Desalination and Water Treatment
www.deswater.com

doi: 10.5004/dwt.2020.25632

182 (2020) 414–433
April

Assessment of relationship between land use/cover and surface water quality trends within the riparian zone: a case study from Sivas, Turkey

Can Bülent Karakuş

Sivas Cumhuriyet University, Faculty of Architecture-Fine Arts and Design, Urban and Regional Planning Department, Sivas, Turkey, Tel. +90 346 219 10 10 (3364); Fax. +90 346 219 13 10; emails: cbkarakus@gmail.com/bkarakus@cumhuriyet.edu.tr

Received 24 September 2019; Accepted 7 February 2020

ABSTRACT

In this study; the effects of land use/land cover (LULC) changes, soil type and slope characteristics on surface water quality trends were evaluated for rainy and dry periods based on the riverside boundary zone concept. The Mann–Kendall test demonstrated the degree and importance of tendencies in all water quality parameters for each riparian area between 2008–2015 and 1999–2015. The LULC changes (between 1999 and 2015), soil types and slope characteristics were demonstrated by geographical information system and remote sensing methods. Pearson correlation analysis was applied to determine the relationships between the variables of water quality parameters with LULC, soil types, and slope. Results show that urban and agricultural areas have a negative impact on water quality and vegetation cover areas play an important role in improving water quality. Negative correlations were found between bare areas and all parameters. LULC changes negatively affected water quality, especially in terms of NH_4, NO_3, total dissolved solids and total phosphorus parameters. Alluvial soils and 0%–2% slope group also negatively affected the water quality. This study demonstrated the spatial-temporal distribution of surface water quality across the watershed and emphasized the importance of the riparian area in determining the variables affecting water quality.

Keywords: Land use/cover; Water quality; Riparian zones; Trend analysis

---

1. Introduction

Rivers have an important role in water supply for agriculture and industrial sectors [1]. Dissolved compounds and suspended solids from mining, agriculture, settlement and industrial sectors due to anthropogenic activities significantly reduce the water quality by being evacuated to rivers [2]. The surface waters, which are negatively affected by human activities, are highly susceptible to pollution for the disposal of wastewaters due to their features of easy accessibility [3]. General characteristics of surface waters may be due to the combination of geomorphological features related to climatic and human activities [4]. The quality of surface waters in a region depends highly on the quality and scope of the industrial, agricultural and other human-related activities in the watersheds of the specific area [5,6]. In recent years; there have been significant changes in the quality and quantity of these water resources due to the development of sectoral activities such as agriculture, industry and urban areas around surface water sources [7]. Water pollution occurs as a result of anthropogenic activities involving population growth, urbanization, industrialization, and agricultural practices [8,9]. Dissolved minerals, microscopic algae concentration, insecticide and herbicide content, heavy metals and other pollutants are the factors that directly affect the water quality [10].

Patterns of land use have a significant impact on river water quality in a watershed and water ecosystems [11].

Development activities such as agriculture, urbanization, forestry and industry, often require more intensive land use, and which increases the transport of pollutants directly to the rivers [12]. Improper land use practices such as urbanization, industrial and agricultural activities, which are directly related to population growth and anthropogenic activities, cause water quality problems in a river watershed. While agricultural land use has a very strong impact on river water nutrients (such as nitrogen and phosphorus), industrial and urban land uses are directly related to organic pollution as well as heavy metals and nutrients [13]. Due to the changing land use practices and changing climatic conditions, overloading of organic matter and nutrients to surface water resources is of great importance for water resources managers [14].

From the past to the present, monitoring the water quality of rivers has been an important issue, due to the assessment of long-term changes in surface water quality and monitoring of water quality variables [15]. Sampling networks of river water quality is a major source of data for monitoring the water quality of rivers and determining the local and temporal vision of rivers [16]. In many countries, to determine the status of rivers and manage aquatic ecosystem resources; Chemical parameters such as dissolved oxygen (DO), pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total nitrogen (TN) and total phosphorus (TP) have been considered as the main criteria [17]. Water quality index (WQI) has been popularly applied in recent years to rapidly and easily obtain water quality information with a global vision [18].

The monitoring of water quality plays an important role in the development, implementation, and evaluation of watershed management policies [19]. Whether the water quality management policies that have already been made are adequate and whether these policies require regulation can be ensured by regular monitoring of water quality based on statistical trend analysis of water quality data [20]. Water quality in rivers is constantly changing. However, if there is a trend or change in water quality, it can be realized through trend analysis. The analysis of water quality trends for water resource managers, stakeholders, and regulators to assess the impact of natural and anthropogenic factors on water quality over an extended time period [21]. Evaluation of long-term water quality trends has become a topic of interest in recent years [22]. The directive 2000/60/EC of the European Parliament and of the Council aims at achieving "good status" until 2015 for surface waters and groundwater in all European countries. According to the Water Framework Directive; determination and evaluation of the tendency arising from anthropogenic activity is a fundamental issue. The determination of periods and locations where rising pollution trends occur will allow water management authorities to take adequate measures.

Land use, soil type, and slope characteristics have become an important issues on water quality. Statistical modelings are widely used to determine the effects of land use on water quality. These models use land use matrices, such as percentage of an urban areas in a watershed and impervious surface cover [23]. To identify how watershed landscape characteristics are associated with the spatial and temporal variations of water quality, many researchers used statistical models combined with geographical information system (GIS) and remote sensed imagery data [24].

In recent years, the concept of the riparian area has been widely used to demonstrate the effects of land use changes on water quality. The riparian areas are defined as linear stripes of vegetation directly adjacent to the water bodies [25]. These are important regulators of the flow of organisms between and within organic matter, water, nutrients and landscape elements [26]. Riparian areas maintain many important ecological and biological functions by interacting with hydrologies, soils and biotic communities which have significant social benefits [27]. Continuous and ecologically functioning riverside corridors have been found to positively affect water quality and habitat as well as to improve the aesthetic features of the landscape [28]. The riparian areas have a significant impact on the protection of water quality. The riparian areas affect the water flows and the energy balance in waterbodies by mediating the flow of matter [29]. Replacement of coastal forests with other types of land cover leads to a decrease in water quality and consequently increase of nutrient and sediment loads against flow [30]. Riparian areas are thought to have the most important impact on river quality [31]. Land use in riparian areas has been used to assess the effects of land use on stream water quality [23,32].

Understanding the relationship between the watershed and the pattern of land use in different spatial scales such as all watershed, riparian areas, and monitoring areas, rational planning of riverside land use in the watershed drainage area, effective watershed protection strategies and reducing non-point resource pollution are critical for management practices [33,34].

Many researchers [24,29,35–37] have used GIS, remote sensing (RS) and statistical analysis methods to demonstrate the effects of land use changes and watershed characteristics on surface water quality and its trends. Researchers' results have shown that the forest cover played an important role in the cleanliness of the water, and that the agricultural land and urban areas caused a decrease in water quality.

Water quality is the focus of the research, which determines the spatial-temporal variations in water quality and trends in water quality due to the seasonal and regional characteristics of river hydrology. Therefore, it is necessary to investigate and evaluate the water quality of watersheds better. In addition to the spatial variations of water quality, it is inevitable to investigate temporal variations. The main purpose of this study is; (1) To reveal trends in surface water quality in Kızılırmak river basin, (2) to determine the effects of land use/land cover (LULC) change, soil type and slope characteristics on surface water quality and (3) to reveal the main factors affecting the variation in quality of surface water.

2. Materials and methods

2.1. Study area

Sivas is located in the upper parts of the Kızılırmak river within the central Anatolian region. In Turkey, the province of Sivas is ranked second in terms of surface area (28,488 km^2) after the province of Konya and is located between 36° and

39°E longitudes and 38° and 41°N latitudes. This study was carried out in the vicinity of the city center of Sivas at 319000-339000-4389000-4415000 Universal Transverse Mercator coordinates (Fig. 1). The study area covers the city center of Sivas and its immediate surroundings, it covers an area of approximately 206.13 km^2. The vast majority of the study area consists of conglomerate-sandstone-mudstone, gypsum, and alluvial deposits, which are not suitable for settlement areas [38]. Considering the city center of Sivas; the city is located within the alluvial unit which is unsuitable for basic conditions and settlement conditions. The Kızılırmak river passing through the middle of the study area constitutes the most important surface water source of Sivas city and its immediate vicinity [39].

The average annual flow rate of Kızılırmak river is 39.42 m^3/s. Kızılırmak river bears the distinction of being the longest river emerging inside Turkey and flowing into the sea inside Turkey too. Kızılırmak with a length of 1151 km, evacuates the waters of an 82.181 km^2 area to the Black Sea. The study area consists of Kızılırmak river and its side branches located in the vicinity of Sivas city center and covers the Kızılırmak Watershed located within the boundaries of the Sivas Province. 29.30% of the study area is residential, 4.5% is urban green areas, 24.51% is bare areas, 11.93% is forest areas, 9.97% is industrial areas and 19.69% in agricultural areas [40]. A large part of the study area is located in the 1,250–1,300 m height class, including Sivas city center. A large part of the city center of Sivas and its close surroundings are located in the slope range between 0%–2% and 2%–6% [39]. The most common soil group in the study area is brown soils. Most of the alluvial soils covering 35.6% of the research area are located around the Kızılırmak river and the side branches of the Kızılırmak river (Fig. 2) [41].

2.2. Data and software

Surface water quality in the study area, data of water quality parameters belonging to observation stations, numerical data of LULC changes, soil type, and slope characteristics constitute the basic data of this study (Table 1). There are six water quality observation stations on the river branches within Kızılırmak watershed. Water quality data for stations 1, 2 and 3 cover the time period between 2008–2015; water quality data for stations 4, 5 and 6 cover the time period between 1999–2015 (Table 2). While average values of water quality data for March, April and May were used in the rainy period, average values of water quality data for July, August and September were used in the dry period. Surface water quality data used in the study were obtained from the General Directorate of State Hydraulic Works (Ankara/Turkey). Landsat satellite images with a spatial resolution of 30 m were used to determine the LULC changes in the areas where the stations in the study area are located. 1/25.000 scaled digital topographic and digital soil maps were used in order to reveal soil type and slope characteristics in the study area. In order to determine the effects of LULC change, soil type and slope characteristics on surface water quality, the units of these data were expressed in % (Table 1).

ERDAS 9.1 was used for the analysis of land use changes in the study area; ArcGIS 10.2 was used for obtaining soil

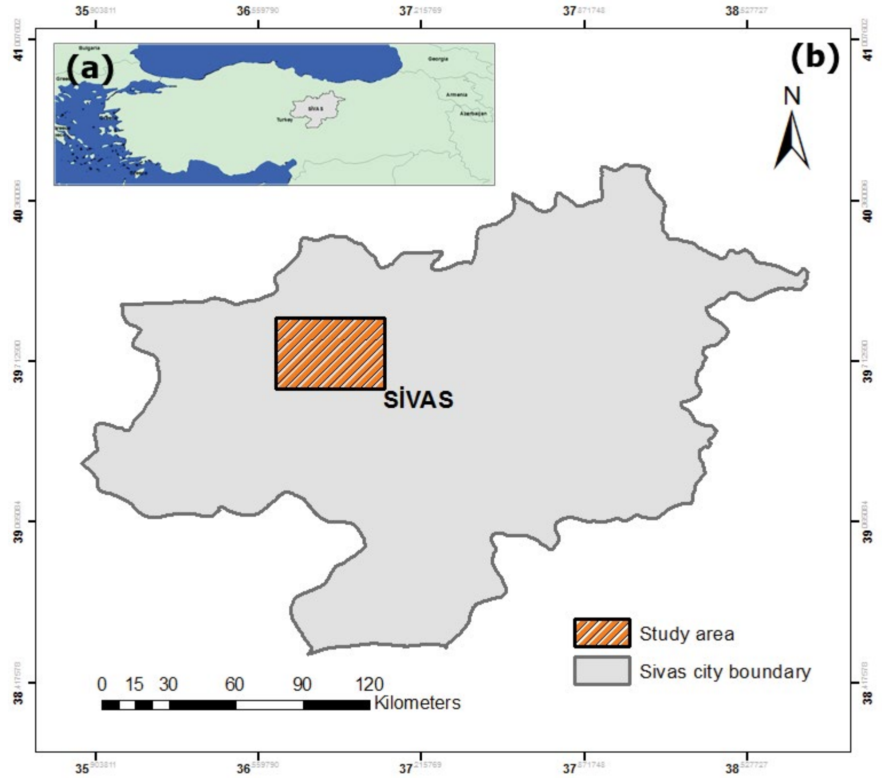

Fig. 1. Location of study area: (a) Sivas Province in Turkey and (b) study area in Sivas Province.

