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The Impacts on Water Quality Parameters of Different Land Uses On Catak Formation: Case of Galyan Dam, Trabzon

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Abstract
Galyan-Atasu dam was built to supply with drinking, using, and industrial water needs of Trabzon and its surroundings. Surface water quality of the streams that feed the dam watershed are under the impact of land uses. This study was conducted to indicate the effect of different land uses to some water quality parameters of the river waters. In the study, a total of 6 sub-watersheds were selected in lower Galyan watershed. Land use (agricultural land, coniferous forests, broad-leaved forests and grassland) of research area was determined using Quick-Bird satellite imagery and forest management map. Over time period 2010 - 2011, water samples were obtained and analyzed for some water quality parameters in order to research their spatio-temporal variability in especial the relationship with land uses. Analysis of variance (ANOVA) showed significant spatial variability in pH, electrical conductivity (EC), total nitrogen (TN), Ca^{++} and K^{+} across sub-watersheds.
Statistical analyses (correlation, regression) by analyzing the average values of the water quality parameters and different land uses patterns revealed that agricultural land was significantly correlated pH and TN, grassland was correlated pH, EC, TN and Ca^{++}, coniferous forest was correlated pH, EC, Ca^{++}, Mg^{++} and K^{+}, broad-leaved forest was correlated pH, TN and K^{+}. The research could provide important informations in sustainable land use for water resource conservation for the dam watershed.

Keywords: Galyan dam, Catak formation, sub-watersheds, land use, water quality parameters

1. Introduction

Water is an ecological product and river water quality is controlled by numerous ecological factors. These ecological factors affect positively or negatively the quality of river waters in watersheds. Anthropogenic land uses and natural land covers host numerous ecological factors in their structures. Recently, researchers have focused on how land uses affect the water quality in the water quality studies. Increase of human impacts in the watersheds can reduce the quality of river waters by increasing of pollution (Richards et al. 1996; Roth et al. 1996; Wang et al. 1997; Fisher et al. 2000; Rhodes et al. 2001; Sliva & Williams 2001; Sponseller et al. 2001; Wittmer et al. 2010). To search in watersheds informs about river water quality for watershed management plans.
Several protected areas are determined according to the Water Pollution Control Regulation (TMEF 2004) in order to protect dam reservoir that supply drinking water against a veriety of pollutants. Therefore, 4 protection areas are described beginning from the maximum water level of the reservoir. These are: absolute (100m), short-distance (1 km), medium-distance (2 km) and long-distance watershed protection area (entire watershed) (Nisanci et al. 2007).
The aim of this study is to reveal the relationship between some water quality parameters and different land uses (agricultural land, grassland, broad-leaved forests and coniferous forests) on Catak geological formations of Galyan-Atasu dam watershed providing drinking water to Trabzon, Turkey. In addition,

water quality parameters determined in the selected sub-watersheds were compared by analysis of variance. This study was carried out on the stream arms near the dam reservoir. Water sampling points in sub-watersheds are in long distance protection area but they are away 1 - 7 km to medium-distance protection area. Because of filling of the dam reservoir in 2011, the results of this study were evaluated in terms of the possible effects of land use on water quality in the future.

2. Study Area

Galyan-Atasu dam which began to fill in 2011 was constructed in order to supply with drinking, using, and industrial water needs of Trabzon and its surroundings during 35 years. Galyan stream joins to Değirmendere River, which flows into the sea at downtown, at approximately the 17th km from the shore. Galyan stream watershed is 12.888,17 ha. Study area on the Catak geological formation of Galyan watershed is 3690.6 ha (GDF 2011). Study area is between 39º 39' – 39º 43' east longitudes and 40º 46' – 40º 49' north latitudes (Fig. 1). The sub-watersheds, which geomorphologically have the characteristic of high mountainous terrain, are in the nature of generally perpendicular and from place to place steep rocky terrain. Average altitudes of the sub-watersheds change between 520 m and 1850 meters (Usta 2011).

In determining the type of climate of the research area, Trabzon meteorology station data (1950-2015) were used. According to Thornthwaite climate analysis (Thornthwaite 1948), the research area is in the climate type of "semi-humid, at medium temperature (mesothermal), moderate water deficient in summer, close to the ocean climate indicated by C2B'2sb'4" symbol".

