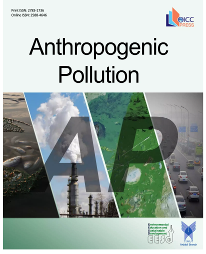


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# Investigation and determination of land use effects on surface water quality in semi-arid areas: Case study on Qarasu River in Iran

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**Abstract:**
Increasing population growth and civilization have caused great impacts on water quality. Among these, changes and excessive exploitation of land use have led to changes in the surface water quality to provide human needs. Therefore, the present study investigated the effects of land use on water quality using a spatial-statistical approach. To this end, the water quality data of 22 water quality-sampling stations were applied in the Qarasu watershed in Ardabil. Then, spatial analysis was conducted, including land use classification maps, watershed mapping and overlaying maps using GIS. Finally, correlation and multiple linear regression analysis were used to determine the relationship between water quality and land use variables. Pearson's correlation coefficient showed proper percentages of vegetation cover, agricultural lands, woodlands, residential users, barren land and forest as well as weak pastureland have significant correlation with water quality variables. Multiple linear regression analysis with stepwise approach also indicated that of dependent parameters as water quality variables, the parameters of pH, Cl, Ca, Mg, Na and SAR are associated with land use as independent parameters including irrigated agriculture, first-grade pasture, third-grade pasture, woodlands, moorland, forest and residential users. Furthermore, validation of the model based on two models of the survey of predicted and actual values as well as root-mean-square error (RMSE) demonstrated good accuracy of the resulting model.

**Keywords:** Water resources management; Land use; Water quality; Correlation

## 1. Introduction

Human disturbances in watersheds besides increased water harvesting and changes in river ecosystems lead to adverse effects on the stability of freshwater resources around the world (Salajegheh et al. 2022; Gleick et al. 2007). Changes in the landscape caused by human activities can have undesirable impacts on water quality and quantity (Ding et al. 2015). Expansion and enhancement of the intensity of land use practices such as agriculture, forestry, urban growth and industrial development have harmful effects (various pollutions) on the health of the river flow (Moghaddam et al. 2021; Fataei and Shiralipoor 2011). The source of these pollutants can be as point or non-point in nature and occur in a large-scale spatio-temporal pattern (Seitz et al. 2011).
Atkinson et al. in 2009 using spatial analysis and multiple regression (stepwise) have developed a prediction model for surfactants, water quality and aquatic habitats based on the characteristics of the Trinity River sub-watershed basin in Texas (Atkinson et al. 2009).
Amiri and Nakanh in 2009 investigated the correlation between the landscape patterns and water quality in Chugoku, Japan (Amiri and Nakane 2009). Yang and Jin in 2010 examined the impact of watershed characteristics on nitrite and nitrate concentrations in Cedar River watershed (at Iowa Minnesota) (Yang and Jin 2010). Verma and colleagues in 2010 conducted a study on the relationship between land use/cover and surface water quality in Damodar basin (Verma et al. 2010).
Nasir and colleagues (2011) determined the sources affecting water quality using five-year information of Klang River (Nasir et al. 2011). Miller and colleagues in 2011 studied the effect of forest, agricultural and urban covers on water

**Table 1.** Values of physicochemical parameters measured in the studied stations in the watershed of Qarasu River in Ardabil province.

