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Presenting the Spatio-Temporal Model for Predicting and Determining Permissible Land Use Changes Based on Drinking Water Quality Standards: A Case Study of Northern Iran

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Abstract: Quantifying the effect of non-point source pollution from different land use types (e.g., agricultural lands, pastures, orchards, and urban areas) on stream water quality is critical in determining the extent and type of land use. The relationship between surface water quality as the primary source of drinking water and land use patterns in suburban areas with an accelerated pace of industrial development and progressive growth of population has drawn much attention recently. This study aims to determine the type and portion of the land use changes over three-time intervals from 2000 to 2015 in the Jajrood River Catchment (Tehran metropolis, north of Iran). We used satellite images of Landsat TM and ETM for 2005, 2010, and 2015 to analyze land use changes as a spatiotemporal model. According to the image processing and analysis, we classified the land uses of the study area into irrigated farming, orchards, pastures, and residential areas. In addition, we used temporal data from sampling stations to identify the relationship between land use and water quality based on a multivariate regression model. The analysis shows a significant correlation between the type and extent of land use and water quality parameters, including pH, Na^+, Ca^+, Mg^+, Cl^-, SO_4^{2-}, NO_3^-, and TDS. Pastures and residential areas had the highest impact on water quality parameters among all land use types. Besides, we have used the regression analysis results to determine the maximum permissible areas of each land use type. Consequently, effective management strategies such as land use optimization in catchment scale for this catchment and similar areas will help to consciously protect and manage the quality of drinking water resources.

Keywords: catchment; Iran; Jajrood River; spatiotemporal model; surface water quality

1. Introduction

Reduction in the water quality and pollution caused by human activities and spatiotemporal changes of various factors, such as land use in the catchment, has become a global crisis [1–3]. Water resources can be affected by climate and land use changes [3–5]. Land use changes at the catchment scale are among the most crucial factors influencing river water quality [6,7], which emitted various pollutions through runoff into the river's water [8,9]. The United Nations (UN) [10] states that 80% of the diseases in developing countries are transmitted by water. For example, contaminated water and poor sanitation are linked to the transmission of illnesses, including polio, cholera, diarrhea, dysentery, typhoid, and hepatitis A [11]. Therefore, land use changes must be controlled to properly manage the water resources in the river catchment [6].

Having access to previously recorded data can help researchers achieve statistical parameters to predict the possible effects in the future [12,13]. Because water quality is a worldwide concern, water quality assessments are being widely investigated [9,14–16]. In this regard, analyzing changes in the drainage catchments is essential in developing effective management strategies to preserve water resources [17–19]. Most water pollution issues are due to the population pressure and the intensification of economic activities in the drainage catchments, which has led to changing land use patterns [8,20,21]. As an example, the result of a study in China, Dongjiang River catchment, was accompanied by the investigation of the effects of changing patterns of land use on the quality of water in the base flow of the river and attempted to use multivariate statistical models [6]. An understanding of river hydromorphology and chemistry is essential for effective river management. It is, however, necessary to have a monitoring program that provides a representative and reliable estimate of river waters' quality due to temporal variations.

Liu et al. [22] evaluated the effects of riparian land use patterns on the summertime water quality in various rivers in Shanghai, China. Their findings imply a tenuous relationship between anthropogenic activities and water quality because green and residential spaces were found to be closer to those analyzed rivers than industrial and commercial land types. Accordingly, literature reviews have indicated that the water quality in the base flow strongly depends on the characteristics of the location and different land use types in the catchment [6,16,23]. Land use planning for water-quality security can be shown by examining the connections between land use, landscape design, and river water quality [24]. In developing countries (like Iran), some poor and remote areas without hydrometric station records make it challenging to quantify water quality. To the best of the authors' knowledge, no attempts were made to evaluate permissible land use changes based on drinking water quality in a semiarid region of the world.