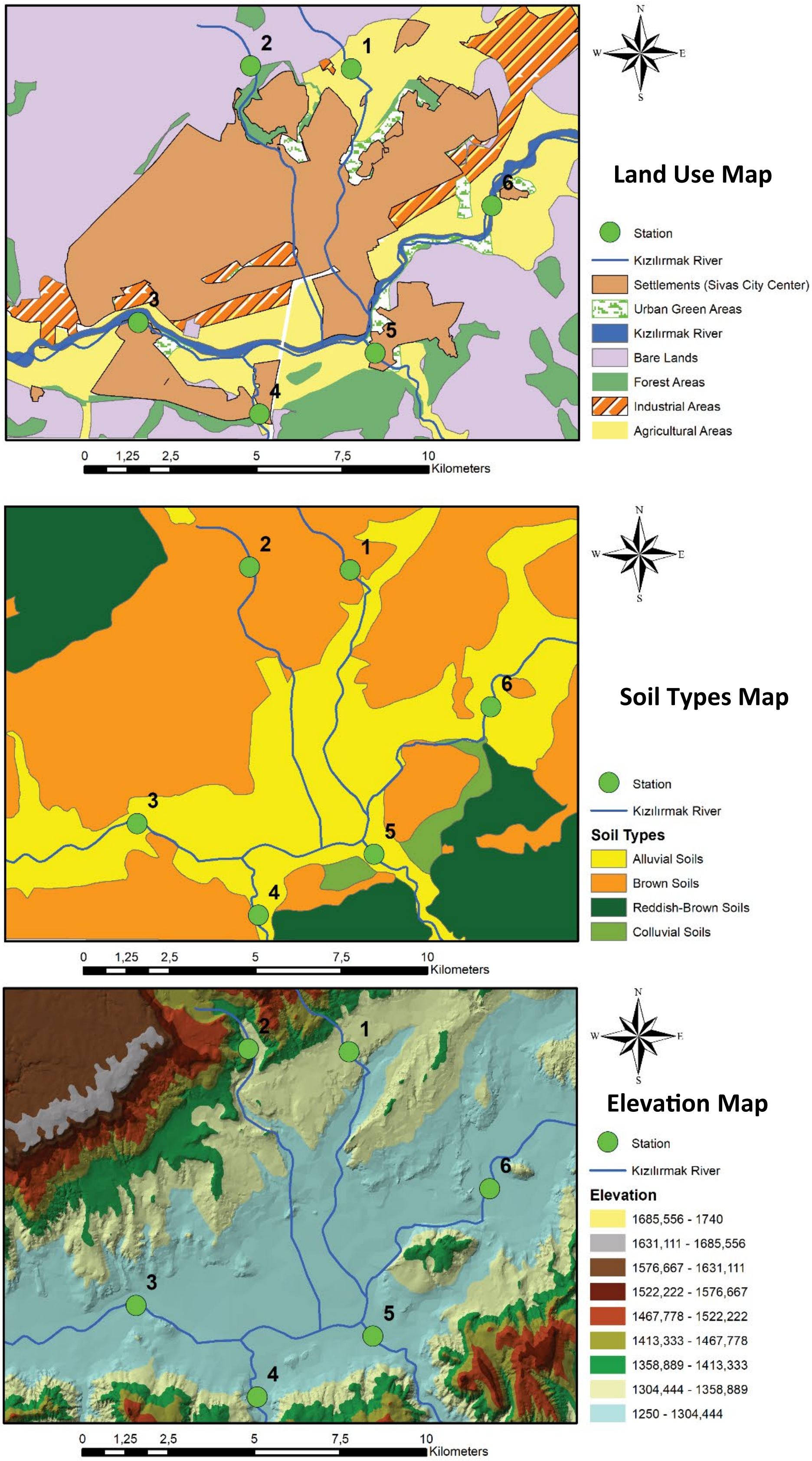

Fig. 2. Land use, topography and soil maps of study area and distribution of the water quality stations.

Table 1
General characteristics of data sets used in the study

Data type	Source	Resolution/scale/period
Water quality BOD, DO, NH_4, NO_3, TDS, TP (mg/L)	Ministry of Environment and Forestry General Directorate of State Hydraulic Works/Turkey	Monthly
Land use change Water, vegetation, urban, bare land, agriculture (%)	U.S. Geological Survey (Landsat satellite images)	30 m
Slope (%)	Ministry of National Defense Map General Command/Turkey	1/25.000
Soil types Alluvial soils; brown soils; reddish-brown soils; colluvial soils (%)	Ministry of Agriculture and Forestry General Directorate of Agricultural Enterprises/Turkey	1/25.000

types and slope maps of the study area; Statistical Package for the Social Sciences Statistics 23 software was used for trend analysis and correlation analysis.

2.3. Studying methodology

The basis of the study method is to reveal the effect of LULC changes belonging to vicinity of Sivas city center and watershed characteristics on water quality trends of Kızılırmak river. In this context, the method applied consists of the stages of: watershed and riparian area formation, determination of LULC changes for different years, identification of soil type and slope characteristics, and determination of trends in water quality. RS methods were used for LULC change analysis and the method of trend analysis was used to determine trends in water quality. Statistical methods were also used to determine the effects of LULC changes and watershed characteristics on water quality (Fig. 3). The WQI values which are used in the analysis within the scope of the study were calculated according to the WQI calculation method [42,43].

All spatial and statistical analysis within the study was conducted according to the river watershed boundaries in the region where all stations were located (Fig. 4).

2.4. Determination of the river watershed boundaries and riparian zones

ArcHydro software, a hydrological toolset of ArcGIS 10.2 software, was used to determine the river watershed boundaries in the Kızılırmak watershed in the study area. The Food and Agriculture Organization of the United Nations recommends creating a buffer zone of 30 m from the riverside line in order to preserve the water quality of the riverside region [29]. In this study, a 30 m buffer zone was formed along with the river network. Based on this buffer zone created, the river watershed boundaries were determined using ArcHydro software and digital elevation model (DEM) (Fig. 4). The DEM used in the study was obtained from 1/25.000 scaled digital topographic maps [39]. ArcGIS 10.2 software was used for DEM model creation and buffer zone analysis.

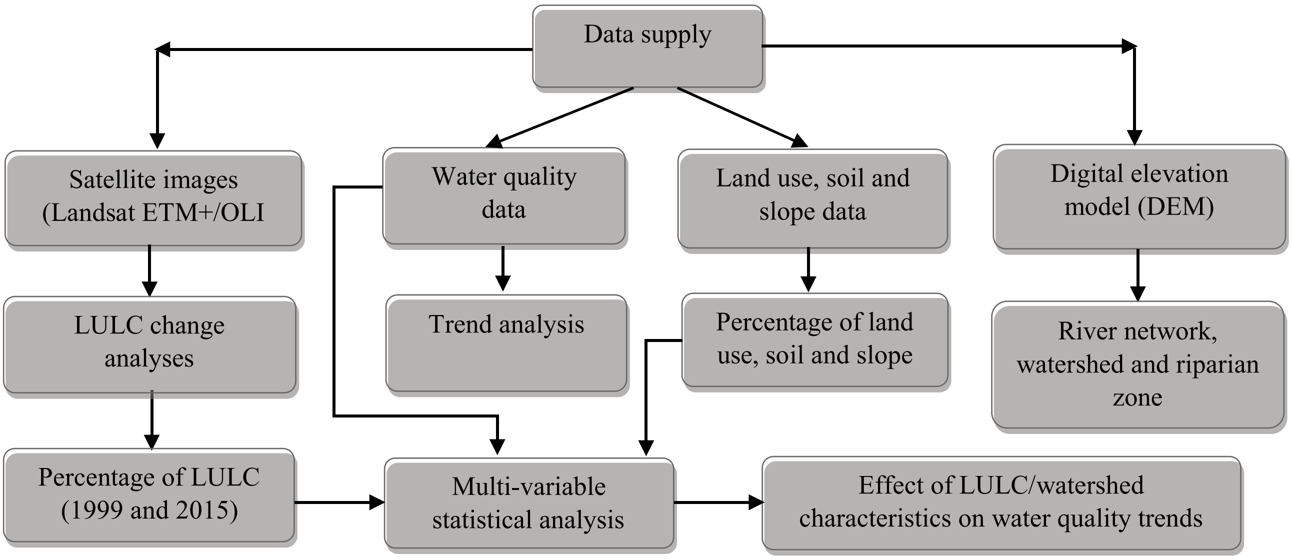

Fig. 3. Flow chart of the method applied in the study.

Table 2
Summary of water quality monitoring stations

Station number	*X* coordinate (m)	*Y* coordinate (m)	*Z* (m)	Land use types	Date range
1	3,31,566	4,406,063	1,335	Agriculture	2008–2015
2	3,28,634	4,406,147	1,387	Forest-bareland	2008–2015
3	3,25,362	4,398,837	1,252	Agriculture-residential	2008–2015
4	3,28,890	4,396,217	1,262	Forest-residential	1999–2015
5	3,32,263	4,397,958	1,255	Agriculture-forest-residential	1999–2015
6	3,35,655	4,402,163	1,260	Agriculture	1999–2015

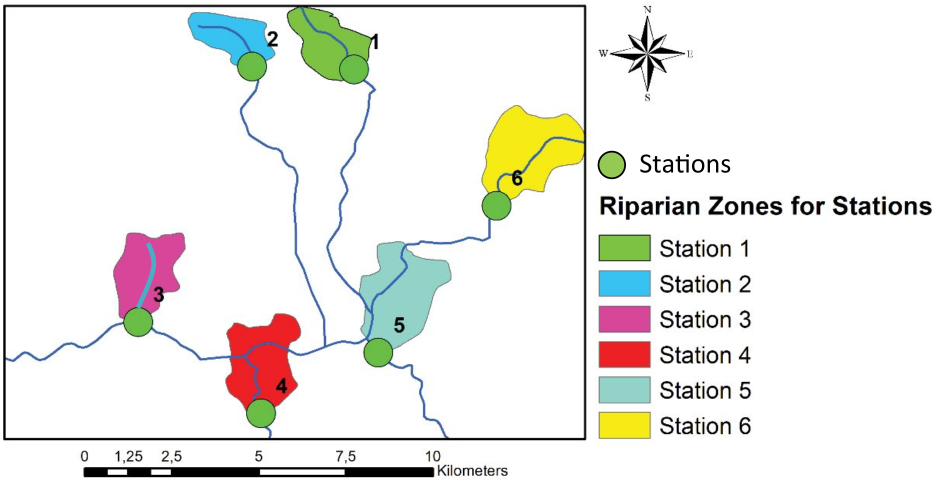

Fig. 4. Riparian zones for stations in the study area.

2.5. LULC, soil type and slope maps

The basis of LULC change analysis is the controlled classification of satellite images of different years. In this study; Landsat-7 ETM+ dated 07.08.1999 and Landsat-8 OLI [44] dated 11.08.2015 satellite images were used to determine the LULC changes in the study area by controlled classification method [44,45]. According to the Anderson et al. and Cover Classification System [46], LULC class with five classes (agriculture, vegetation, settlement, water, and bare land) have been defined to determine the differences in LULC in the study area. Using the confusion matrix and kappa coefficient [47] accuracy assessment analysis was performed to determine the accuracy of LULC changes [48]. For the accuracy assessment carried out within the scope of the study, 512 and 526 ground control points were used for 1999 and 2015 years respectively. Overall accuracy values for LULC change maps belonging to 1999 and 2015 years were determined as 90.43% and 94.11%, respectively. The kappa coefficient values for the LULC change maps belonging to 1999 and 2015 years were determined as 0.87 and 0.92, respectively [44]. According to United States Geological Survey, the minimum required value for overall accuracy in terms of LULC changes from Landsat satellite images is 85% [49]. In this study; the overall accuracy of LULC maps was found to be excellent.