| Catio Mg/l | Anions Mg/l | SAR - | TH Mg/l | Na Mg/l | Mg Mg/l | Ca Mg/l | $So_4$ Mg/l | Cl Mg/l | $Hco_3$ Mg/l | pH - | Ec $\mu$mho/cm | TDS Mg/l | Station |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11.86286 | 12.07143 | 3.137571 | 317.1429 | 5.52 | 2.414286 | 3.928571 | 3.885714 | 4.071429 | 4.114286 | 7.675714 | 1268.857 | 887.7143 | 19-873 |
| 5.15 | 5.275 | 1.26575 | 175 | 1.65 | 1.35 | 2.15 | 0.925 | 3.175 | 1.175 | 7.8925 | 520.5 | 364.25 | 19-150 |
| 4.882 | 5.02 | 0.7062 | 193.5 | 1.012 | 1.55 | 2.32 | 0.61 | 3.09 | 1.32 | 7.712 | 495.5 | 346.5 | 19-144 |
| 1.6275 | 1.708333 | 0.45775 | 62.5 | 0.3775 | 0.391667 | 0.858333 | 0.35 | 1.108333 | 0.25 | 8.010833 | 170.8333 | 119.1667 | 19-149 |
| 4.47 | 4.657143 | 0.507286 | 188.5714 | 0.698571 | 1.242857 | 2.528571 | 0.771429 | 3.157143 | 0.728571 | 7.855714 | 457.7143 | 320.2857 | 19-151 |
| 15.17636 | 16.34545 | 4.932727 | 328.1818 | 8.612727 | 2.963636 | 3.6 | 4.854545 | 4.963636 | 6.527273 | 7.776364 | 1530.545 | 1071.182 | 19-053 |
| 13.19111 | 13.45556 | 4.052667 | 336.1111 | 6.468889 | 2.522222 | 4.2 | 3.444444 | 4.588889 | 5.422222 | 7.592222 | 1331.444 | 931.5556 | 19-065 |
| 16.05818 | 16.18182 | 3.450455 | 444.0909 | 7.176364 | 3.454545 | 5.427273 | 4.909091 | 4.081818 | 7.190909 | 7.409091 | 1610.182 | 1126.909 | 19-101 |
| 3.075 | 3.15 | 0.8235 | 111.25 | 0.85 | 0.65 | 1.575 | 0.375 | 2.375 | 0.4 | 7.6775 | 314.5 | 219.75 | 19-095 |
| 5.375 | 5.883333 | 1.633167 | 160.8333 | 2.158333 | 1.25 | 1.966667 | 2.033333 | 2.833333 | 1.016667 | 7.803333 | 541.1667 | 378.1667 | 19-097 |
| 7.05125 | 7.2 | 0.47825 | 310.625 | 0.83875 | 2.5375 | 3.675 | 1.0125 | 3.0875 | 3.1 | 7.8325 | 718 | 502.125 | 19-022 |
| 4.08 | 4.22 | 1.277 | 132 | 1.44 | 1.08 | 1.56 | 1.1 | 2.5 | 0.62 | 8.148 | 418.2 | 292.2 | 19-981 |
| 36.1 | 36.1 | 3.536 | 1195 | 12.2 | 11.75 | 12.15 | 12.2 | 5.4 | 18.5 | 7.875 | 3610 | 2527 | 19-059 |
| 13.53333 | 13.76667 | 5.248 | 256.6667 | 8.4 | 2.066667 | 3.066667 | 5.166667 | 3.633333 | 4.966667 | 8.06 | 1366.333 | 956 | 19-055 |
| 1.495 | 1.561667 | 0.42525 | 58.33333 | 0.328333 | 0.4 | 0.766667 | 0.45 | 0.825 | 0.286667 | 8.019167 | 229.8333 | 111.75 | 19-049 |
| 5.396923 | 5.646154 | 1.041769 | 199.6154 | 1.404615 | 1.6 | 2.392308 | 1.084615 | 3.769231 | 0.792308 | 7.876154 | 548.1538 | 383.4615 | 19-099 |
| 1.356667 | 1.466667 | 0.450333 | 53.33333 | 0.29 | 0.433333 | 0.633333 | 0.25 | 0.983333 | 0.233333 | 7.645 | 143 | 99.66667 | 19-152 |
| 6.994167 | 7.125 | 1.559 | 232.0833 | 2.3525 | 1.716667 | 2.925 | 1.266667 | 4.55 | 1.308333 | 7.725 | 705.3333 | 493.25 | 19-026 |
| 3.896364 | 3.972727 | 0.877545 | 142.7273 | 1.041818 | 1.045455 | 1.809091 | 0.536364 | 2.709091 | 0.727273 | 7.598182 | 397.2727 | 277.7273 | 19-051 |
| 3.764545 | 3.954545 | 1.045455 | 130.4545 | 1.155455 | 0.836364 | 1.772727 | 0.509091 | 3.190909 | 0.254545 | 7.762727 | 387.2727 | 270.7273 | 19-093 |
| 4.596364 | 4.754545 | 0.683364 | 184.5455 | 0.905455 | 1.6 | 2.090909 | 0.8 | 2.063636 | 1.890909 | 7.575455 | 467.0909 | 326.4545 | 19-148 |
| 7.831667 | 8.75 | 3.072 | 187.0833 | 4.09 | 1.325 | 2.416667 | 3.316667 | 3.708333 | 1.725 | 7.761667 | 848.5833 | 593.5833 | 19-910 |

