July 7, 2002
Landsat 5	TM	June 23, 2010

2.3 Long-term trend analysis of surface water quality

Trend analysis determines whether the measured values of a variable increase or decrease during a time period. Several methods are available for the detection and/or quantification of trends: Graphical methods, regression analysis, Spearman's rho, Kendall's tau, and Sen's T tests. A comprehensive review of statistical approaches used for trend analysis of water quality time series is provided by Esterby [1996].

Methods for trend analysis of water quality data should consider some of the characteristics commonly found in the water quality data. Some of these common characteristics are: non-normality, missing values, outliers, seasonality, autocorrelation, and dependence on other variables such as rainfall or streamflow [Helsel and Hirsch, 2002]. To this end, the underlying conceptual model used in trend analysis of water quality variable Y can be written as

$$Y_t = X_t + S_t + T_t + \alpha_t$$

where Y_t is the water quality observation at time t, X_t is the exogenous variable expected to affect the value of Y, S_t is the seasonal component at time t, T_t is the trend in Y, and α_t is the noise component at time t. In trend analysis one wishes to appropriately account for X_t, S_t and α_t so that T_t can be detected and accurately quantified [Mc Leod et al., 1991].

In this study, long term changes of water quality data were investigated using the trend analysis methodology proposed by Helsel and Hirsch [2002]. General characteristics of the time series of water quality data (normality of the distribution, presence of seasonality and dependency upon streamflow) were first determined through graphical studies, such as normal Quantile-Quantile plots, box and whisker plots, scatter plots, and statistical hypothesis tests. When necessary, log transformation was applied in attempt to correct anomalies and reduce the number of outlier values.

For normally distributed variables, parametric methods (linear regression and analysis of covariance: ANCOVA), and for non-normal variables, nonparametric methods (Mann - Kendall and seasonal Kendall tests) were applied to detect long term trends. For those variables which were dependent upon flow, the effects of discharge were eliminated (flow-adjustment) using ANCOVA and the LOESS method accordingly. Seasonal variability was also considered in the analysis using the seasonal Kendall and ANCOVA for non-normal and normal variables, respectively.

2.4 Long-term land-use change

To investigate the likely impact of land-use changes on water quality trends, land-use changes during the study period were examined.
Remote sensing data were used to determine the land-use change between the years of 1967, 1988, 1992, 2002, and 2010. The aerial photographs of 1967 were scanned, geo-referenced and visually interpreted to create land use map for the year 1967. Landsat images of 1988, 1992, 2002, and 2010 imported to Clark lab's GIS software IDRISI 15.0, geo-registered, and projected into the Universal Transverse Mercator (UTM) coordinating system. All non-thermal bands of the images were used to create spectral signatures for classification. Five land use classes, including forest, cropland-rangeland, residential areas, roads, and bare lands were considered, based on field surveys and the land use data generated by other studies. The images were classified using the supervised maximum likelihood classification method [Jensen, 1996]. The accuracy of the classification was verified by randomly generated reference points using a stratified random algorithm [Jensen, 1996]. Field surveys, the historical LULC data, and 1:25,000 topographic maps were used to provide reference information for both the classification and the accuracy assessment.
Finally the land use maps for different dates were super-imposed to detect changes in land use over a period of time.

3 RESULTS

Normality analysis of the water quality data series by Q-Q plots and Shapiro–Wilk test revealed that Mg^{2+}, Ca^{2+}, HCO_3^-, hardness, and pH are normally distributed and Cl, TDS, K^+, Na^+, SAR, and EC have non-normal distribution. After log-transformation, Cl^- and TDS conformed to normal distribution but other variables remained non-normal.
To determine whether or not a given water quality variable is dependent upon flow; the scatter plot of the variable against discharge was plotted. Figure 2 displays scatter plots for some of the water quality variables.

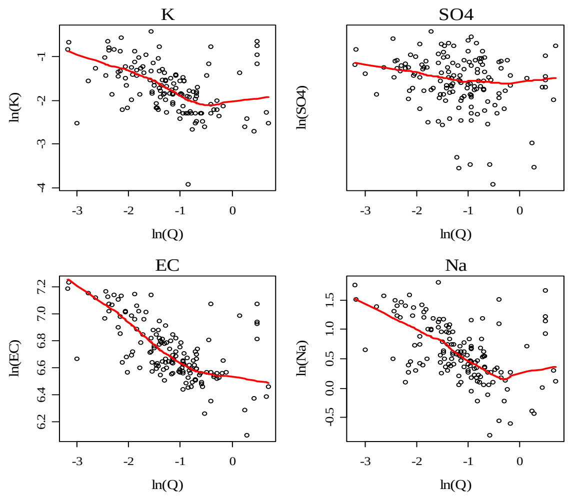

Figure 2: Scatter plots of Ln-transformed water quality variables against Ln-transformed flows for the Ziarat River

Box and whisker plots, showing seasonal trends of selected water quality variables are given in Figure 3.