While soil types in the study area are classified as 3 categories; alluvial soils, brown soils, and colluvial soils, slope groups divided into 6 classes as 0%–2%, 2%–6%, 6%–12%, 12%–20%, 20%–30% and 30%–50%.

2.6. Trend analysis

A trend test is applied to analyze gradual changes or tendencies on hydrological and meteorological data [50]. Trend analysis methods are used to determine whether there is a tendency to decrease or to increase in a given data set [51]. Nonparametric tests are often used for data that is not normally distributed and is frequently encountered in hydrological time series and is missing data [52,53]. The choice of nonparametric methods is advantageous because it will make the problem independent from the statistical distribution of data set [51,53]. In this study; Mann–Kendall trend test was used to determine changes in WQI trends and water quality parameters of all stations between the mentioned years.

2.7. Mann–Kendall test

Mann–Kendall test is a non-parametric test and is one of the most widely used trend monitoring methods in the world to identify important trends in hydrological and meteorological time series [50,52,54]. This test is widely used in environmental sciences, because it is a simple structure, reliable, can overcome missing data and handle data below a certain limit.[55] This test compares the relative size of the sample data [56]. The first advantage of this test is that the data do not require any special distribution [57,58]. The second advantage of this test is that it shows low sensitivity for sudden fractures due to non-homogeneous time series. The main focus of the Mann–Kendall test is to identify all binary differences between successive elements in a time series [57].

In this method, the existence of a trend is tested with a null hypothesis (H0). Depending on the acceptance or rejection of the null hypothesis, it is decided whether the trend is present [51]. The Mann–Kendall test statistic[59,60] is calculated using the following equation.

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}\left(x_j - x_i\right) \tag{1}$$

Here n is the number of data points.

In x_i and x_j, i and j time series ($j > i$), data values sgn (x_j–x_i) are the signal function and it is expressed as follows.

$$\operatorname{sgn}\left(x_j - x_i\right) = \begin{cases} +1, \text{ eğer } x_j - x_i > 0 \\ 0, \text{ eğer } x_j - x_i = 0 \\ -1, \text{ eğer } x_j - x_i < 0 \end{cases} \tag{2}$$

Variance is formulated as follows.

$$\operatorname{Var}(S) = \frac{n(n-1)(2n+5) - \sum_{m}^{i=1} t_i\left(t_i - 1\right)\left(2t_i + 5\right)}{18} \tag{3}$$

Here n = is the number of data points, m = is the number of connected groups, t_i = is the number of links in the scope of i. A linked group consists of a set of sample data with the same value. If the sample size meets $n > 10$ requirements, the standard normal test statistic value of Z_S is calculated by the following equation [61]. Whether the variance of the determined Mann–Kendall test is significant, is determined by calculating the standard normal variable Z with the following equation and by comparing critical Z value [62]. While negative Z_S values mean a decreasing trend, positive Z_S value indicates an increasing trend [61].

$$Z_S = \begin{cases} \dfrac{S-1}{\sqrt{\operatorname{Var}(S)}}, \text{ eğer } S > 0 \\ 0, \text{ eğer } S = 0 \\ \dfrac{S+1}{\sqrt{\operatorname{Var}(S)}} \text{ eğer } S < 0 \end{cases} \tag{4}$$

In the Mann–Kendall approach; if data have a series of positive correlations, the significance of the trend is at a considerable level, whereas the significance of the trend is at a negligible level if data have a series of negative correlations [63].

2.8. Correlation analysis

Pearson correlation analysis is used to determine the relationship between two variables and to determine whether there is a positive or negative linear relationship between two variables [12]. If the correlation coefficient is close to +1 or –1, there is a linear relationship between x and y variables [64]. Table 3 shows the evaluation intervals of the correlation coefficient (r) calculated from the Pearson correlation analysis. If the r-value is in the range of 0.5–1.0, this means that there is a high correlation between the two variables, indicating a strong positive relationship between the two variables. If r value is between 0.3 and 0.5, there is a moderate correlation [12].

Pearson correlation analysis was applied to determine the relationships of LULC, soil type and slope characteristics of the study area with water quality. In Pearson correlation analysis, LULC changes, soil type, and slope properties are considered as independent variables and water quality components are considered as dependent variables.

3. Results

3.1. LULC composition

Fig. 5 shows the changes in the LULC in the 17-year time period. In 1999 and 2015, the most dominant types of land use within the watershed boundaries of all stations are bare lands and agricultural lands. In 1999 and 2015, the bare lands were respectively 65.14% (station 2) and 51.44% (station 2) of the study area. On the other hand, agricultural lands constituted the second dominant land use type with rates of 46.32% (station 1) in 1999 and 49.98% (station 1) in 2015.

When the spatial distribution values for LULC belonging to 1999 and 2015 are analyzed (Table 4), it is seen that urban settlement areas increase rapidly in all station areas. The highest increase in the urban settlement area was in station 5 and the increase rate in urban settlement area in this region was realized as 13.86%. Other stations in terms of size of the increasing rates of urban settlement area were listed as follows; 2 (11.12%), 6 (7.25%), 4 (5.8%), 1 (3.79%) and 3 (3.76%). The bare areas of all stations in the study area decreased and the stations with the highest decrease in the bare lands were station 6 (% –25.33) and 3 (% –22.61). The agricultural lands within the watershed boundary of all stations increased. The highest increase in agricultural land was observed at station 6 (21.74%), while stations 3 (16.4%), 4 (7.32%), 1 (3.66%), 5 (2.88%) and 2 (2.15%) followed it respectively. In terms of vegetation; stations 1, 2, 3 and 4 showed an increase, while

Table 3
Interpretation of the size of a Pearson correlation [12]

Correlation, r	Negative	Positive
None	–0.09 to 0.0	0.0–0.09
Small	–0.3 to –0.1	0.1–0.3
Medium	–0.5 to –0.3	0.3–0.5
Strong	–1.0 to –0.5	0.5–1.0

there was a decrease in stations 5 and 6. Most of the areas in the nude land class within the watershed boundaries of stations 5 and 6 turned into agricultural and residential areas (Table 4, Fig. 5). This situation created a threat to surface water sources within the specified limits. It is thought that the main reason why most of the bare areas are transformed into urban settlements and agricultural lands is the transition from village to urban settlements that can be seen in Sivas for years [44].

3.2. Soil type and slope

The soil group with the highest distribution in the study area is the brown soils. The station where this soil group is most distributed in station 2 (95.9%) located north of the study area. Alluvial soils have the highest distribution (73.53%) in the watershed where station 6 is located. On the other hand, the colluvial soils have very little distribution (4.2%) in the study area and this soil group is present in the watershed where station 5 is located (Table 5, Fig. 6).

The slope range of the watersheds where all stations are located is classified into 6 groups. The slope group with 0–2% slope range is the dominant slope group in the study area. The watersheds where this slope group has most distribution by area (%) are the watersheds in station 4 (89.72%) located south of the study area and station 6 (82.18%) located northeast of the study area. The watersheds where this slope group has lowest distribution by area (%) are the watersheds where station 1 (22.22%) and station 2 (23.24%) are located. In terms of spatial distributions, this slope group is followed by slope groups in the range of 2%–6% and 6%–12% slope. The slope group with the least distribution in the study area is the slope group between 30%–50% (Table 5, Fig. 7).

3.3. Trends in water quality

In order to determine the time-dependent changes in surface water quality, trend analysis methods were applied on the calculated WQI values [65,66] and on the parameters of surface water quality for time periods 2008–2015 (for stations 1, 2 and 3) and 1999–2015 (for stations 4, 5 and 6). Belonging to rainy and dry periods, the trend analysis results obtained with the Mann–Kendall test can be seen in Table 6 and the spatial distribution of the trends obtained can be seen in Figs. 8 and 9.

According to Table 6; if $p < 0.05$ and $p < 0.01$ conditions do not occur, the positive τ values of the water quality parameters show an increasing trend in the relevant water quality parameters, on the other hand, the negative τ values indicate a decreasing trend in the water quality parameters. However, in both cases, it is understood that these increasing and decreasing trends are not statistically significant. In case of $p < 0.05$ and $p < 0.01$ conditions, the increases, and decreases in trends of the parameters are statistically significant.

According to the Mann–Kendall test results (Table 6); in the rainy period, a negative decrease in the total dissolved solids (TDS) parameter of stations 1 and 2 and a positive increase in the NO_3 parameter of stations 2, 4 and 6 were observed. In the dry period, a positive increase in the DO parameter of station 1; a negative decrease in the DO parameter of station 3; a positive increase in the BOD parameter of stations 3, 5 and 6; a positive increase in the NH_4 parameter of stations 3 and 6; a positive increase in the NO_3 parameter of stations 3, 4, 5 and 6; and a negative decrease in TP parameter of station 3, were observed. A positive increase was observed in the TP and WQI parameters of stations 4, 5 and 6 in both wet and dry periods. It was found that decreases and increases in these trends were statistically significant ($p < 0.05$ and $p < 0.01$). In general; WQI parameter in rainy (wet) period and NO_3, TP and WQI parameters in dry period showed an increasing tendency at three stations (stations 4, 5, 6) with a significance level of 0.01 ($p < 0.01$) (Figs. 8 and 9).

3.4. Impact of LULC, soil types and slope on water quality

Hydrological behavior in a watershed is controlled by LULC, soil, and topography [67]. Changes in LULC and soil properties affect the hydrological processes, nutrient loads and surface water quality in watershed [68–70]. Land use in drainage watersheds is one of the most important man-made driving forces affecting the quality change in water environment. Land use patterns of different types and sizes have a significant effect on water quality of surface waters having receiving environment characteristics [71]. Urban land use causes major changes in surface water environments including water quality, conductivity, nutrients, rivers habitat, riverside ecosystems, and biodiversity [72]. Rivers and lakes are the receiving environment for pollutants originating from residential, agricultural and industrial areas. It affects water quality such as nutrient concentrations and sediment composition depending on the flows originating from agricultural land. Therefore, it is necessary to determine the effects of

Table 4
LULC (%) of six watersheds for 1999 and 2015 in the Kızılırmak river basin

Station number	LULC – 1999					LULC–2015				
	AGR	VEG	URB	WAT	BAR	AGR	VEG	URB	WAT	BAR
1	46.32	1.4	1.72	0	50.56	49.98	5.18	5.51	0	39.33
2	3.55	24.13	7.16	0.02	65.14	5.7	24.43	18.28	0.15	51.44
3	6.68	5.80	34.01	0.19	53.33	23.08	7.68	37.77	0.75	30.72
4	27.9	26.4	16.35	3.93	25.42	35.22	28.25	22.15	2.19	12.19
5	26.33	12.16	11.77	5.05	44.69	29.21	10.43	25.63	4.36	30.37
6	18.86	7.74	19.78	6.72	46.9	40.6	6.17	27.03	4.64	21.57