**Table 2.** Output of Pearson model between land use relationships and water quality.

| | IR | DF | IF1 | IF2 | IF3 | Fr | Th | Ci | Wa | Na | Ba |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TDS | .068 | .132 | .148 | .249 | .107 | .081 | .202 | .095 | .377 | .421 | .107 |
| Ec | .054 | .136 | .207 | .255 | .104 | .068 | .203 | .096 | .362 | .431 | .104 |
| pH | .182 | .477 | .183 | .142 | .013 | .153 | .010 | .162 | .460 | .211 | .013 |
| $Hco_3$ | .084 | .117 | .300 | .456 | .087 | .141 | .199 | .106 | .306 | .348 | .087 |
| $So_4$ | .089 | .140 | .160 | .362 | .103 | .208 | .247 | .064 | .287 | .337 | .103 |
| Cl | .110 | .119 | .116 | .204 | .232 | .041 | .334 | .202 | .331 | .420 | .232 |
| Ca | .074 | .211 | .286 | .203 | .097 | .053 | .165 | .213 | .364 | .493 | .097 |
| Mg | .054 | .080 | .291 | .352 | .130 | .088 | .261 | .225 | .239 | .469 | .130 |
| Na | .075 | .139 | .033 | .175 | .104 | .156 | .185 | .048 | .477 | .434 | .104 |
| TH | .064 | .145 | .284 | .257 | .111 | .064 | .200 | .219 | .314 | .484 | .111 |
| SAR | .106 | .166 | .011 | .155 | .127 | .250 | .204 | .033 | .453 | .415 | .127 |
| Sum.A | .067 | .120 | .140 | .263 | .110 | .091 | .207 | .097 | .371 | .414 | .110 |
| Sum.K | .068 | .131 | .144 | .251 | .105 | .083 | .198 | .092 | .383 | .441 | .105 |

quality in the river basin of Kaskaskia, Illinois, America (Zefrehei et al. 2019; Miller et al. 2011). Uriarte et al. in 2011 using water quality data between 1977 and 2000, precipitation and land use maps investigated the effect of land use on river water quality in four spatial scales of watersheds, sub-watersheds, 60 m buffer along watersheds and 60 m buffer along sub-watersheds in Puerto Rico (Uriarte et al. 2011). Curry and colleagues in 2011 examined the relationship between land use disturbance indices and water quality changes in the Byskayn Bay watershed in Florida (Carey et al. 2011). Zhou and colleagues in 2012 studied the effects of landscape pattern on water quality in Dongjiang River watershed, China (Zhou et al. 2012).

This study was conducted to examine the relationship between river water quality and land use/cover in Qarasu watershed in Ardabil province, northwestern Iran.

## 2. Materials and methods

In terms of country division, Qarasu watershed is located in the center of Ardabil province in northwest of Iran. Baliqlu River that originates from rain, snowmelt and springs on the slopes of Sabalan Mountain after crossing through the middle of Ardabil city in Anzob village, near the Samian village is connected to the Qarasu River that originates from the western slopes of Talesh mountains and after crossing through Ardebil plain flows into northwestern direction and is flowing down to Aras River within Aslanduz city. The Landsat 8 satellite images of 2014 were used in order to prepare a land use map. For this purpose, after atmospheric and geometric correcting carried out on image, existing land use in the region was extracted based on supervised classification.

Statistical correlation and regression analyses determined the relationship among variables in SPSS 16.0 software. In this section, since the condition of using linear regression is normality of dependent variables related to water quality, so firstly all data used in the study were tested for normal distribution through Shapiro-Wilk test. The results showed that the variables did not match with normal distribution. The outlier data were identified and removed and were tested for normality again. Since the data are quantitative, Pearson's