In the Tehran metropolis (Iran) and surrounding areas, the Jajrood river is one of the primary sources of drinking water [25] and a water quality indicator in the management strategies of river water quality in terms of standards. Since the land use type can have either positive or negative impacts on the river water quality, it is necessary to define the role and contribution of each land use type on water quality and the authorized threshold to transform a maximum allocation of land use, especially in cases that the water supply goes through storage or use of direct transmission of rivers (e.g., Jajrood River) for drinking. The primary sources of water pollutants are divided into two groups: (a) point source pollution and (b) non-point source pollution [26,27]. Therefore, as the factors of production are identifiable, the type, amount, and location of pollutants emission from point sources such as factories, farms, and aquaculture to rural or urban runoff surfaces (such as a river or a dam) are actually can be controlled and harnessed by several ways [28]. However, this issue does not apply to non-point sources of pollutants, including the areas under different land uses such as forest, grassland, agriculture and the like, usually due to the uncertainty of the type, amount, location and pollutants entrance to runoff surface flows and even groundwater resources. Due to rainfall events in different land uses, contaminations are carried by surface runoffs and even sub-surface flows and enter into centered surface flows in streams and rivers [29].

Given the history of research and the existence of water stress in the world, especially in countries suffering from drought, such as Iran, proper management of water resources through the management of land around them, which directly affects water quantity and quality, is essential [30]. It is worth mentioning that the applied model and methods in this research are used in a different type of water resources research; Rostammiri et al. [31] analyzed the qualitative changes of groundwater resources via a spatial–temporal model. Their findings demonstrated that the extent of the earth's surface has altered through time, with a rise in urban land and a decline in agricultural and bare lands [31]. Therefore, by managing land uses in the catchment area, rivers can be protected, which are an essential source of drinking water supply and effective in the sustainability of a community. Hence, this research aimed to use the spatiotemporal analysis and multivariate regression models to predict and determine the relationship between land use changes on river water quality at the catchment level.

2. Materials and Methods

2.1. Study Area

The studied area is a part of the Jajrood River catchment (latitude of 35.46 to 36.30 N and longitude of 51.24 to 51.50 E) up to the input of the Latyan dam in the northeast of the metropolis of Tehran, capital of Iran (Table 1 and Figure 1). The average annual rainfall in the catchment is 711 mm, and the average annual temperature is 26 °C. Melting snow in the mountains of central Alborz increases the flow of the Jajrood River. The maximum and minimum precipitations in this catchment are in November (69.8 mm) and July (11.2 mm), respectively [32]. The highest and lowest temperatures are 42 °C in summer and −30 °C in winter [33]. According to the classification of the De Martonne index, the climate of the study area changes from downstream to upstream of the catchment, from a cold semi-arid to a very humid cold climate. Most of the winds in the region are southwest or south. From the morphological point of view, the Jajroud catchment is located in a mountain unit and has water erosion. The predominant soil texture in the area is clay-sand type [34]. The study area includes some faults and folds to the south [35,36]. The soil of this catchment consists of alluvial sediments, gravel, and sand. The highest altitude of the Jajrood catchment is 4000 m above sea level [36]. The main activities of agriculture and horticulture are located in the river's riparian zone and several villages and cities along the way [32,34].