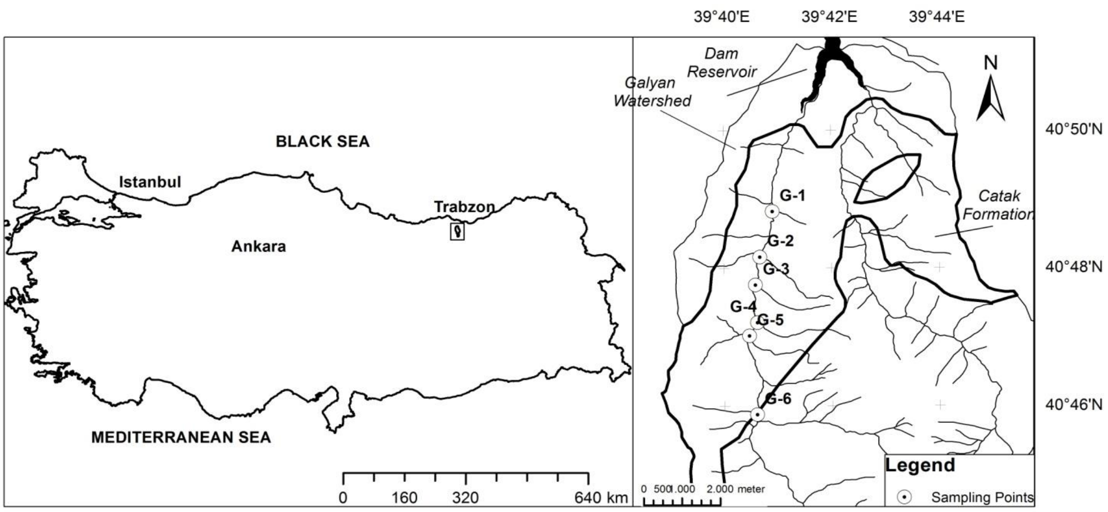


Figure 1. Location of research area

In the Catak geological formation outcrops basalt, andesitic lava and pyroclastics, sandstone, siltstone, marn, shale and alternation of red-burgundy-colored clayey limestone layer or levels (Guven 1993).

The study areas are located in the north of Colchis part of Euxine – Colchis flora area of world's flora zones' Holarctic zone according to Davis' (1988). Picea orientalis and Fagus orientalis are the dominant tree species in Galyan watershed (GDF 2011). In the sub-watersheds that have been chosen as the subject of the study, Picea orientalis dominates in coniferous forest areas and Fagus orientalis dominates in broad-leaved forest areas. Because of social pressure to Fagus orientalis forests in some sub-watersheds (G-1), Alnus glutinosa species are becoming dominant or entering easily to mix in time.

3. Methods

3.1. Land use analysis

High-resolution satellite imagery is commonly preferred today, since it facilitates determining land use (Forney et al. 2001; Forney et al. 2002). Updated land use status of sub-watersheds has been obtained from Quick-Bird satellite imagery of 0.6 m precision, shot in the year 2009. After the process of overlaying satellite images and topographic maps, land use of sub-watersheds has been categorized as coniferous forest, broad-leaved forest, agricultural land and grassland. ArcGIS 10.1 Desktop GIS software was used to determine the composition of land use. To reveal ownership status of study area were utilized from management plans.

3.2. Water sampling and analysis

Different methods are used for water samplings at watersheds with mixed land use in water quality works. In this study, water sampling has been done via sampling of stream arms (De La Crétaz and Barten 2007). Study has been done in a total of 6 sub-watersheds. The sub-watersheds in Galyan watersheds have been coded as G-1, G-2....... G-6 and some characteristics of these watersheds have been demonstrated on Table 1.

Table 1. Land use according to QuickBird satellite imagery and management plan of sub-watersheds

		MANAGEMENT MAP						Total
		Dominant Species (Ha)				Grassland (Ha)	Agricultural (Ha)	
	SUB_WATERSHEDS	Hornbeam	Beech	Alder	Spruce			
QUICKBIRD SATELLITE IMAGERY	**G1_Total**	19.3		46.1			12.1	77.5
	Agricultural land			0.5			5.4	5.9
	Broad_Leaved Forest	19.3		45.6			6.7	71.6
	G2_Total		17.7	19.5	50.3	3.5	89.1	180.1
	Coniferous Forest		11.3	13.3	34.1	2.9	16.1	77.7
	Grassland			1.1	5.5	0.6	34.5	41.7
	Agricultural Land		0.6	0.5	0.2		26.0	27.3
	Broad_Leaved Forest		5.8	4.6	10.5		12.5	33.4
	G3_Total	3.4	27.2	6.7		7.3	75.2	119.8
	Coniferous Forest	0.3	1.8	1.5		1.3	1.2	6.1
	Grassland	1.3	0.6	0.3		1.3	20.4	23.9
	Agricultural Land		0.7	0.4			31.4	32.5
	Broad_Leaved Forest	1.8	24.1	4.5		4.7	22.2	57.3
	G4_Total	2.0	35.3			48.8	20.8	106.9
	Coniferous Forest		2.3			0.6	0.1	3.0
	Grassland	0.2	1.9			39.3	4.8	46.2
	Agricultural Land		1.7			0.4	5.7	7.8
	Broad_Leaved Forest	1.8	29.4			8.5	10.2	49.9
	G5_Total		122.8		121.4	2.8	76.1	323.1
	Coniferous Forest		49.7		75.6	1.0	15.1	141.4
	Grassland		6.3		3.0	0.4	17.4	27.1
	Agricultural Land		0.3				13.4	13.7
	Broad_Leaved Forest		66.5		42.8	1.4	30.2	140.9
	G6_Total	33.7	68.7		42.7	7.6	14.9	167.6
	Coniferous Forest	2.5	16.0		22.5	1.4	0.3	42.7
	Grassland	0.7	0.5		1.2	3.1	0.6	6.1
	Agricultural Land	0.4	0.3				6.6	7.3
	Broad_Leaved Forest	30.1	51.9		19.0	3.1	7.4	111.5
							Coniferous Forest_Total	270.9
							Grassland_Total	145.0
							Agricultural Land_Total	94.5
							Broad_Leaved_Total	464.6
Total		58.4	271.7	72.3	214.4	70.0	288.2	975.0