AGR: Agriculture, VEG: Vegetation, URB: Urban, WAT: Water, BAR: Bare land

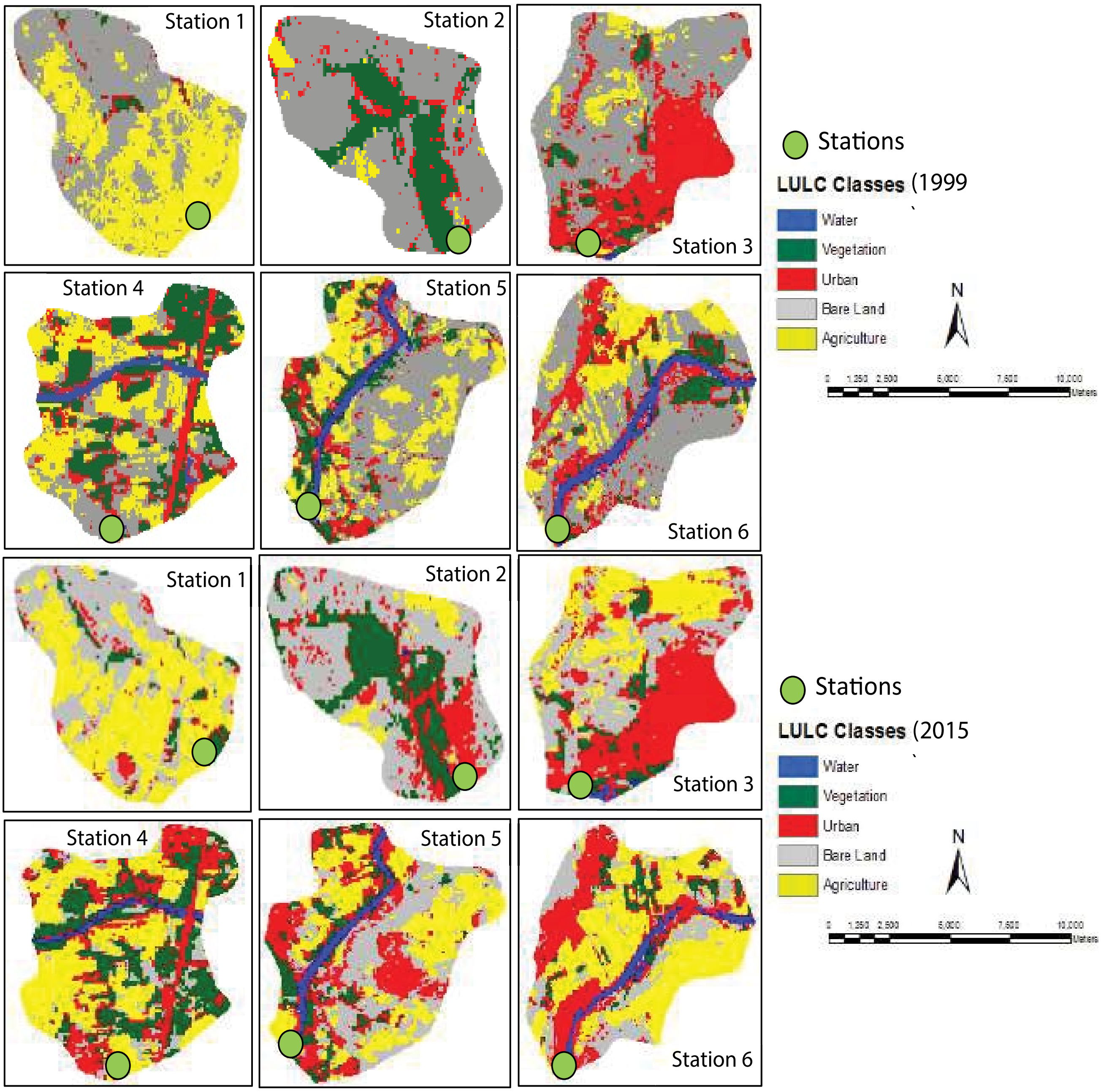

Fig. 5. LULC for six watersheds and riparian zones for 1999 and 2015 in the Kızılırmak river basin.

Table 5
Percentages of soil types and slope (%) in the six watersheds

Station number	Soil types (%)			Slope (%)					
	Brown	Alluvial	Colluvial	0–2	2–6	6–12	12–20	20–30	30–50
1	93.93	6.07	0	22.22	25.44	27.05	20.61	4.51	0.18
2	95.9	4.1	0	23.24	17.43	21.99	17.01	14.11	6.22
3	66.67	33.33	0	26.83	31.25	29.04	10.51	2.30	0.07
4	28.77	71.23	0	89.72	7.09	2.52	0.62	0.05	0.00
5	45.8	50	4.2	50.35	33.51	10.34	2.49	1.40	1.91
6	26.47	73.53	0	82.18	8.84	4.05	2.76	1.73	0.42

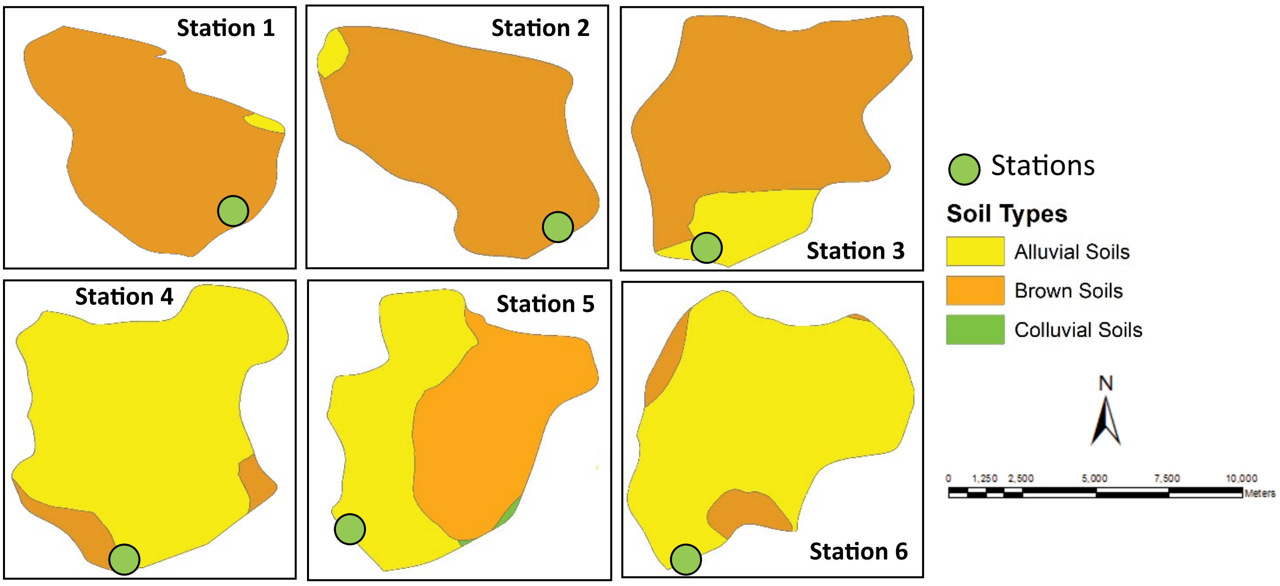

Fig. 6. Soil types for six watersheds and riparian zones in the Kızılırmak river basin.

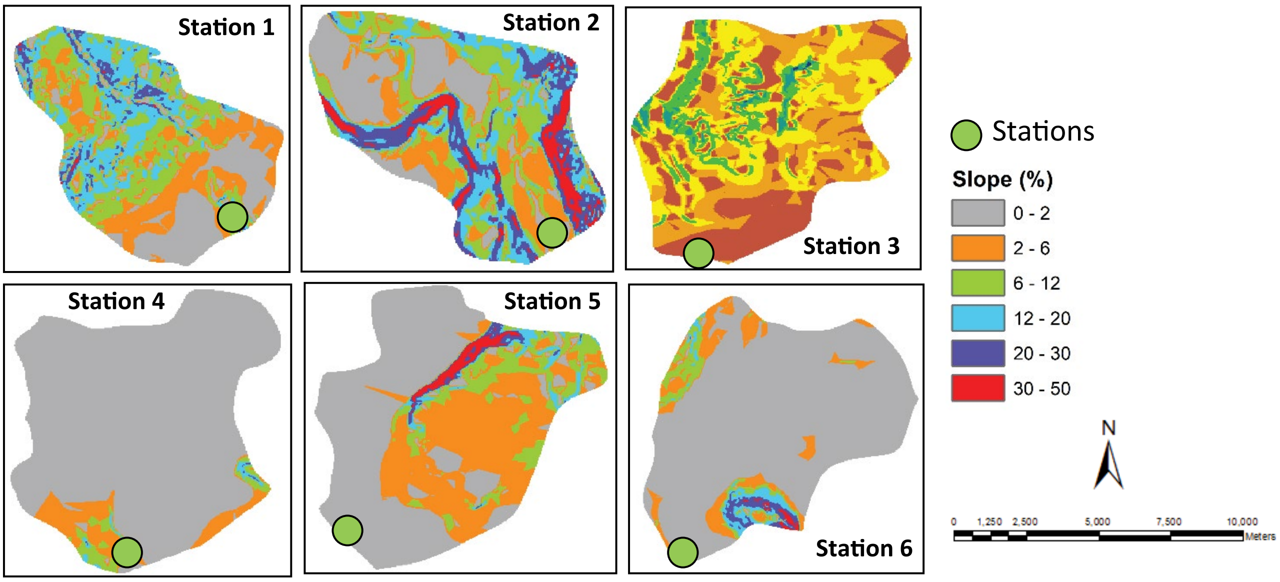

Fig. 7. Slope for six watersheds and riparian zones in the Kızılırmak river basin.

land use patterns on water quality, especially in areas where significantly anthropogenic existence is evident [73].

Land use varies according to soil types. while spruce forests dominate the mountainous areas, fertile soils on the plains are used agriculturally. Loose soils which are used agriculturally lead to high suspended particle loads and high nutrient concentrations in rivers because of surface flow and erosion [74,75]. In general, changes in land use, especially the conversion of forests or open land into agricultural and urban land uses lead to deterioration of drinking water quality [76].

Topographic features such as slope and collection area are also important factors affecting watershed hydrology and river water quality [77]. When water quality is correlated with land slope, high slope values in the watershed increase erosion and as a result, water quality is deteriorated by increasing particulate matter entering waterbody [24,78,79].

In this study, while the data of 1999 and 2015 were used to determine the relationships between LULC and water quality parameters, the data of 2008 and 2015 (years of common data belonging to 6 stations) were used to determine the relationships between soil types and slope on the one hand and water quality parameters on the other. When correlation analysis was performed between the variables used in the study, the areal values (%) were used for LULC, soil types, and slope variables, while for water quality variables, mg/L was used as the concentration unit of the variable. In this study; the correlation coefficients and significance levels

Table 6
Results of the Mann–Kendall test for the water parameters of the stations on the Kızılırmak river basin in the wet and dry season

Station 1 (2008–2015)		Wet season		Dry season		
Parameter	τ	p	Trend	τ	p	Trend
BOD	0.483	0.115		0.540	0.072	
DO	0.143	0.621		0.643*	0.026	
NH_4	0.189	0.524		0.567	0.056	
NO_3	0.357	0.216		0.074	0.802	
TDS	–0.571*	0.048		–0.214	0.458	
TP	0.154	0.608		0.463	0.123	
WQI	0.286	0.322		0.500	0.083	

Station 2 (2008–2015)		Wet season		Dry season		
Parameter	τ	p	Trend	τ	p	Trend
BOD	0.454	0.140		0.231	0.444	
DO	–0.071	0.805		0.429	0.138	
NH_4	0.242	0.425		0.564	0.063	
NO_3	0.691*	0.018		0.429	0.138	
TDS	–0.714*	0.013		–0.286	0.322	
TP	0.222	0.451		0.148	0.615	
WQI	0.286	0.322		0.143	0.621	

Station 3 (2008–2015)		Wet season		Dry season		
Parameter	τ	p	Trend	τ	p	Trend
BOD	0.118	0.698		0.701*	0.023	
DO	–0.214	0.458		–0.071	0.805	
NH_4	0.416	0.161		0.691*	0.018	
NO_3	0.109	0.708		0.786**	0.006	
TDS	0.214	0.458		0.357	0.216	
TP	–0.386	0.199		–0.593*	0.044	
WQI	0.071	0.805		–0.071	0.805	

Station 4 (1999–2015)		Wet season		Dry season		
Parameter	τ	p	Trend	τ	p	Trend
BOD	0.053	0.771		0.342	0.061	
DO	–0.015	0.934		–0.385*	0.034	
NH_4	0.122	0.504		0.214	0.232	
NO_3	0.474**	0.008		0.529**	0.003	
TDS	–0.074	0.680		0.015	0.934	
TP	0.435*	0.015		0.726**	0.000	
WQI	0.632**	0.000		0.868**	0.000	

Station 5 (1999–2015)		Wet season		Dry season		
Parameter	τ	p	Trend	τ	p	Trend
BOD	0.090	0.619		0.521**	0.004	
DO	–0.199	0.266		–0.465**	0.009	
NH_4	0.023	0.901		0.191	0.284	
NO_3	0.237	0.187		0.598**	0.001	
TDS	–0.170	0.343		0.000	1.000	
TP	0.428*	0.020		0.483**	0.007	
WQI	0.500**	0.005		0.603**	0.001	

Station 6 (1999–2015)		Wet season		Dry season		
Parameter	τ	p	Trend	τ	p	Trend
BOD	0.197	0.280		0.363*	0.049	
DO	–0.207	0.248		–0.352	0.052	
NH_4	0.069	0.707		0.412*	0.023	
NO_3	0.468**	0.009		0.498**	0.006	
TDS	0.029	0.869		0.221	0.217	
TP	0.697**	0.000		0.721**	0.000	
WQI	0.794**	0.000		0.721**	0.000	

*Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).