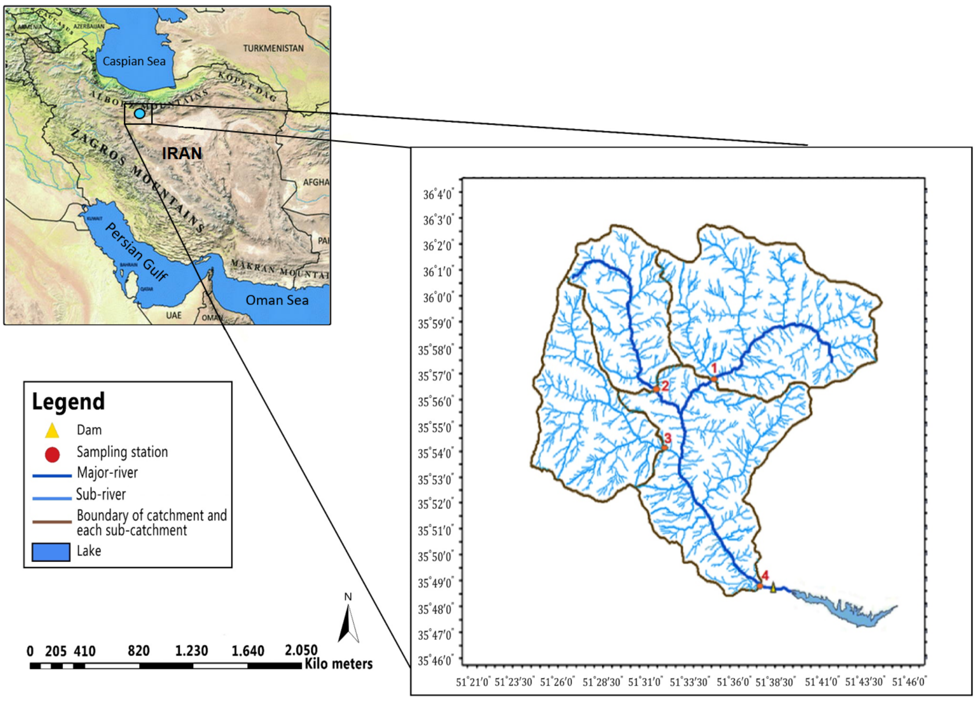

Figure 1. Location of the Jajrood catchment, and water quality sampling stations (1. Rooteh; 2. Meygoon; 3. Ahar; 4. Central Latyan).

Table 1. The sub-catchments extent.

Sub Catchments	Area (ha)
Rooteh	15,579.7
Meygoon	7124.4
Ahar	9266.8
Central Latyan	13,420.1
Total	45,390.9

2.2. Water Quality Data and Land Use Status

Due to the extent of the studied catchment and the different characteristics of each sub-catchment, this study was carried out using information from four hydrometric stations and measuring the water quality. The available annual average data from four sampling stations (Figure 1) from 2000 to 2015 (as a three-time intervals average in 5 years) were obtained from the Water Resources Research Center (TAMAB) [37]. These stations are located in densely populated areas and farms to monitor the water quality. Among the water quality parameters, according to Iran's National Standard for Drinking Water Quality (ISIRI 2009) [38] and the adequacy of available and reliable data, parameters of pH, Na^+, Ca^+, Mg^+, Cl^-, SO_4^{2-}, NO_3^-, and TDS were selected. After field sampling, to avoid microbial degradation, the samples were held at 4 °C in a refrigerator without acid preservation. The parameter of pH was measured using a Hach HQ40d portable meter (Düsseldorf, Germany). For the rest of the parameters, we used the APHA manual (1992) [39] to analyze the water samples in the Landlaboratory. Land use data in Jajrood catchment, including orchards, pastures, residential areas, and irrigated farming, has been processed and reviewed using the periodic method of remotely measuring using available satellite images of Landsat TM/ETM in three-time intervals of 2005, 2010, and 2015 with Arc GIS software (Ver. 10.3; ESRI, Redlands, CA, USA) [40]. All images were classified into the four above-mentioned land use classes. Cloud-free images were chosen during the summer season (i.e., July to August), when vegetation is at its peak productivity. We used images from the same season to minimize variations in reflectance between land use classes [41]. The percentage of land use of the available areas in the catchment scale is used to determine the permissible limit of use based on the drinking water quality in this river.

The catchment area of the Jajroud River, which is mainly the habitat of *Ovis gmelini* and *Capra aegagrus*, does not have a favorable vegetation cover due to the excessive use of cattle ranchers, but at high altitudes, the vegetation cover includes *Pistacia atlantica*, *Amygdalus orientalis*, and *Astragalus* Sp. Most orchards in the region have apple trees [34]. Irrigated farming lands cultivate some crops such as *Solanum melongena* L., *Solanum tuberosum* L., *Lycopersicum esculentum* L., *Cucumis sativus* L., *Allium cepa* L., and *Triticum aestivum* L. The orchards of this catchment have various types of fruits such as *Prunud domestica* L., *Armeniaca bulgar* L., *Prunus armeniaca* L., *Prunus cerasus* L., and *Pearpyrus communis* L. [42].

A heightened resident population on the edge of the river is a risk to the hygienic and environmental state that has direct and indirect effects on water quality. There are cesspools for residential areas' sewage discharge. However, topographic situations consist of a high slope of the ground, and the rock beds under the residential areas on the river's edge cause a division of sewage from underground layers to reach the river. All of the residential areas have been forced to use septic tanks for discharging their sewage, but it requires continuous oversight to reach a proper performance [43].