**Table 3.** Pearson's model output for relationship between land use and water quality.

| | IR | DF | IF1 | IF2 | IF3 | Fr | Th | Ci | Wa | Na | Ba |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TDS | .068 | .132 | .148 | .249 | .107 | .081 | .202 | .095 | .377 | .421 | .107 |
| Ec | .054 | .136 | .207 | .255 | .104 | .068 | .203 | .096 | .362 | .431 | .104 |
| pH | .182 | .477 | .183 | .142 | .013 | .153 | .010 | .162 | .460 | .211 | .013 |
| $Hco_3$ | .084 | .117 | .300 | .456 | .087 | .141 | .199 | .106 | .306 | .348 | .087 |
| $So_4$ | .089 | .140 | .160 | .362 | .103 | .208 | .247 | .064 | .287 | .337 | .103 |
| Cl | .110 | .119 | .116 | .204 | .232 | .041 | .334 | .202 | .331 | .420 | .232 |
| Ca | .074 | .211 | .286 | .203 | .097 | .053 | .165 | .213 | .364 | .493 | .097 |
| Mg | .054 | .080 | .291 | .352 | .130 | .088 | .261 | .225 | .239 | .469 | .130 |
| Na | .075 | .139 | .033 | .175 | .104 | .156 | .185 | .048 | .477 | .434 | .104 |
| Sakhti-k | .064 | .145 | .284 | .257 | .111 | .064 | .200 | .219 | .314 | .484 | .111 |
| SAR | .106 | .166 | .011 | .155 | .127 | .250 | .204 | .033 | .453 | .415 | .127 |
| Sum.A | .067 | .120 | .140 | .263 | .110 | .091 | .207 | .097 | .371 | .414 | .110 |
| Sum.K | .068 | .131 | .144 | .251 | .105 | .083 | .198 | .092 | .383 | .441 | .105 |

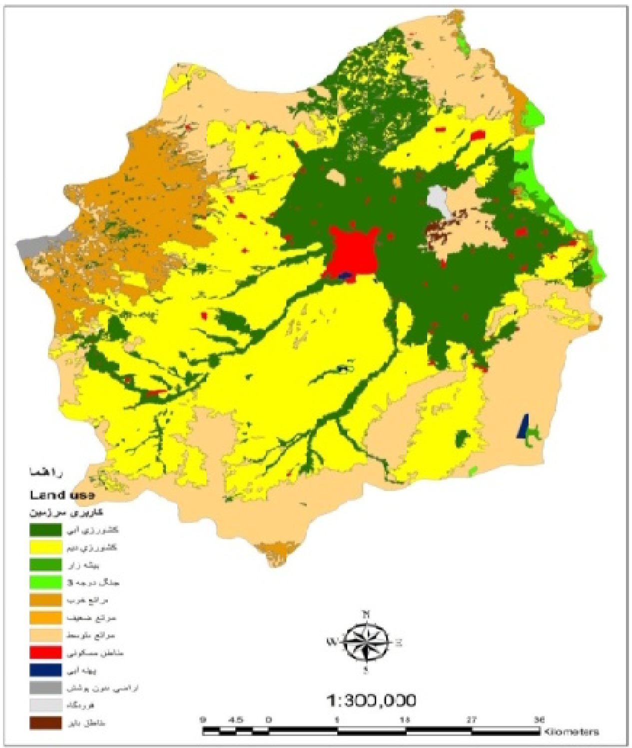


**Figure 1.** Land use/cover map of study Qarasu watershed in Ardebil province.

correlation test was used to analyze the relationship between water quality variables and predictor variables of land use. Finally, multiple linear regression analysis with stepwise approach was employed to examine the relationship between water quality and land use.

## 3. Results

Land use/cover map was prepared in 11 categories including agriculture, dry land areas, good pastureland, average pastureland, poor pastureland, third-grade forest, woodlands, urban areas, water bodies, land without coverage and barren land. Land use/cover information is marked in the study area of Qarasu River watershed in Figure 1. The classes of rain-fed agriculture, average rangeland and irrigated agriculture with 39.12, 25.86 and 22 coverage percentage respectively consist of dominant land cover.

### 3.1 Water quality data

Data on river water quality collected from the sampling stations located on rivers are usually presented as tables with several water quality measurement parameters along with name, profile and geographic coordinates of sampling stations. The water quality data of Ardabil Regional Water Company were used in this study. The sampling stations located on Qarasu River watershed have been listed in Table 1. The water quality variables measured in these stations include temperature, total hardness, sum of anions and cations, TDS, EC, pH, $HCo_3$, CL, $So_4$, Ca, Mg, SAR, Na.