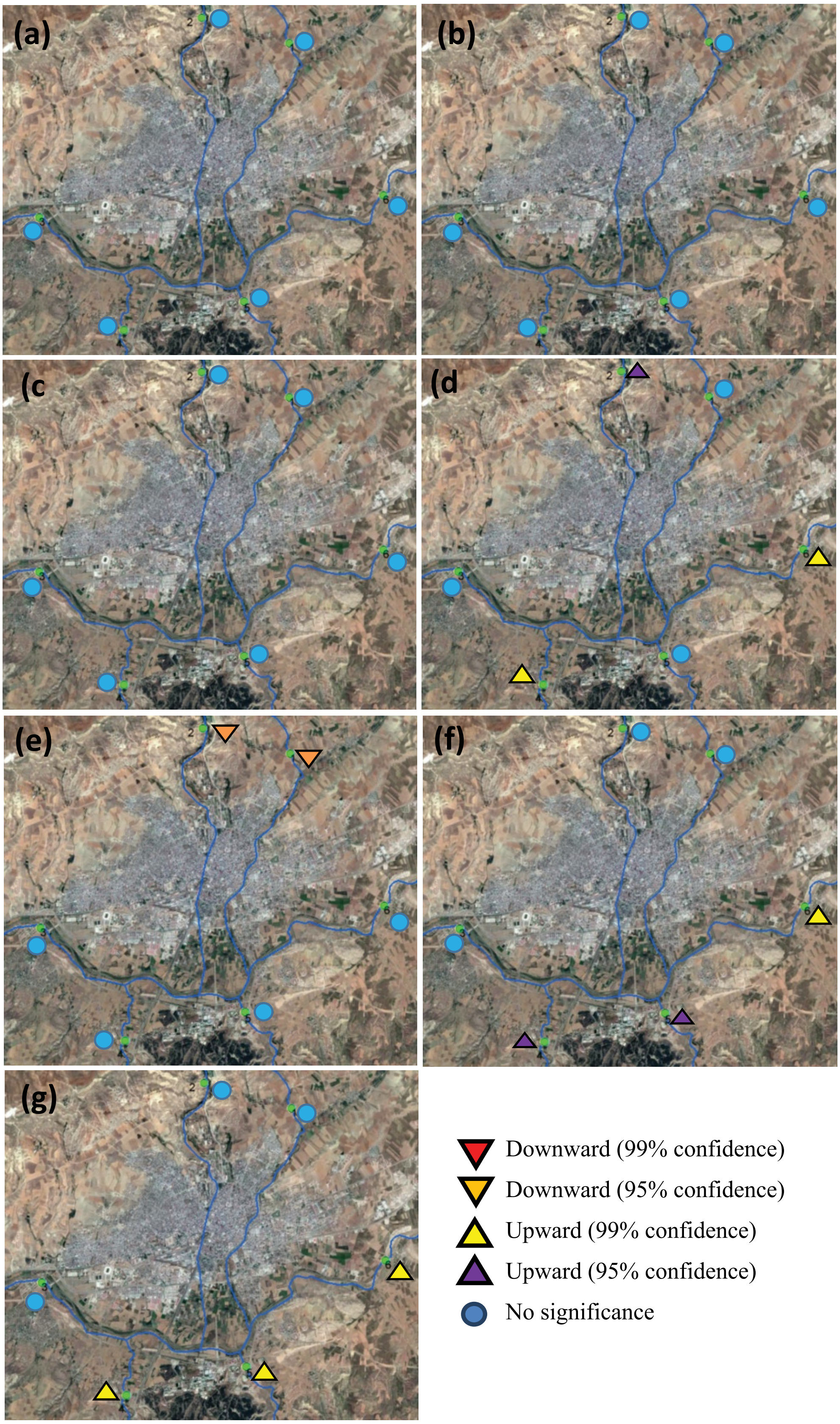

Fig. 8. Temporal trends of water quality for (a) BOD, (b) DO, (c) NH$_4$, (d) NO$_3$, (e) TDS, (f) TP, and (g) WQI for wet season in the Kızılırmak river basin.

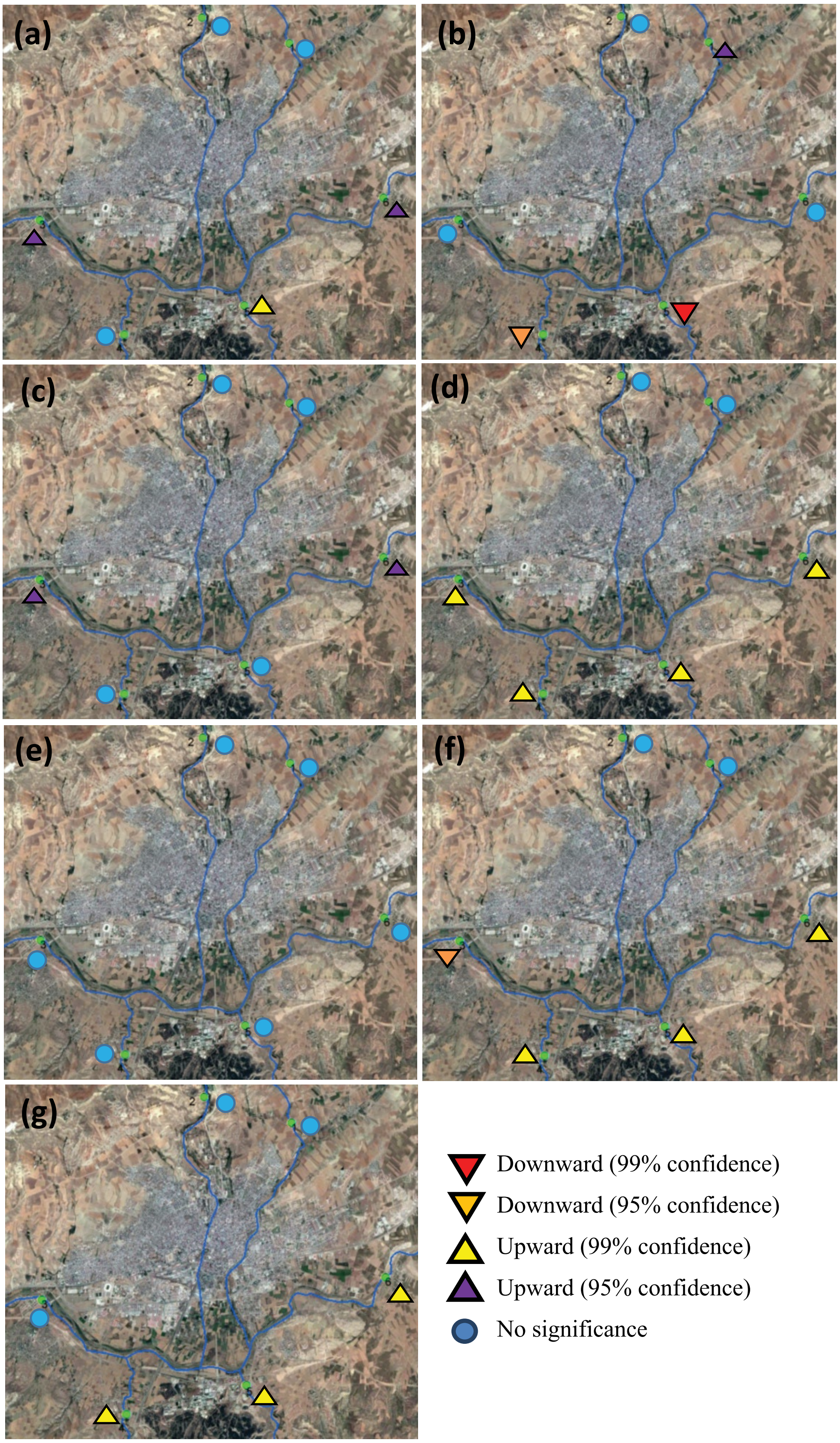

Fig. 9. Temporal trends of water quality for (a) BOD, (b) DO, (c) NH$_4$, (d) NO$_3$, (e) TDS, (f) TP, and (g) WQI for dry season in the Kızılırmak river basin.

calculated for the relationship between LULC changes, soil types and slope on the one hand and water quality parameters on the other are shown in Tables 7–9.

In 1999; there is a strong negative correlation between agricultural areas and DO in a rainy period, while it is between agricultural areas and TDS in a dry period. In the same year, a strong positive correlation was determined between urban areas and TP parameter in a dry period. These correlations were statistically significant ($p < 0.05$) (Table 7).

In 2015; according to the evaluation interval of Pearson correlation coefficient (Table 3), the urban areas showed a strong correlation ($-1.0 < r < -0.5$) in the negative direction with DO, and positive correlation with the other parameters in both periods. The negative strong correlation between urban areas and DO was found to be statistically significant in a dry period ($r = -0.902$*, $p < 0.05$). In rainy and dry periods, the strongest positive correlations of urban areas ($0.5 < r < 1.0$) occurred with the NH_4 and TDS parameters. Especially in a dry period, strong positive correlations between urban areas and NH_4 and TDS parameters were found to be statistically significant. In both periods, agricultural areas showed positive correlations with all water quality parameters. The strongest positive correlations ($0.5 < r < 1.0$) with agricultural areas were observed with TP parameter in a rainy period; while they were seen with BOD parameter in a dry period. In rainy and dry periods, the strongest positive correlations ($0.5 < r < 1.0$, $p < 0.05$) were observed between agricultural areas and NO_3 and TP parameters. In addition, strong positive correlations ($0.5 < r < 1.0$) were observed during rainy period between agricultural areas and TP; while in a dry period, they were observed between agricultural areas and BOD. Urban areas and agricultural areas were also observed as land use patterns affecting the WQI parameter in both periods. There was a "strong" positive correlation between urban areas and WQI in rainy period and a "moderate ($0.3 < r < 0.5$)" positive correlation in a dry period. There was a "weak" positive correlation ($0.1 < r < 0.3$) in rainy period while there was a "moderate" positive correlation in a dry period between agricultural areas and WQI. While there was a positive

Table 7
Pearson correlation coefficients between the water quality parameters and LULC for six stations in 1999 and 2015