2.3. Data Analysis

This research uses descriptive statistics to analyze land use characteristics and river water quality parameters. To test water quality variables and land use parameters, we have conducted an analysis of variance; we have used SPSS software (Ver. 24.0) [44]. We have performed the Pearson correlation analysis to examine the relationship between different land use types and water quality variables at a significant level of 0.05 and

0.01. Then, a multivariate regression model was used to determine this relationship type. The water quality was considered as a dependent variable to evaluate the effects of land use changes in the catchment. To determine the best model for predicting each variable, we compared the regression equation with R^2 and indicated that the amount of change in the dependent variable could be described by changes in the independent variables. The relationships between spatiotemporal variables (land use pattern types) and the use of drinking water quality parameters based on the national standard of Iran have been determined by solving a multivariate regression model. This way, we determined the maximum permitted area of land use, causing no pollution and no changes in the river's water quality in the spatiotemporal range.

Sensitivity analysis is primarily conducted to ascertain how the change in model variables impacts the model output [45,46]. Sensitivity is often assessed by a relatively small change in a parameter from its prediction [31]. The constant amount of 9% was considered as the change in the regression model variables (i.e., residential area and pastures) to do sensitivity analysis for this study. Overall, 9% was added to them in 2015 to assess how sensitive water quality measures were to changes in the pasture. The residential neighborhood was left unchanged at the same time. The parameters for determining water quality were then determined using the updated land use percentages. A similar process was used for the sensitive residential area change.

3. Results

3.1. Descriptive Analysis

Table 2 shows that the mean value of physicochemical parameters of water quality in three-time intervals in the area in the second period increased, but this amount except pH and NO_3^- decreased in the third period. Therefore, based on Iran's National Standard for Drinking Water Quality (ISIRI 2009) [38], all quantified parameters are within permissible limits.

Table 2. Mean of physicochemical parameters of water quality in three-time intervals.

Sampling Stations	Time Intervals (Year)	pH	TDS (mg/L)	Na^+ (mg/L)	Mg^+ (mg/L)	Ca^+ (mg/L)	SO_4^{2-} (mg/L)	Cl^- (mg/L)	NO_3^- (mg/L)
Rooteh	2005–2000	8.04	144.18	0.19	0.73	1.58	0.56	0.15	4.40
	2010–2005	7.91	152.81	0.16	0.65	1.96	0.59	0.22	3.80
	2015–2010	8.19	147.52	0.23	0.67	1.79	0.62	0.22	4.32
Meygoon	2005–2000	7.80	317.93	1.25	1.71	2.28	1.46	0.72	4.00
	2010–2005	7.85	383.97	1.67	1.68	3.35	1.97	1.16	4.60
	2015–2010	7.86	319.96	1.17	1.62	2.78	1.49	0.81	4.44
Ahar	2005–2000	7.78	3136.77	32.15	9.61	9.46	29.83	17.00	3.40
	2010–2005	7.61	4912.89	45.34	15.28	9.93	35.73	27.44	3.60
	2015–2010	7.64	2172.50	17.88	6.63	7.73	16.37	10.16	4.44
Central Latyan	2005–2000	7.85	216.13	0.47	0.86	2.35	0.78	0.46	3.14
	2010–2005	7.86	196.26	0.37	0.76	2.38	0.75	0.33	4.40
	2015–2010	8.07	206.46	0.56	0.83	2.35	0.89	0.46	5.10
Jajrood Catchment	2005–2000	7.87	953.75	8.52	3.23	3.92	8.16	4.58	3.74
	2010–2005	7.81	1411.48	11.89	4.59	4.40	9.76	7.29	4.10
	2015–2010	7.94	711.61	4.96	2.44	3.66	4.84	2.91	4.58

The results show that most of the spatial and environmental changes in the catchment area of the Jajrood River have taken place upstream of this catchment (Tables 2 and 3; Figure 2). According to the land use position results at the three-time points based on ETM and TM Landsat images and their comparison with field measurement results, there are four different types of land use in the study area: orchards, irrigated farming, pastures, and residential areas. During the 15 years (2000 to 2015), the land use of the study area was determined and explained (Figure 2). According to the area statistics data in Table 3 and Figure 2, it is apparent that in all three periods, the extent of orchards and irrigated farming lands decreased, and the extent of pastures and residential areas increased. In fact, irrigated farming lands had the least land use in all three-time points, 0.3% in 2005 vs. 0.2% in 2015. Orchards in 2005 included 9.0% (equals 4087.2 ha) of the area, and in 2015, it included 6.3% of the area (2844.8 ha). During the study period, pastures occupy most of the area, covering over 90% of it, so animals like rams, sheep, and goats farm there. From 2005 to 2015, the above-mentioned land use was increased with a certain trend. In 2005, it included 89.4% equals 40,574.1 ha of the area and in 2015, it included 90.3% of the area, 40,996.4 ha. Additionally, residential areas land use has been increasing, so that in 2005 was 1.3% equals 602.65 ha and it got 3.2% (1474.6 ha) in 2015. Therefore, periodical land use changes as spatial and temporal variables have significant, meaningful, and often temporary effects on water quality that directly depend on the size and location of sub-catchments as independent ecosystems (Figure 2).