### 3.2 Correlation

The correlation analysis was used to evaluate the relationship between two variables. There are several methods for studying the correlation; appropriate coefficient can be chosen based on the type of analyzed data. Because of quantitative nature of variables in this stud, Pearson's correlation coefficient can be used for variables with normal distribution. After logarithmic data conversion, Shapiro-Wilk test results showed this condition in the data. Therefore, Pearson's correlation coefficient was used for the data, which the results are presented in the following.

Pearson's correlation test results at the significance level of 0.05 between land use variables and river water quality showed that:

TDS variable were positively correlated with the variables of EC, $HCo_3$, $So_4$, Ca, Mg, Na, total hardness, SAR and sum of anions and cations. EC variable had positive correlation with the variables of TDS, $HCo_3$, $So_4$, Cl, Ca, Mg, Na, total hardness, SAR and sum of anions and cations. pH variable has a negative correlation with the variables of three-grade pastureland, woodlands and barren land. $HCo_3$ variable were positively correlated with the variables of TDS, EC, $So_4$, Cl, Ca, Mg, Na, total hardness, SAR and sum of anions and cations. $So_4$ variable showed positive relationship with the variables of TDS, EC, $Hco_3$, Cl, Ca, Mg, Na, total hardness, SAR and sum of anions and cations. Cl variable had positive association with the variables of TDS, EC, $Hco_3$, $So_4$, Mg, Na, total hardness, SAR and sum of anions and cations. Ca variable are positively correlated with the variables of TDS, EC, $Hco_3$, $So_4$, Cl, Mg, Na, total hardness, SAR and sum of anions and cations as well as is negatively correlated with third-grade forest land. Mg variable indicated positive correlation with the variables of TDS, EC, $Hco_3$, $So_4$, Cl, Na, total hardness, SAR and sum of anions and cations. Na variable has positive relationship with the variables of TDS, EC, $Hco_3$, $So_4$, Cl, Mg, Ca, total hardness, SAR and sum of anions and cations as well as is negatively correlated with residential use and first-grade pastureland. Total hardness variable were positively correlated with the variables of TDS, EC, $Hco_3$, $So_4$, Cl, Ca, Mg, Na, SAR and sum of anions and cations. SAR variable showed positive association with the variables of TDS, EC, $Hco_3$, $So_4$, Cl, Ca, Mg, Na, total hardness, sum of anions and cations as well as is negatively correlated with residential use and first-grade pastureland. Sum of anions variable were positively correlated with the variables of TDS, EC, $Hco_3$, $So_4$, Cl, Ca, Mg, Na, total hardness, SAR and sum of cations. Sum of cations variable had positive correlation with the variables of TDS, EC, $Hco_3$, $So_4$, Cl, Ca, Mg, Na, total hardness, SAR and sum of anion.

### 3.3 The relationship between land use and water quality

In the current study, the stepwise approach of multiple linear regressions was used for modeling the relationship between land use and river water quality. Table 3 shows the Pearson's model implemented to study the relationship between land use and water quality.

According to ANOVA regression equations and correlation shown in Table 3, it is revealed that:

In the predictive model of pH, among independent variables, variables of third-grade pastureland, woodlands and barren land have been significant. The coefficient of determination ($R = 0.719$) showed that the mentioned variables predict 71% of pH concentration changes in sub-watersheds of study area. To check the validity of model, the Shapiro-Wilk test was used to examine the normality of residuals; the results indicated that residuals were normal in 95% confidence interval.

$$H = 0.002\mathrm{IF3} + (-0.549)\mathrm{Th} + 0.517\mathrm{Ba} + 7.842$$

In the predictive model of Cl, among independent variables, forest variable has been significant. The coefficient of determination ($R = 0.718$) indicated that the mentioned variable can predict 71% of cl concentration changes in sub-watersheds of study area. To confirm the validity of model, the Shapiro-Wilk test was used to examine the normality of residuals; the results indicated that residuals were normal in 95% confidence interval.

$$\mathrm{Cl} = -0.079\mathrm{Fr} + 4.799$$

In the predictive model of Ca, among independent variables, the forest variable has been significant. The coefficient of determination ($R = 0.631$) demonstrated that the mentioned variable can predict 63% of Ca concentration changes in sub-watersheds of study area. To approve the validity of model, the Shapiro-Wilk test was used to examine the normality of residuals; the results indicated that residuals were normal in 95% confidence interval.