Sampling Period			LULC classes (1999)				LULC classes (2015)			
			AGR	VEG	URB	BAR	AGR	VEG	URB	BAR
Wet season	BOD	r	0.448	0.900	0.300	–0.951	0.311	0.026	0.430	–0.781
		p	0.704	0.287	0.806	0.201	0.548	0.961	0.394	0.067
	DO	r	–0.999*	0.563	0.751	0.669	0.156	0.589	–0.810	0.441
		p	0.031	0.448	0.459	0.534	0.768	0.218	0.051	0.382
	NH_4	r	0.970	0.621	–0.866	–0.510	0.201	–0.186	0.766	–0.211
		p	0.156	0.574	0.334	0.659	0.702	0.724	0.076	0.688
	NO_3	r	0.995	0.852	–0.642	–0.773	0.770*	0.467	0.130	–0.548
		p	0.066	0.351	0.556	0.437	0.039	0.350	0.806	0.261
	TDS	r	0.815	0.690	–0.182	–0.985	0.027	0.119	0.805	–0.834*
		p	0.393	0.064	0.883	0.110	0.959	0.822	0.053	0.039
	TP	r	0.841	0.337	–0.981	–0.207	0.870*	0.120	0.076	–0.630
		p	0.364	0.781	0.126	0.867	0.344	0.822	0.886	0.180
	WQI	r	0.992	0.710	–0.800	–0.609	0.298	0.014	0.628	–0.919**
		p	0.080	0.498	0.410	0.584	0.566	0.979	0.182	0.010
Dry season	BOD	r	0.203	–0.436	–0.827	0.553	0.491	–0.547	0.151	–0.361
		p	0.870	0.713	0.380	0.627	0.322	0.262	0.775	0.482
	DO	r	–0.302	0.420	–0.447	0.890	0.340	0.380	–0.902*	0.083
		p	0.805	0.388	0.705	0.302	0.510	0.457	0.014	0.875
	NH_4	r	0.956	0.579	–0.891	–0.464	0.075	–0.315	0.854*	–0.362
		p	0.190	0.607	0.300	0.693	0.888	0.543	0.030	0.481
	NO_3	r	0.634	0.974	0.083	–0.996	0.890*	0.273	0.289	–0.740
		p	0.563	0.146	0.947	0.060	0.021	0.600	0.579	0.093
	TDS	r	–0.997*	–0.746	0.768	0.649	0.103	–0.351	0.853*	–0.616
		p	0.047	0.464	0.443	0.550	0.845	0.495	0.031	0.192
	TP	r	0.672	0.081	0.998*	0.054	0.940*	0.038	0.115	–0.720
		p	0.531	0.948	0.041	0.966	0.414	0.944	0.829	0.107
	WQI	r	0.111	–0.518	–0.771	0.628	0.394	–0.053	0.378	–0.834*
		p	0.929	0.654	0.439	0.568	0.440	0.921	0.460	0.039

AGR: Agriculture, VEG: Vegetation, URB: Urban, WAT: Water, BAR: Bare land

*Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).

Table 8
Pearson correlation coefficients between the soil types and slope on the one hand a water quality parameters on the other for six stations in 200

Sampling period			Soil types			Slope (%)					
			Brown soils	Alluvial soils	Colluvial soils	0–2	2–6	6–12	12–20	20–30	30–50
Wet season	BOD	r	–0.645	0.607	0.799	0.845*	–0.008	–0.733	–0.736	–0.355	0.038
		p	0.167	0.201	0.056	0.043	0.988	0.097	0.095	0.489	0.943
	DO	r	0.027	0.001	–0.490	0.258	–0.618	–0.202	0.021	0.187	0.131
		p	0.960	0.999	0.324	0.621	0.191	0.701	0.968	0.723	0.805
	NH_4	r	–0.511	0.515	0.022	0.494	–0.410	–0.535	–0.404	–0.131	–0.035
		p	0.300	0.296	0.967	0.320	0.419	0.274	0.427	0.804	0.948
	NO_3	r	0.070	–0.058	–0.221	–0.305	0.418	0.511	0.046	–0.199	–0.311
		p	0.895	0.912	0.674	0.557	0.410	0.300	0.932	0.705	0.548
	TDS	r	–0.889*	0.873*	0.453	0.697	–0.116	–0.702	–0.907*	–0.634	–0.330
		p	0.018	0.023	0.367	0.124	0.827	0.120	0.012	0.177	0.523
	TP	r	–0.806	0.834*	–0.333	0.874*	–0.763	–0.735	–0.648	–0.532	–0.501
		p	0.053	0.039	0.519	0.023	0.078	0.096	0.164	0.277	0.312
	WQI	r	–0.804	0.826*	–0.229	0.878*	–0.660	–0.719	–0.738	–0.648	–0.556
		p	0.054	0.043	0.662	0.021	0.153	0.108	0.094	0.164	0.252
Dry season	BOD	r	–0.739	0.712	0.630	0.731	–0.269	–0.882*	–0.831*	–0.379	0.016
		p	0.093	0.113	0.180	0.099	0.606	0.020	0.040	0.459	0.976
	DO	r	0.015	–0.017	0.042	0.284	–0.550	–0.473	0.005	0.368	0.467
		p	0.978	0.974	0.937	0.586	0.258	0.344	0.992	0.473	0.350
	NH_4	r	–0.436	0.387	0.959**	0.251	0.368	–0.446	–0.556	–0.364	–0.002
		p	0.387	0.448	0.003	0.632	0.472	0.375	0.252	0.478	0.997
	NO_3	r	–0.813*	0.822*	–0.004	0.953**	–0.745	–0.926**	–0.777	–0.492	–0.296
		p	0.049	0.045	0.994	0.003	0.089	0.008	0.069	0.321	0.568
	TDS	r	–0.697	0.699	0.108	0.475	–0.073	–0.382	–0.639	–0.542	–0.417
		p	0.124	0.123	0.839	0.341	0.891	0.455	0.172	0.267	0.411
	TP	r	–0.989**	0.985**	0.271	0.952**	–0.465	–0.928**	–0.962**	–0.720	–0.450
		p	0.000	0.000	0.603	0.003	0.353	0.008	0.002	0.107	0.370
	WQI	r	–0.997**	0.993**	0.261	0.925**	–0.424	–0.888*	–0.969**	–0.727	–0.461
		p	0.000	0.000	0.617	0.008	0.402	0.018	0.001	0.102	0.358

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

correlation between the bare areas and only DO parameter in both periods, negative correlations were found between the bare areas and all parameters except the DO (Table 7). In both periods of 1999 and 2015, vegetation cover and DO had the highest positive correlation values and the correlations in a rainy period were represented as "strong" and the correlations in a dry period were represented as "moderate". In view of the riparian area boundaries in rainy and dry periods in the 17-year period between 1999 and 2015, it is seen that urban and agricultural areas are related with deterioration of water quality (Table 7) due to the increase in urban and agricultural areas (Table 4).

When the correlations between the water quality parameters of 2008 and soil types are examined; there were negative correlations between brown soils and TDS parameter in a rainy period and between brown soils and NO_3, TP and WQI parameters in a dry period. These correlations were statistically significant at $p < 0.05$ and $p < 0.01$ levels. In the same year, there were positive correlations between alluvial soils and TDS and WQI parameters in the rainy period and between alluvial soils and NO_3, TP and WQI parameters in a dry period. These correlations were also statistically significant at $p < 0.05$ and $p < 0.01$ levels. Colluvial soils were positively correlated with NH_4 only in a dry period, this correlation was also significant at $p < 0.01$ level (Table 8).

When the correlations belonging to 2015 between the soil types and the water quality parameters within the boundaries of the riparian area are examined; it was seen that especially alluvial soils have a negative impact on water quality. In the rainy period, positive correlations were determined between the alluvial soils and BOD, TDS and WQI parameters ($0.5 < r < 1.0$) and these correlations were found as statistically significant ($r = 0.818$*, $r = 0.849$*, $r = 0.898$*; $p < 0.05$). While in a dry period, positive correlations were determined between alluvial soils and NO_3, TP and WQI parameters. In this period, the correlations between NO_3 and TP parameters and alluvial soils were statistically significant at $p < 0.05$ level; while the

Table 9
Pearson correlation coefficients between the soil types and slope on the one hand a water quality parameters on the other for six stations in 2015

Sampling period			Soil types			Slope (%)					
			Brown soils	Alluvial soils	Colluvial soils	0–2	2–6	6–12	12–20	20–30	30–50
Wet season	BOD	r	–0.787	0.818*	–0.402	0.814*	–0.709	–0.638	–0.644	–0.525	–0.507
		p	0.063	0.047	0.430	0.048	0.115	0.173	0.167	0.285	0.305
	DO	r	0.462	–0.457	–0.191	–0.140	–0.364	–0.008	0.441	0.645	0.589
		p	0.356	0.363	0.717	0.791	0.478	0.988	0.381	0.167	0.219
	NH_4	r	–0.082	0.088	–0.089	–0.175	0.418	0.372	–0.127	–0.338	–0.380
		p	0.877	0.868	0.867	0.740	0.409	0.468	0.810	0.512	0.458
	NO_3	r	–0.643	0.614	0.641	0.632	–0.142	–0.753	–0.770	–0.430	–0.054
		p	0.168	0.194	0.171	0.178	0.789	0.084	0.073	0.394	0.918
	TDS	r	–0.847*	0.849*	0.127	0.683	–0.188	–0.550	–0.872*	–0.716	–0.505
		p	0.033	0.032	0.811	0.135	0.721	0.258	0.023	0.110	0.306
	TP	r	–0.649	0.678	–0.393	0.829*	–0.887*	–0.744	–0.475	–0.336	–0.341
		p	0.164	0.139	0.441	0.041	0.018	0.090	0.341	0.514	0.508
	WQI	r	–0.880*	0.898*	–0.156	0.899*	–0.442	–0.606	–0.799	–0.760	–0.666
		p	0.021	0.015	0.767	0.047	0.380	0.202	0.057	0.080	0.149
Dry season	BOD	r	–0.501	0.515	–0.150	0.474	–0.378	–0.413	–0.319	–0.343	–0.372
		p	0.311	0.296	0.777	0.342	0.461	0.415	0.538	0.506	0.467
	DO	r	0.203	–0.189	–0.288	0.138	–0.526	–0.198	0.290	0.251	0.133
		p	0.700	0.720	0.580	0.795	0.283	0.706	0.577	0.631	0.801
	NH_4	r	–0.298	0.312	–0.195	0.048	0.196	0.174	–0.277	–0.432	–0.476
		p	0.566	0.547	0.711	0.928	0.709	0.742	0.595	0.393	0.340
	NO_3	r	–0.913*	0.901*	0.392	0.913*	–0.474	–0.974**	–0.935**	–0.530	–0.195
		p	0.011	0.014	0.442	0.011	0.342	0.001	0.006	0.279	0.712
	TDS	r	–0.707	0.714	0.006	0.481	–0.080	–0.331	–0.655	–0.607	–0.508
		p	0.116	0.111	0.991	0.335	0.881	0.522	0.158	0.201	0.303
	TP	r	–0.880*	0.874*	0.275	0.912*	–0.541	–0.953**	–0.819*	–0.557	–0.312
		p	0.021	0.023	0.598	0.011	0.267	0.003	0.046	0.251	0.547
	WQI	r	–0.962**	0.964**	0.142	0.927**	–0.521	–0.884*	–0.882*	–0.676	–0.469
		p	0.002	0.002	0.788	0.008	0.290	0.020	0.020	0.140	0.348

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

correlation between WQI and alluvial soils was found to be statistically significant at $p < 0.01$ level. There were negative correlations between brown soil and TDS and WQI parameters in the rainy period, and between brown soils and NO_3, TP and WQI parameters in a dry period. These negative correlations were identified as statistically significant correlations ($-1.0 < r < -0.5$; $p < 0.05$, $p < 0.01$). There were generally negative correlations between the colluvial soils which show the least distribution in this study area and water quality parameters. On the whole, the negative impact of colluvial soils on water quality in the study area was found little to be negligible (Table 8).

The slope groups within the boundaries of the riparian area are categorized into 6 categories and the effect of each slope group on water quality was demonstrated. According to correlation analysis; in rainy and dry periods of 2008 and 2015, the slope group which affects the water quality negatively was 0%–2%, slope group. In both years, there was a strong positive correlation between 0%–2% slope group and BOD, TP and WQI parameters in the rainy period and between 0%–2% slope group and NO_3, TP and WQI parameters in a dry period. These correlations were statistically significant at $p < 0.01$ and $p < 0.01$ levels. The negative effects of all slope groups except 0%–2% slope group on water quality were found to be low in stated years (Tables 8 and 9).

4. Discussion

LULC change, soil types and land slope are the most important factors affecting surface water quality. In order to fully understand the effect of LULC change on surface water quality, the effect of each land use pattern on surface water quality parameters should be demonstrated. Accordingly, it is necessary to emphasize the importance of contaminants affecting the water ecosystem such as dissolved ions, solids, nutrients and organic carbon in the evaluation of surface water quality. For example; high DO values indicate better water quality as they are essential for the survival of aquatic organisms. Therefore, all water quality parameters, such as DO, are good indicators for assessing water quality-related with land use [80].