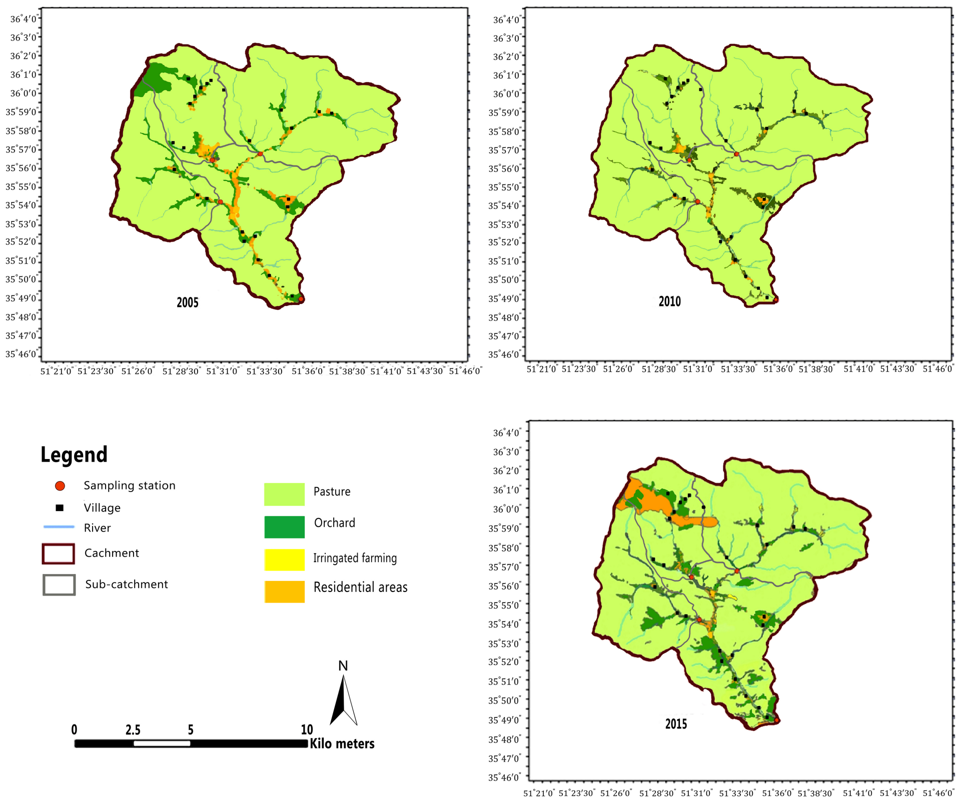

Figure 2. Land use map for the Jajrood catchment during study period.

Table 3. Periodic comparison of land use change in the Jajrood catchment and sub-catchments.