$$\mathrm{Ca} = -0.068\mathrm{Fr} + 1.916$$

In the predictive model of Mg, among independent variables, irrigated agriculture variable has been significant. The coefficient of determination ($R = 0.627$) revealed that the mentioned variable can predict 62% of Mg concentration changes in sub-watersheds of study area. To check the validity of model, the Shapiro-Wilk test was used to examine the normality of residuals; the results indicated that residuals were normal in 95% confidence interval.

$$\mathrm{Mg} = -0.02\mathrm{IR} + 1.089$$

In the predictive model of Na, among independent variables, first-grade pastureland and residential use variables have been significant. The coefficient of determination ($R = 0.718$) showed that the mentioned variables predict 71% of pH concentration changes in sub-watersheds of study area. To prove the validity of model, the Shapiro-Wilk test was used to examine the normality of residuals; the results indicated that residuals were normal in 95% confidence interval.

$$\mathrm{Na} = -0.058\mathrm{IF1} + 0.124\mathrm{Ci} + 2.915$$

In the predictive model of SAR, among independent variables, first-grade pastureland and residential use variables have been significant. The coefficient of determination ($R = 0.741$) found that the mentioned variables predict 74% of SAR concentration changes in sub-watersheds of study area. To determine the validity of model, the Shapiro-Wilk test was used to examine the normality of residuals; the results indicated that residuals were normal in 95% confidence interval.

$$\mathrm{SAR} = -0.052\mathrm{IF1} + 0.092\mathrm{Ci} + 2.294$$

## 4. Discussion

The results of Pearson's correlation test at the significance level of 5% between land use and water quality variables in the Qarasu River watershed demonstrated that, among the 11 categories of land use, there are significant correlations among percentage of variables including good pastural cover, agricultural land, woodland, residential use, barren land, forest and poor pastural cover with water quality variables. More specifically, the variable of good pastural cover percentage has a direct relationship with the average concentration of water quality parameters including Na and SAR; in other words, the values of Na and SAR parameters have elevated with increasing the percentage of good pasture in the region, reducing the values of sodium and sodium adsorption ratio in downstream. The findings of the present study confirms the results of Steele and Peterson's works completed in 2011; they found that the sodium concentration has a direct relationship with the percentage of urban land use (Steele and Aitkenhead-Peterson 2011).

The results showed a direct and negative relationship between agricultural land use and average concentration of water quality factors including Mg in areas with high percentage of agricultural land uses. The percentage of woodlands variable showed direct and reversed relationship with the average concentration of water quality parameters including pH; the woodland use in the study area has acidic pH. The percentage of residential use variable had direct relationship with the average concentration of water quality parameters including Na and SAR; this means that the

values of Na and SARA variables have also enhanced with increasing the percentage of residential use. This can be due to human activities and pollutions and in some cases because of changes in soil hydrological groups in these areas. Zampella and colleagues in 2007 found that the percentage of land use in urban areas is directly related to the changes in the values of Ca, Cl, EC, pH, and Mg (Zampella et al. 2007).
Barren land variable has a direct and positive relationship with an average concentration of water quality parameters including pH; probably no certain activities such as grazing and human activities have led to alkaline pH in these areas due to calcareous combination of river bedrock. The percentage of forestland use variable has a direct subtractive relationship with the average concentration of water quality parameters including Cl and Ca; in other words, the concentrations of mentioned parameters have been reduced in downstream by increasing the percentage of forest cover in the watersheds of study area. The results in this regard are in line with the findings of Li and Zhang in 2008. They have observed the lowest concentration of anions and cations in water in areas with dominant forest cover (Li and Zhang, 2008).

## 5. Conclusion

The results obtained from the present study demonstrated that the values of water quality parameters have changed with increasing the percentage of different land uses in the Qarasu watershed. This means that the river water quality has been largely influenced toward downstream due to increased pollution load within the river and entering multiple sources of contaminants caused by tributaries join and the establishment of various residential, agricultural and industrial land uses in the region and connecting to each other along the river. The values of water quality parameters have been changed in downstream in this area of study region, indicating the effects of land use changes on surface water quality of the Qarasu River.

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