Many previous studies have demonstrated the relationships between land use changes and surface water quality. Huang et al. [81] have found a positive relationship in their study between cultivated land (%) and NH_3–N and DO parameters depending on improved agricultural activities and chemical fertilizer use in Chaohu region. The researchers also have emphasized that there is a negative correlation between TP and TN concentrations and cultivated land (%). The researchers who stated that forest areas and pasture areas have a positive effect on water quality have determined that these areas and TP, TN, NH_3–N, and COD parameters are negatively correlated, while they are positively correlated with DO. According to the researchers; while TP, TN, NH_3–N and COD were positively correlated with residential areas, DO were negatively correlated with them and the increase in the residential area decreased the water quality. Ding et al. [82] and Wang et al. [83] have found a positive relationship between water quality and pasture area, which means that both forests and pastures have a positive impact on water quality. The increase in forest land and pasture area reduces the concentration of TP, TN and oxygen-consuming substances, increases the concentration of DO and consequently improves the water quality [81]. Kibena et al. [12] have found strong positive correlations between agricultural areas and TN, TP and total suspended solids parameters. Mello et al. [29] have suggested that forest areas within the riverside and watershed boundaries improve water quality, while urban areas and agricultural areas deteriorate it. In the study conducted by the researchers, there was a positive correlation between forest areas and DO, whereas there were negative correlations between forest areas and solids, TN and TP. According to the researchers; while there was a negative correlation between urban areas and DO, there was a positive correlation between urban areas and other parameters. On the other hand, agricultural areas showed positive correlations with all parameters. The study conducted by Ye et al. [84], has put forward the effects of land use and topography on the water quality of the Xiangxi River. According to the researchers; The water quality of Xiangxi River was negatively affected by topography and land use. Many studies similar to these studies [72,85–87] have demonstrated the impact of land use patterns on water quality.

In this study; at stations 4, 5 and 6 located in the south and northeast of the study area, WQI parameters showed an increasing tendency, thus the surface water quality was very low. it is thought that the reason for this decrease in water quality originates from settlement, industry and agricultural areas which have been developed in these regions over time.

The results obtained in this study on the effects of LULC changes on water quality support the many studies mentioned above. According to the results obtained; between 1999 and 2015, while the settlements and agricultural areas increased within the boundaries of the riparian area where all stations were located, bare lands decreased. In general, bare lands in these areas have turned into settlement and agricultural areas. While areas covered with vegetation within the boundaries of riparian area where stations 1, 2, 3 and 4 located were increasing, vegetation in areas where stations 5 and 6 located decreased. In rainy and dry periods especially in the regions where stations 4, 5 and 6 located, the values of BOD, NH_4, NO_3, TP, and WQI parameters increased and increasing trends in NO_3, TP, and WQI parameters were found as statistically significant. While there were positive correlations between residential areas and BOD, NH_4, TP and WQI parameters due to the increase in settlement areas, DO values showed negative trends in the specified time interval and negative correlations were obtained between residential areas and DO. BOD, NO_3 and TP parameters showed increasing trends in the mentioned time interval with the increase of agricultural areas and positive correlations between agricultural areas and especially NO_3 and TP parameters were found to be significant. LULC changes negatively affected water quality, especially in terms of NH_4, NO_3, TDS, and TP parameters.

When the soil types in the study area and the surface water quality data of 2008 and 2015 are evaluated together; positive correlations between alluvial soils and especially NO_3, TP and WQI parameters were found and alluvial soils in the study area negatively affected water quality. The slope group, which has the highest distribution in the study area (especially in stations 4, 5 and 6), is the slope group in the range of 0%–2% and this slope group negatively affected water quality in the study area.

5. Conclusion

This study shows the effects of LULC change, soil type and slope characteristics on surface water quality trends in the regions where surface water quality stations located within the boundaries of riparian area near Sivas city center. Results obtained from the study; LULC, soil types and slope variables have shown that have a very high impact on the deterioration of water quality. Considering the LULC changes; the increase of settlements and agricultural areas in the study area has affected the water quality negatively. Sewage and industrial discharges originating from residential and industrial areas have deteriorated water quality within the boundaries of riparian area. Fertilizers used together with the increase in agricultural areas will contaminate the river water together with the surface flow. On the other hand, the vegetation in the surface soil of agricultural land can also play an important role in the retention of pollutants. Areas covered with vegetation have played an important role in improving water quality. Alluvial soils that show a very high distribution within the boundaries of riparian area in the study area and 0%–2% slope group are other factors causing the deterioration of water quality. The impact of all three factors (LULC, soil type, and slope) on water quality can be better explained by riparian area boundaries obtained by micro-scale. In this study; there is a significant relationship between the LULC change, soil types and land slope on the one hand and the increasing trends of water quality parameters on the other. This relationship revealed that LULC change has been one of the most important factors affecting surface water quality.

Acknowledgements

I would like to thank the staff of the General Directorate of State Hydraulic Works (Ankara/Turkey), who helped us with water quality data.

References

[1] J. Pizarro, P.M. Vergara, J.A. Rodríguez, A.M. Valenzuela, Heavy metals in Northern Chilean Rivers: spatial variation and temporal trends, J. Hazard. Mater., 181 (2010) 747–754.

[2] S. Carpenter, N. Caraco, D. Correll, R.A. Howarth, V.S. Sharpley, Nonpoint pollution of surface waters, Ecol. Appl., 8 (1998) 559–568.

[3] A.Y. Zhang, Q. Wang, C. Wu, W. Ma, M. Zhou, K. Cao, Spatial and Temporal Analysis of Water Quality Trends in the Min River Basin, 2012 International Symposium on Geomatics for Integrated Water Resource Management, IEEE, Lanzhou, China, 2012, pp. 1–7.

[4] R.C. Ferrier, A.C. Edwards, D. Hirst, I.G. Littlewood, C.D. Wattsc, R. Morris, Water quality of Scottish Rivers: spatial and temporal trends, Sci. Total Environ., 265 (2001) 327–342.

[5] K.P. Singh, A. Malik, D. Mohan, S. Sinha, Multivariate statistical techniques for the evaluation of spatial and temporal variations in water quality of Gomti River (India): a case study, Water Res., 38 (2004) 3980–3992.

[6] S. Yıldız, C.B. Karakuş, Estimation of irrigation water quality index with development of an optimum model: a case study, Environ. Dev. Sustainability, (2019) 1–16, https://doi.org/10.1007/s10668-019-00405-5.

[7] K. Zeinalzadeh, E. Rezaei, Determining spatial and temporal changes of surface water quality using principal component analysis, J. Hydrol.: Reg. Stud., 13 (2017) 1–10.

[8] L. Claessens, C. Hopkinson, E. Rastetter, J. Vallino, Effect of historical changes in land use and climate on the water budget of an urbanizing watershed, Water Resour. Res., 42 (2006), doi: 10.1029/2005WR004131.

[9] S. Li, W. Liu, S. Gu, X. Cheng, Z. Xu, Q. Zhang, Spatio-temporal dynamics of nutrients in the Upper Han River Watershed, China, J. Hazard. Mater., 162 (2009) 1340–1346.

[10] C.B. Karakuş, Evaluation of groundwater quality in Sivas Province (Turkey) using water quality index and GIS-based analytic hierarchy process, Int. J. Environ. Health Res., 29 (2019a) 500–519.

[11] J.J. Rothwell, N.B. Dise, K.G. Taylor, T.E.H. Allott, P. Scholefield, H. Davies, C.A. Neal, Spatial and seasonal assessment of river water chemistry across North West England, Sci. Total Environ., 408 (2010) 841–855.

[12] J. Kibena, I. Nhapi, W. Gumindoga, Assessing the relationship between water quality parameters and changes in landuse patterns in the Upper Manyame River, Zimbabwe, Phys. Chem. Earth Parts A/B/C, 67 (2014) 153–163.

[13] H. Bu, W. Meng, Y. Zhang, J. Wan, Relationships between land use patterns and water quality in the Taizi River Watershed, China, Ecol. Indic., 41 (2014) 187–197.

[14] F. Kilonzo, F.O. Masese, A. Van Griensven, W. Bauwens, J. Obando, P.N. Lens, Spatial–temporal variability in water quality and macro-invertebrate assemblages in the Upper Mara River Watershed, Kenya, Phys. Chem. Earth Parts A/B/C, 67 (2014) 93–104.

[15] V.Z. Antonopoulos, D.M. Papamichail, K.A. Mitsiou, Statistical and trend analysis of water quality and quantity data for the Strymon River in Greece, Hydrol. Earth Syst. Sci. Discuss, 5 (2001) 679–692.

[16] R. Bouza-Deaño, M. Ternero-Rodríguez, A.J. Fernández-Espinosa, Trend study and assessment of surface water quality in the Ebro River (Spain), J. Hydrol., 361 (2008) 227–239.

[17] S.A. Hwang, S.J. Hwang, S.R. Park, S.W. Lee, Examining the relationships between watershed urban land use and stream water quality using linear and generalized additive models, Water, 8 (2016) 155.

[18] W. Sun, C. Xia, M. Xu, J. Guo, G. Sun, Application of modified water quality indices as indicators to assess the spatial and temporal trends of water quality in the Dongjiang River, Ecol. Indic., 66 (2016) 306–312.

[19] S.Y. Korkanç, S. Kayıkçı, M. Korkanç, Evaluation of spatial and temporal water quality in The Akkaya Dam Watershed (Niğde, Turkey) and management implications, J. Afr. Earth Sci., 129 (2017) 481–491.

[20] H.W. Lee, K.J. Bhang, S.S. Park, Effective visualization for the spatiotemporal trend analysis of the water quality in the Nakdong River of Korea, Ecol. Inf., 5 (2010) 281–292.

[21] M.E. Shoda, L.A. Sprague, J.C. Murphy, M.L. Riskin, Water-quality trends in US rivers, 2002 to 2012: relations to levels of concern, Sci. Total Environ., 650 (2019) 2314–2324.

[22] J. Abaurrea, J. Asín, A.C. Cebrián, M.A. García-Vera, Trend analysis of water quality series based on regression models with correlated errors, J. Hydrol., 400 (2011) 341–352.

[23] S. Giri, Z. Qiu, Z. Zhang, Assessing the impacts of land use on downstream water quality using a hydrologically sensitive area concept, J. Environ. Manage., 213 (2018) 309–319.

[24] H. Chang, Spatial analysis of water quality trends in the Han River Watershed, South Korea, Water Res., 42 (2008) 3285–3304.

[25] D.M. Whitaker, W.A. Montevecchi, Breeding bird assemblages along undisturbed shorelines and riparian buffer strips, J. Wildl. Manage., 63 (1999) 167–179.

[26] S.W. Vince, M.L. Duryea, E.A. Macie, A. Hermansen, Forests at the Wildland-Urban Interface: Conservation and Management, CRC Press, Boca Raton, London, New York, Washington, D.C., 2005.

[27] J. Klapproth, J. Johnson, Understanding the Science Behind Riparian Forest Buffers: Effects on Plant and Animal Communities, Virginia Cooperative Extension, Publication Number 420–152, Virginia Polytechnic Institute and State University, Virginia, 2009.

[28] R. Forman, M. Godron, Landscape Ecology, John Wiley & Sons, New York, 1986.

[29] K. Mello, R.A. Valente, T.O. Randhir, A.C.A. Dos Santos, C.A. Vettorazzi, Effects of land use and land cover on water quality of low-order streams in Southeastern Brazil: watershed versus Riparian Zone, Catena, 167 (2018) 130–138.

[30] X. Yang, S. Blagodatsky, M. Lippe, F. Liu, J. Hammond, J. Xu, G. Cadisch, Land-use change impact on time-averaged carbon balances: rubber expansion and reforestation in a biosphere reserve, South-West China, Ecol. Manage., 372 (2016) 149–163.

[31] National Resources Council (NRC), Riparian Areas: Functions and Strategies for Management, National Academy Press, Washington D.C., 2002.