Sub-Catchments	Land Use	Year						The Trend of Changes in Land Use Area (ha)	
		2005		2010		2015			
		Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)	2005–2010	2010–2015
Rooteh	Orchard	471.8	3	513	3.3	479	3.1	Increasing 41.2	Decreasing 34.0
	Irrigated Farming	33.3	0.2	2.5	0	70.7	0.5	Decreasing 30.9	Increasing 68.2
	Pastures	15,048.9	96.6	15,000.1	96.3	14,854.4	95.3	Decreasing 48.8	Decreasing 145.7
	Residential Areas	25.6	0.2	64.1	0.4	175.6	1.1	Increasing 38.5	Increasing 111.5
Sum		15,579.7	100	15,579.7	100	15,579.7	100	-	-
Meygoon	Orchard	1192.7	16.7	881.7	12.4	495.5	7	Decreasing 311.0	Decreasing 386.3
	Irrigated Farming	16.9	0.2	5	0.1	3.4	0	Decreasing 11.9	Decreasing 1.6
	Pastures	5564.5	78.2	5567.6	78.1	5514.7	77.4	Decreasing 3.0	Decreasing 52.8
	Residential Areas	350.3	4.9	670.1	9.4	1110.8	15.6	Increasing 319.9	Increasing 440.7
Sum		7124.4	100	7124.4	100	7124.4	100	-	-
Ahar	Orchard	463.4	5	574.2	6.2	781.4	8.4	Increasing 110.8	Increasing 207.2
	Irrigated Farming	0	0	157.3	1.7	0	0	Decreasing 157.3	Decreasing 157.3
	Pastures	8787.9	94.8	8522.4	92	8367.5	90.3	Decreasing 265.5	Decreasing 154.9
	Residential Areas	15.4	0.2	12.9	0.1	117.9	1.3	Decreasing 2.6	Increasing 105.1
Sum		9266.8	100	9266.8	100	9266.8	100	-	-
Central Latyan	Orchard	1959.2	15	1350	10	1089	8	Decreasing 609.3	Decreasing 261.0
	Irrigated Farming	76.8	1	3	0	1	0	Decreasing 73.8	Decreasing 2.0
	Pastures	11,272.8	83	11,969.9	89	12,059.9	90	Increasing 697.1	Increasing 89.9
	Residential Areas	111.3	1	97.2	1	270.2	2	Decreasing 14.1	Increasing 173.0
Sum		13,420.1	100	13,420.1	100	13,420.1	100	-	-
Jajrood Catchment	Orchard	4087.2	9	3318.9	7.3	2844.8	6.3	Decreasing 768.3	Decreasing 474.1
	Irrigated Farming	127	0.3	167.8	0.4	75.1	0.2	Increasing 40.8	Decreasing 92.7
	Pastures	40,574.1	89.4	41,060	90.5	40,996.4	90.3	Increasing 485.8	Decreasing 63.6
	Residential Areas	602.7	1.3	844.3	1.9	1474.6	3.2	Increasing 241.6	Increasing 630.3
Sum		45,390.9	100	45,390.9	100	45,390.9	100	-	-

3.2. Regression Results

We have developed multivariate regression models to establish the maximum permissible land use types based on simulating the interaction between spatiotemporal variables and water quality measurements. The maximum recommended area of each type of land use that affects water quality has been estimated using information from Iran's National Standard for Drinking Water Quality (ISIRI 2009) [38] (see Tables 4 and 5). Our simulations have shown that the most critical link between various land uses has been found. The land use changes in three levels in time alignment with existing satellite imagery indicated a correlation and a strong correlation between land use and water quality parameters. Our analysis shows that the relationship between land use and water quality parameters is discernible.

Since our model shows the most significant relationship between pastures and residential areas, there is no possibility of changing the area and reducing the land share at the area's level to prevent social challenges such as social conflicts due to the replacement of residential areas. Therefore, the existing situation must be maintained to preserve the river's water quality, and only in this situation will there be a possibility to change the use of the pasture. This way, the pasture can be converted to other uses, such as orchards and irrigated farming, as these uses do not affect water quality at the main catchment.

Table 4. Multivariate regression model in Jajrood catchment.

Multivariate Regression Model	Independent Variables *	Dependent Variable	R^2	*p*-Value
pH = −16.758 + 0.101 PA + 0.085 RA	PA, RA	pH	0.884	0.012
TDS = −57,018.252 + 654.820 PA − 437.620 RA	PA, RA	TDS	0.836	0.018
Cl^- = −346.607 + 3.968 PA − 2.759 RA	PA, RA	Cl^-	0.812	0.023
SO_4^{2-} = −277.802 + 3.246 PA − 3.285 RA	PA, RA	SO_4^{2-}	0.809	0.023
NO_3^- = −7.145 + 0.116 PA + 0.387 RA	PA, RA	NO_3^-	0.766	0.035
Na^+ = −314.598 + 3.627 PA − 2.950 RA	PA, RA	Na^+	0.790	0.025
Mg^+ = −171.392 + 1.973 PA − 1.350 RA	PA, RA	Mg^+	0.774	0.033
Ca^+ = −57.077 + 0.689 PA − 0.463 RA	PA, RA	Ca^+	0.800	0.024

* (PA) Pasture; (RA) Residential Area.

Table 5. Maximum permissible land use types in Jajrood catchment.