Water samples were obtained at a depth of approximate 10 cm using polyethylene 0.5 L bottles (2 samples). Water samples have been preserved at +4 ºC in refrigerator by using reactives that conform to EPA (1983) standards to perform analyses. Water temperature (T), pH and electrical conductivity (EC) were determined on site using Orion 5 Star. Total nitrogen (TN) (0.5 - 15.0 mg/l N measuring range) and total phosphate (TP) (0.2 - 15.3 mg/l measuring range) have been determined via photometric method in UV-VIS Shimadzu 1800 brand device by using Spectroquant brand kits. Ca^{++}, Mg^{++}, K+ and Na^{+} cations have been measured by Shimadzu AA-6601 Atomic Absorption Spectrophotometer (APHA 1989).

3.3. Statistical analyses

Relationships between water quality parameters and land use ratios were tested using Pearson's correlation with statistical significance set priori at $p< 0.05$. Analysis of variance (ANOVA) was used to compare variations in water quality parameters of sub-watersheds under different land use with significance set at $p<0.05$ (Duncan). All the statistical analyses were applied using SPSS 16.0 for windows (SPSS 2011).

4. Results

4.1. Land use distribution

Areas covered with vegetation in the sub-watersheds are at ratios that vary between 49.5% and 92.5%. Land use in these watersheds varies as agricultural land (4.2% and 27.0%), grassland (4.1% and 43.2%), broad-leaved forest area (18.2% and 92.5%) and coniferous forest area (2.8% and 43.6%) (Fig. 2).

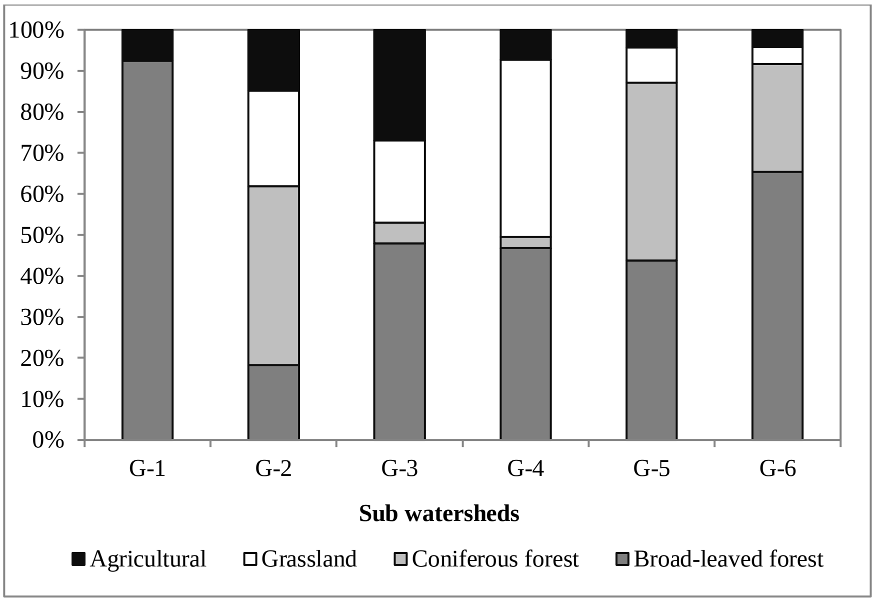


Figure 2. Percent of land uses in sub-watersheds

In order to reveal the status of land use of the sub-watersheds was used QuickBird satellite imagery. Satellite images reveal the current situation, but they do not give information about the ownership status. In Table 1 is given land use both the according to QuickBird satellite imagery and management map.