[32] M.E. Baker, D.E. Weller, T.E. Jordan, Improved methods for quantifying potential nutrient interception by riparian buffers, Lands Ecol., 21 (2006) 1327–1345.

[33] B. Pratt, H. Chang, Effects of land cover, topography, and built structure on seasonal water quality at multiple spatial scales, J. Hazard. Mater., 209 (2012) 48–58.

[34] C.P. Tran, R.W. Bode, A.J. Smith, G.S. Kleppel, Land-use proximity as a basis for assessing stream water quality in New York State (USA), Ecol. Indic., 10 (2010) 727–733.

[35] J. Chen, J. Lu, Effects of land use, topography and socio-economic factors in river water quality in a mountainous watershed with intensive agricultural production in East China, PLoS One, 9 (2014) e102714.

[36] Z. Jia, J. Bian, Y. Wang, Impacts of urban land use on the spatial distribution of groundwater pollution, Harbin City, Northeast China, J. Contam. Hydrol., 215 (2018) 29–38.

[37] M. Sharifinia, B. Adeli, A.R. Nafarzadegan, Evaluation of water quality trends in the Maroon River Watershed, Iran, from 1990 to 2010 by WQI and multivariate analyses, Environ. Earth Sci., 76 (2017) 781.

[38] GDMRE, 1/25.000 Scale Digital Geology Map of the Study Area, General Directorate of Mineral Research and Explorations, Ankara, 2005.

[39] GCM, 1/25.000 Scale Digital Topographic Map of the Study Area, Ministry of National Defense, General Command of Mapping, Ankara, 2005.

[40] GDSP, 1/100.000 Scale Environmental Plan Map, Ministry of Environment and Urban Planning General Directorate of Spatial Planning, Ankara, 2015.

[41] GDVS, 1/25.000 Scale Digital Soil Map of the Study Area, Ministry of Food, Agriculture and Livestock, Ankara, 2001.

[42] S.M. Sadat-Noori, K. Ebrahimi, A.M. Liaghat, Groundwater quality assessment using the water quality index and GIS in Saveh-Nobaran Aquifer, Iran, Environ. Earth Sci., 71 (2014) 3827–3843.

[43] J. Yisa, T. Jimoh, Analytical studies on water quality index of River Landzu, Am. J. Appl. Sci., 7 (2010) 453.

[44] C.B. Karakuş, The impact of land use/land cover (LULC) changes on land surface temperature in Sivas city center and its surroundings and assessment of urban heat island, Asia-Pac. J. Atmos. Sci., 55 (2019) 669–684.

[45] C.E. Churches, P.J. Wampler, W. Sun, A.J. Smith, Evaluation of forest cover estimates for haiti using supervised classification of Landsat data, Int. J. Appl. Earth Obs. Geoinf., 30 (2014) 203–216.

[46] J.R. Anderson, E.E. Hardy, J.T. Roach, R.E.A. Witmer, Land Use and Land Cover Classification System for Use with Remote Sensor Data, US Government Printing Office, DC: U.S. Geological Survey, 1976, No. Professional Paper 964, Washington.

[47] P. Olofsson, G.M. Foody, S.V. Stehman, C.E. Woodcock, Making better use of accuracy data in land change studies: estimating accuracy and area and quantifying uncertainty using stratified estimation, Remote Sens. Environ., 129 (2013) 122–131.

[48] S.S. Rwanga, J.M. Ndambuki, Accuracy assessment of land use/land cover classification using remote sensing and GIS, Int. J. Geosci., 8 (2017) 611.

[49] N. Bakr, D.C. Weindorf, M.H. Bahnassy, S.M. Marei, M.M.E. Badawi, Monitoring land cover changes in a newly reclaimed area of Egypt using multi-temporal Landsat data, Appl. Geogr., 30 (2010) 592–605.

[50] A. Zhang, C. Zheng, S. Wang, Y. Yao, Analysis of streamflow variations in the Heihe River Watershed, Northwest China: trends, abrupt changes, driving factors and ecological influences, J. Hydrol.: Reg. Stud., 3 (2015) 106–124.

[51] K. Yenigün, M.U. Ülgen, Trends in maximum flow data in climate change axis and monitoring of impact on dam safety, Dicle Univ. Eng. Faculty Eng. J., 7 (2016) 343–354.

[52] D. Duhan, A. Pandey, Statistical analysis of long term spatial and temporal trends of precipitation during 1901–2002 at Madhya Pradesh, India, Atmos. Res., 122 (2013) 136–149.

[53] S. Yue, P. Pilon, G. Cavadias, Power of the Mann–Kendall and Spearman's Rho tests for detecting monotonic trends in hydrological series, J. Hydrol., 259 (2002) 254–271.

[54] T. Partal, E. Kahya, Trend analysis in Turkish precipitation data, Hydrol. Processes, 20 (2006) 2011–2026.

[55] T. Salmi, A. Maatta, P. Anttila, T.R. Airola, T. Amnel, Detecting Trends of Annual Values of Atmospheric Pollutants by the Mann–Kendall Test and Sen's Slope Estimates-the Excel Template Application Makesens, Publications on Air Quality, Finnish Meteorological Institute, 2002, pp. 1456–789X.

[56] R.O. Gilbert, Statistical Methods for Environmental Pollution Monitoring, Van Nostrand Reinhold, New York, 1987.

[57] J. Jaagus, Climatic changes in Estonia during the second half of the 20th century in relationship with changes in large-scale atmospheric circulation, Theor. Appl. Climatol., 83 (2006) 77–88.

[58] Y.S. Yu, S. Zou, D. Whittemore, Non-parametric trend analysis of water quality data of rivers in Kansas, J. Hydrol., 150 (1993) 61–80.

[59] H.B. Mann, Nonparametric tests against trend, Econometrica, 13 (1945) 245–259.

[60] M.G. Kendall, Rank Correlation Methods, Griffin, London, UK, 1975.

[61] M. Gocic, S. Trajkovic, Analysis of changes in meteorological variables using Mann–Kendall and Sen's Slope estimator statistical tests in Serbia, Global Planet. Change, 100 (2013) 172–182.

[62] M. Büyükyıldız, A. Berktay, Trend analysis of Sakarya Watershed precipitation using nonparametric tests, J. Faculty Eng. Arch. Selcuk Univ., 19 (2004) 23–38.

[63] R. Kumar, S. Singh, S.S. Randhawa, K.K. Singh, J.C. Rana, Temperature trend analysis in the Glacier Region of Naradu Valley, Himachal Himalaya, India, Geoscience, 346 (2014) 213–222.

[64] S. Bajpayee, R. Das, B. Ruj, K. Adhikari, P.K. Chatterjee, Assessment by multivariate statistical analysis of ground water geochemical data of Bankura, India, Int. J. Environ. Sci., 3 (2012) 870.

[65] C.R. Ramakrishnaiah, C. Sadashivaiah, G. Ranganna, Assessment of water quality index for the groundwater in Tumkur Taluk, Karnataka State, India, J. Chem., 6 (2009) 523–530.

[66] S. Tyagi, B. Sharma, P. Singh, R. Dobhal, Water quality assessment in terms of water quality index, Am. J. Water Res., 1 (2013) 34–38.

[67] S. Elfert, H. Bormann, Simulated impact of past and possible future land use changes on the hydrological response of the Northern German Lowland 'Hunte' catchment, J. Hydrol., 383 (2010) 245–255.

[68] A.L. De La Cretaz, P.K. Barten, Land Use Effects on Streamflow and Water Quality in the Northeastern United States, CRC Press, Boca Raton, FL, 2007.

[69] R. Wan, S. Cai, H. Li, G. Yang, Z. Li, X. Nie, Inferring land use and land cover impact on stream water quality using a bayesian hierarchical modeling approach in the Xitiaoxi River watershed, China, J. Environ. Manage., 133 (2014) 1–11.

[70] D. Ierodiaconou, L. Laurenson, M. Leblanc, F. Stagnitti, G. Duff, S. Salzman, V. Versace, The consequences of land use change in nutrient exports: a regional scale assessment in South-West Victoria, Australia, J. Environ. Manage., 74 (2005) 305–316.

[71] Z. Teixeira, H. Teixeira, J.C. Marques, Systematic processes of land use/land cover change to identify relevant driving forces: implications on water quality, Sci. Total Environ., 470 (2014) 1320–1335.

[72] X. Dai, Y. Zhou, W. Ma, L. Zhou, Influence of spatial variation in land-use patterns and topography on water quality of the rivers inflowing to fuxian lake, a large deep lake in the Plateau of Southwestern China, Ecol. Eng., 99 (2017) 417–428.

[73] M.N. Damanik-Ambarita, P. Boets, H.T.N. Thi, M.A.E. Forio, G. Everaert, K. Lock, P.L.S. Musonge, N. Suhareva, E. Bennetsen, S. Gobeyn, T.L. Ho, L. Dominguez-Granda, P.L.M. Goethals, Impact assessment of local land use on ecological water quality of the Guayas River basin (Ecuador), Ecol. Inf., 48 (2018) 226–237.

[74] M. Kändler, C. Seidler, Hydrochemical load in a small river following heavy rain events, Folia Geogr. Ser. Geogr. Phys. XL, 40 (2009) 27–32.

[75] M. Kändler, K. Blechinger, C. Seidler, V. Pavlů, M. Šanda, T. Dostál, J. Krása, T. Vitvar, M. Štich, Impact of land use on water quality in the upper nisa catchment in the Czech Republic and in Germany, Sci. Total Environ., 586 (2017) 1316–1325.

[76] A. Erol, T.O. Randhir, Watershed ecosystem modeling of land-use impacts on water quality, Ecol. Modell., 270 (2013) 54–63.

[77] J.G. Arnold, R. Srinivasan, R.S. Muttiah, J.R. Williams, Large area hydrologic modeling and assessment part i: model development, J. Am. Water Resour. Assoc., 34 (1998) 73–89.

[78] C. Richards, L.B. Johnson, G.E. Host, Landscape scale influences on stream habitats and biota, Can. J. Fish. Aquat. Sci., 53 (1996) 295–311.

[79] L. Sliva, D.D. Williams, Buffer zone versus whole catchment approaches to studying land use impact on river water quality, Water Res., 35 (2001) 3462–3472.

[80] J. Tu, Spatial variations in the relationships between land use and water quality across an urbanization gradient in the watersheds of Northern Georgia, USA, Environ. Manage., 51 (2013) 1–17.

[81] J. Huang, J. Zhan, H. Yan, F. Wu, X. Deng, Evaluation of the impacts of land use on water quality: a case study in the Chaohu Lake basin, Sci. World J., 2013 (2013), https://doi.org/10.1155/2013/329187.

[82] S. Ding, Y. Zhang, B. Liu, W. Kong, W. Meng, Effects of riparian land use on water quality and fish communities in the headwater stream of the Taizi River in China, Front. Earth Sci. Eng., 7 (2013) 699–708.

[83] R. Wang, T. Xu, L. Yu, J. Zhu, X. Li, Effects of land use types on surface water quality across an anthropogenic disturbance gradient in the upper reach of the Hun River, Northeast China, Environ. Monit. Assess., 185 (2013) 4141–4151.

[84] L. Ye, Q.H. Cai, R.Q. Liu, M. Cao, The influence of topography and land use on water quality of Xiangxi River in three gorges reservoir region, Environ. Geol., 58 (2009) 937–942.

[85] S.W. Lee, S.J. Hwang, S.B. Lee, H.S. Hwang, H.C. Sung, Landscape ecological approach to the relationships of land use patterns in watersheds to water quality characteristics, Landscape Urban Plann., 92 (2009) 80–89.

[86] T. Zhou, J. Wu, S. Peng, Assessing the effects of landscape pattern on river water quality at multiple scales: a case study of the Dongjiang River Watershed, China, Ecol. Indic., 23 (2012) 166–175.

[87] Y. Qu, X. Wang, L. Wang, A.N. Rousseau, Landscape influences on water quality in riparian buffer zone of drinking water source area, Northern China, Environ. Earth Sci., 75 (2016) 114.