Permissible Area of Pasture (ha)	Permissible Area of Pasture (%)	Permissible Area of Residential Areas (ha)	Permissible Area of Residential Areas (%)	Water Quality Permissible Limit (mg/ l)	Multivariate Regression Model
1471.3	9.92	79.5	−10.34	6.5–9	pH = −16.758 + 0.101 PA + 0.085 RA
1074.8	7.25	86.92	−11.3	1500	TDS = −57,018.252 + 654.820 PA − 437.620 RA
1213.5	8.19	−11.23	1.46	400	Cl^- = −346.607 + 3.968 PA − 2.759 RA
1691.7	11.41	−34.22	4.45	400	SO_4^{2-} = −277.802 + 3.246 PA - 3.285 RA
5412.2	36.51	34.2	−4.45	50	NO_3^- = −7.145 + 0.116 PA + 0.387 RA
1341.2	9.05	73.85	−9.6	200	Na^+ = −314.598 + 3.627 PA − 2.950 RA
1111.1	7.49	−516.1	67.11	30	Mg^+ = −171.392 + 1.973 PA - 1.350 RA
1509.2	10.18	−481.95	62.67	300	Ca^+ = −57.077 + 0.689 PA − 0.463 RA

3.3. Sensitivity Analysis of Land Use Change and Water Quality

The results of the sensitivity test and its analysis show that the use of the pasture has dramatically increased in relation to the change of the TDS parameter and increase, which indicates its greater sensitivity (Table 6). Based on this, the following scenarios can be predicted:

A- With the increase in pastures and residential areas extent in the study catchment area, the TDS values of the river water will exceed the permissible limit.

B- The increase of other drinking water quality parameters in this catchment area occurs when the extent of residential areas increases.

Table 6. Sensitivity analysis of regression model in Jajrood catchment.

Water Quality Parameters	Values of Water Quality Parameters for Residential Areas Change (mg/L)	Values of Water Quality Parameters for Pastures Area Change (mg/L)
pH	8.7	7.0
TDS	3139.4	6408.5
Cl^-	21.4	37.4
$SO_4{}^{2-}$	22.5	34.8
$NO_3{}^-$	8.0	3.1
Na^+	22.5	35.0
Mg^+	9.4	19.6
Ca^+	0.4	9.7

4. Discussion

The results confirm the validity of the results of the research conducted by Donohue et al. [47] and Huang et al. [48], indicating the importance and effectiveness of the two components of the characteristics and the precipitation in accordance with the location of their catchment on the one hand and the type, extent, and status of land use change in a location and time on the other hand. The results of this study are in the context of the previous literature reviews. It has been suggested that reducing the surface waters quality has an irrefutable relationship with the expansion of rural areas, agricultural, industrial, and tourism activities at the upper catchment of rivers supplying dams (e.g., Baoying and Yuanqing [49], Józwiakowski et al. [50], Bahroun and Chaib [51], Wang and Kalin [52], Rimba et al. [53]). A 283% increase in stream nitrate was observed as a result of conversion from forests to agricultural lands [54]. According to Baoying and Yuanqing [49], an enormous development in tourist infrastructure will negatively impact water quality. Brontowiyono et al. [55] showed that different land uses in Indonesia significantly correlate with contaminant sources. In addition, all parameters of the study showed an increase in the water quality trend based on concentration values. Eighty-seven percent of urban land use causes significant water pollution, according to Camara et al. [56]. Moreover, as demonstrated by Park et al. [57], riparian land use types influence stream-based biological communities more than riparian land use patterns.

Different levels of tourism-related water quality interference were reported by Wang et al. [58], mostly in terms of the makeup of the bacterial community. The reductions in the surface waters quality are mainly caused by the destruction of the catchment's ecological balance, environmental pollution, and intensification of water quality reduction in reservoir dams. In principle, there is no doubt that dealing with these challenges requires an overall view and multidisciplinary approach to manage the land in the area and the entire catchment of dams [59].

Due to land use change, land degradation may affect soil degradation, affecting the biogeochemical cycles [60–62]. The consensus of the experts has been involved in the impact of actions and activities of the human factor, particularly land use changes, by converting natural areas such as meadows, pastures, and forests [63]. Various land use types have remarkable impacts on ecohydrological processes, biogeochemical cycles, pollution generation, and transport on surface water [64,65].