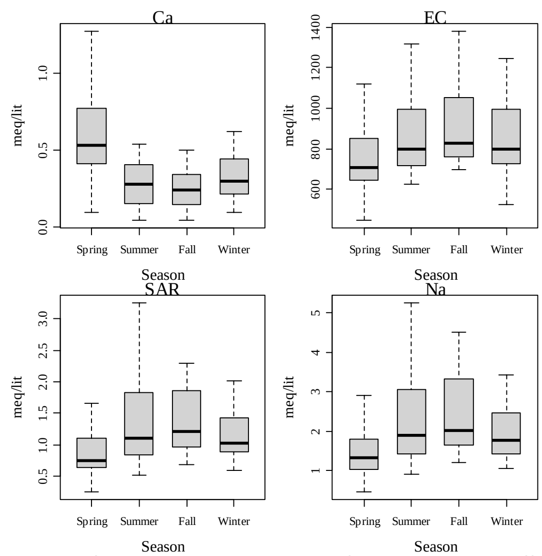

Figure 3: Box plots of water quality variables of Ziarat River in different seasons

Trend analysis results of the water quality variables using parametric and non-parametric methods are presented in Tables 2 and 3, respectively.

Table 2. Results of trend analysis using parametric methods

Water quality variable	Type of test	Coefficient	p-value	Trend
Mg^{2+}	ANCOVA	4.45	0.00	Increasing
HCO_3^-	ANCOVA	18.29	0.00	Increasing
pH	linear regression	1.85	0.07	No trend
Ca^{2+}	linear regression	14.30	0.00	Increasing
Cl^-	ANCOVA	11.64	0.00	Increasing
TDS	ANCOVA	2.19	0.03	Increasing
Hardness	ANCOVA	8.68	0.00	Increasing

Table 3. Results of trend analysis using non-parametric methods

Water quality variable	Type of test	Coefficient	p-value	Trend
Na^+	Mann-Kendall	0.09	0.00	Increasing
K^+	Seasonal Kendall	0.18	0.00	Increasing
SO_4^{2-}	Mann-Kendall	-0.05	0.17	Decreasing
EC	Seasonal Kendall	0.19	0.00	Increasing
SAR	Mann-Kendall	0.08	0.02	Increasing

The results showed that, of the 12 water quality variables, 10 variables demonstrated statistically significant increasing trend, one variable showed no significant trend, and only one variable exhibited a decreasing trend.

The results of our study on the land-use changes in the Ziarat catchment during the period of 1967-2010, are represented in Table 4. The results demonstrate that, during the 43 year period, the area of forests decreased by 981.7 hectares, while the area of cropland-rangelands increased by 657.18 hectares, as well as the area of residential areas which increased by 84.28 hectares.

Table 4. Areas of land use classes in different years for the Ziarat catchment

	1967		1988		1992		2002		2010	
land use classes	Area (ha)	Percent (%)	Area (ha)	Percent (%)	Area (ha)	Percent (%)	Area (ha)	Percent (%)	Area (ha)	Percent (%)
Forest	7750.3	79.9	7303.6	75.3	7291.0	75.2	6890.7	71.1	6768.6	69.8
Cropland-Rangeland	1743.5	18.0	2159.9	22.3	2075.0	21.4	2424.3	25	2400.7	24.8
Residential	13.2	0.14	44.2	0. 4	46.9	0.48	68.3	0.7	97.4	1
Barren	170.7	1.8	146.7	1.5	231.5	2.4	221.7	2.3	297.7	3.1
Road	20.5	0.21	43.8	0.45	53.6	0.55	92.7	0.96	133.7	1.4

The agreement between increasing trends of developed areas (cropland-rangeland, residential, roads), and increasing trends of most of the water quality variables reveals that land-use change has been one of the most important factors influencing the river water quality.

4 DISCUSSION

The analysis of water quality data reveals the importance of anthropogenic activities in combination with rock-soil-water interaction in the chemistry of the Ziarat River. Based on field observations and measurements, increasing trends of most of the variables can be most likely attributed to factors such as land-use change, soil erosion happened particularly on croplands, road construction without technical considerations, high erosion potential for some geologic formation, extensive occurrence of landslides particularly along the drainage network, wastewater generated from domestic activities, and effluents of organic wastes of animal origin into the river.

The catchment of the Ziarat River supplies water for the catchment inhabitants and also meets about 20-30% of water demands of Gorgan (the city in downstream of the catchment with a population of about 300000 persons). Therefore, there is growing concern about the potential effects of extensive land-use change and resultant changes in the hydrological regime and quality of the water resources of the catchment. Despite its significance, our understanding of water quality attributes and its temporal/spatial variations for the Ziarat River is limited.