For example, agricultural land can increase the concentration of non-point source pollution in adjacent areas of rivers by applying fertilizers and pesticides [66,67]. Most fertilizers used in agricultural land cover are not absorbed by plants; instead, they can build up in soils, volatilize and release gases into the atmosphere, or wash into streams or groundwater supplies [68]. Urban areas impact water quality because of high pollutant discharge, increasing suspended solids, nutrients, and metals in surface waters [52]. While increasing bare land areas, deforestation will decrease water storage capacity, rainfall interception loss, and soil and water conservation of the forest canopy [69]. Deforestation also increases the runoff and sediment volume, affecting the pollutant load [70]. In other words, due to reduced rain retention capacity, runoff and erosion are dramatically increased [71]. According to Bu et al. [72], the forest land was the most appropriate land use to improve river water quality in China. In another study, Nafi'Shehab et al. [73] concluded that the un-fragmented forest can improve water quality and reduce pollutants' release. A study by Huang et al. [48] has found that residential growth is also associated with an increase in domestic sewage discharge, which can reduce the quality of water by significantly adding nutrients to it. Petersen et al. [74] investigated how variations in land use affected the quality of surface water and came to the conclusion that there is a strong link between land use and water quality. With the above description, non-point sources pollutions, considering water quality degradation, include any water quality degradation that reduces its value for humans and nature; it can be concluded that non-point quality reducing sources consist of various independent variables such as spatial, temporal and spatiotemporal, in which the land use type as an independent spatiotemporal variable is of particular importance.

However, due to the heterogeneity between the spatial characteristics of the surface runoff production zones (catchment as independent natural ecosystems), it is necessary, depending on the spatial and temporal conditions and even the climatic, socio-economic, cultural, and environmental characteristics, the abstract analysis is performed, and regional application models are presented. Our sensitivity test results showed that pasture land use has dramatically increased the change in the TDS parameter. This finding is in line with other researchers [75–78]. Similar to our finding, Adeola Fashae et al. [79] showed a remarkable variation of TDS in surface water across the land use types, with the residential areas having the greatest TDS. There are a number of sociocultural factors responsible for high TDS levels in residential areas, including the inappropriate disposal of household water into water channels, excessive fertilizer use by farmers on floodplains, and uncontrolled effluent discharges. It should be noted that a majority of TDS is composed of inorganic salts (e.g., sulfates, chlorides, bicarbonates, carbonates, magnesium, sodium, potassium, and phosphates) [80].

Furthermore, Lee et al. [81], based on their research findings, emphasized that depending on the spatial characteristics of the catchment and different land use types in different intervals in their range, water quality changes in the rivers, hence because of different environmental characteristics of each catchment and the heterogeneity of spatiotemporal variations in them, the results cannot be the same. In other words, the results are always relative.

In addition, we found that multivariate linear regression models provided simple but useful analytical methods for predicting water quality in various land uses. For routine water quality monitoring in river basins, these models can be used to select a few appropriate parameters to minimize management costs. This finding is in line with previous research [82].

Access to water microbiological data and other physical and chemical parameters was not possible in this study (first limitation). Therefore, we suggest that future studies include microbiological indicators in addition to chemical parameters because the primary cause of human sickness is connected to microbiological water pollution.

Although multivariate linear regression model is an effective approach for identifying land use change and surface water quality, this model does not appear to quantitatively estimate the contribution of respective land use intensity on the surface water quality because they are based on mechanistic relationships between sources and receptors (second limitation). Hence, we suggested that future research will focus on understanding the exact mechanisms of the effect of land use intensity on surface water quality by adopting an alternative "sources-receptors model".

5. Conclusions

We concluded that in the catchment of the rivers such as the studied area, the change in water quality is a function of the type and extent of land use in spatiotemporal areas of different catchments, but the effect of land use change is not the same on changing the amount and the type of water quality parameters. Our findings revealed that the independent variables influencing water quality are spatial variables with almost constant values. These independent variables include slope, aspect, elevation, geological characteristics and formations, soil properties, and geomorphology. These variables are predominant in permanent rivers like the Jajrood River. However, the results show that the types and extents of land use as spatiotemporal variables resulting from human activities significantly impact water quality. In this regard, pastures and residential areas had the highest impact on water quality parameters among all land use types.

In addition, we presents a model to determine the maximum permissible areas of each land use type to develop effective management strategies for this catchment. To decrease and manage water stress or scarcity, we suggested that all countries, especially in arid and semiarid climate zones, should identify the effects of different land uses to evaluate cause-effect responses to land use changes.

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