Although the chemical fertilizers and pesticides effects have not been dealt within this study, plowing the steep slopes for dry farming throughout the catchment and application of chemical fertilizers and pesticides on these farms, and also construction of access roads can cause non-point source pollution and flushing of soil salts during rainy seasons, when the soil surface is rarely covered with vegetation or plant residues.

In the middle parts of the catchment, the existence of shale and marl layers has increased the potential risk of debris flows and landslides occurrence [Mousavi, 2012]. Fast increasing trend of buildings and roads construction on hill slopes and also replacement of deep-rooted trees with short-rooted crops has a negative impact on the above mentioned hazards that, in turn, leads to water quality changes in the Ziarat River.

Variation of TH and $HCO3^-$ is possibly due to dissolution of minerals such as calcite through $HCO3^-$ weathering process. In contrast, EC, Cl^- parameters are reactive components that are partially of anthropogenic origin [Khazheeva et al., 2007]. EC qualitatively reflects the status of inorganic contamination and is a measure of TDS in waters [McCutcheon et al., 1993]. In the Ziarat River, EC values follow an inverse pattern with the river discharge, which shows the dilution effect. High EC values are observed as a direct result of decreased rainfall /discharge and increased agricultural land-use and built-up intensity in the river catchment.

5 CONCLUSIONS

The results of this study show that, in-stream water quality trends of the Ziarat catchment has been likely related to land-use change. Although the study does not provide direct quantification of causality between discovered land-use change and water quality trends in the study area, but extensive land-use changes and the increasing trends of most of water quality variables supports to some extent the above hypothesis. There are a number of other natural and human-induced driving factors involved that adds to the complexity of the river system and its attributes. The uncertainty in this context needs to be addressed through further investigations.

To avoid a serious threat to the health of stream ecosystem and local communities in the Ziarat catchment, pollutants particularly agricultural runoff and human wastes should be controlled effectively through implementing proper management policies and actions. It seems appropriate to apply the best management practices over the entire catchment to curb some of the environmental issues raised above. Of the best ways to mitigate the downgrading trend of river water quality, establishment of riparian vegetation as well as on-site remediation is recommended.

REFERENCES

Chin D.A. 2006. Water quality engineering in natural systems. John Wiley & Sons, Inc. 610 pp.

Esterby S.R. 1996. Review of methods for the detection and estimation of trends with emphasis on water quality applications. *Hydrological Processes* 10: 127 – 149.

Groppo J.D., Moraes J.M.D., Beduschi C.E., Genovez A.M. and Martinelli L.A. 2008. Trend analysis of water quality in some rivers with different degrees of development within the Saopaulo State, Brazil. *River. Res. Applic*. 24: 1056–1067.

Helsel D.R. and Hirsch R.M. 2002. Statistical Methods in Water Resources, Chapter A3, Techniques of Water-Resources Investigations of the United States Geological Survey. Book 4, Hydrologic analysis and interpretation. 510 pp.

Jensen J.R. 1996. Introductory Digital Image Processing: A Remote Sensing Perspective, Prentice Hall, New Jersey, USA.

Khazheeva Z.I., Tulokhonov A.K., Dashibalova L.T. 2007. Seasonal and spatial dynamics of TDS and major ions in the Selenga River. *Water Res.*, 34 (4), 444–449

McCutcheon, S.C., Martin J., Barnwel T.O. 1993. Water quality. Maidment, D.R. (Eds.), Handbook of Hydrology. McGraw-Hill Inc., New York.

McLeod A.I., Hipel K.W. and Bodo B.A. 1991. Trend analysis methodology for water quality time series. *Environmetrics* 2(2):169–200.

Mousavi S.M. 2012. Application of Rosgen classification for the Ziarat watershed, Gorgan, *Journal of American Science* 8(4): 184-189

Potts J.M., Hirst D., Miller J.D., Edwards A.C. and Elston D.A. 2003. Comparison of trends in stream water quality. *Hydrol. Process*. 17, 2449 – 2462.

Vörösmarty C.J., Lévêque C., Revenga C., Bros R., Caudill C., Chilton J., Douglas E.M., Meybeck M., Prager D., Balvanera P., Barker S., Maas M., Nilsson C., Oki T. and Reidy C.A. 2005. Fresh Water in Millennium Assessment. Chapter 7. pp 165- 207. http://www.millenniumassessment.org/en/Condition.aspx

Walling D.E., Fang D., 2003. Recent trends in the suspended sediment loads of the world's rivers. *Global and Planetary Change* **39:**111–126.

Zare Garizi A., Sheikh V. and Sadoddin A. 2011. Assessment of seasonal variations of chemical characteristics in surface water using multivariate statistical methods. *International Journal of Environmental Science and Technology* 8(3): 581-592.