The amount of agricultural land and grassland according to QuickBird are 94.5 ha and 145.0 ha, respectively. However, the amount of agricultural land and grassland according to management plan are 288.2 ha and 70.0 ha, respectively. This case reveals a difference in the area of 193.7 ha as private ownership. QuickBird satellite imagery and management map were overlaid and it was seen that most of these areas has been assessed as grassland (75.0 ha) by the people living in the villages. The remaining areas, or the time to leave the territory of the people living in villages or stop the use, are where the return to the forest. In fact, the amount of land covered with vegetation according to the current situation increased 118.7 ha (Table 1).

4.2. Water quality parameters

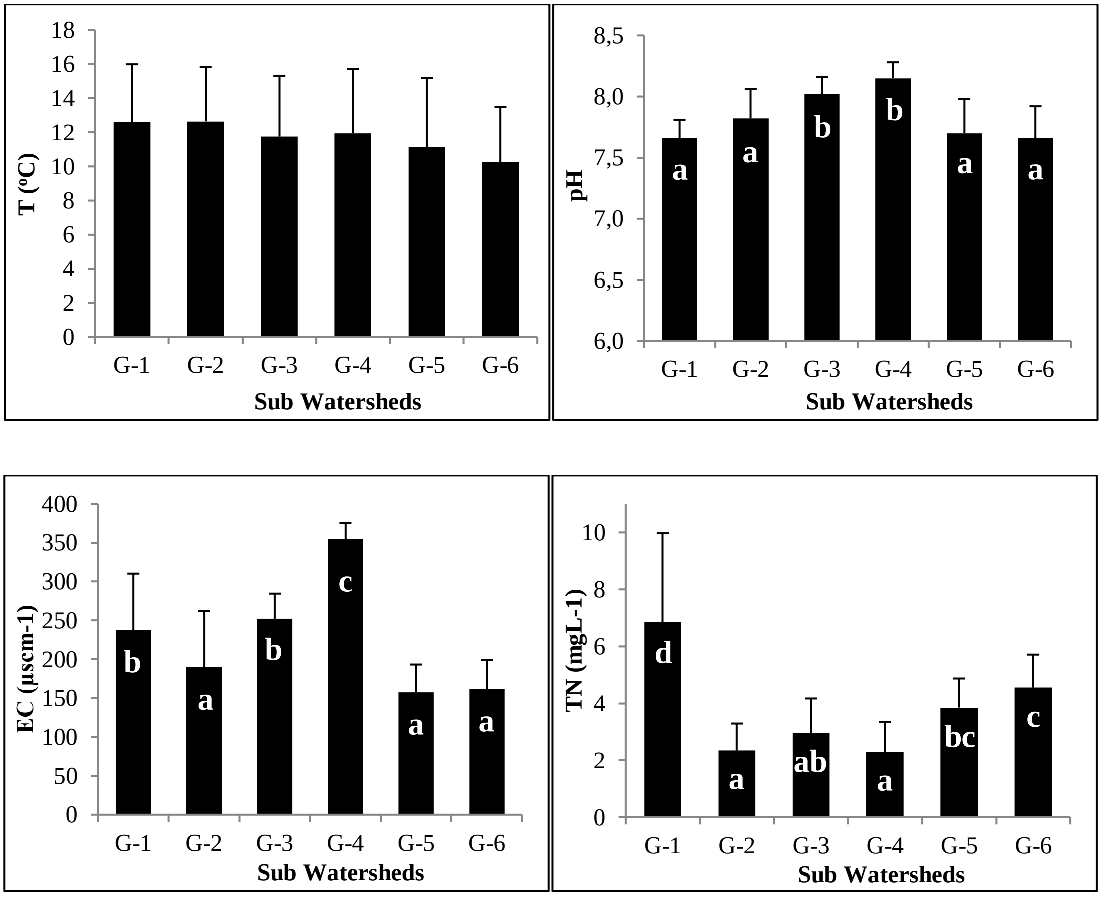
The average values of the water quality parameters measured in the stream waters of the sub-watersheds have been presented on Table 2 and Figure 3. Analysis of variance (ANOVA) indicated statistically significant differences in pH, EC, TN, Ca^{+2} and K^{+} across sub-watersheds. According to sub-watersheds, the average values of water quality parameters are given in Table 2.

4.3. Linking land use and water quality parameters

Correlation analyses between water quality parameters and different land use patterns revealed that agricultural lands were significantly correlated pH ve TN, grassland was significantly correlated pH, EC, TN and Ca, coniferous forest was correlated pH, EC, Ca, Mg and K, broad-leaved forest was correlated pH, TN and K (Table 3).

Table 2. Mean concentrations of water quality parameters

Water quality parameters	Sub-Watersheds					
	G-1	G-2	G-3	G-4	G-5	G-6
T (ºC)	12.60	12.64	11.75	11.95	11.13	10.24
pH	7.66	7.82	8.02	8.16	7.70	7.66
EC (µscm^{-1})	237.62	189.66	252.23	354.67	157.37	161.72
TN (mg/l)	6.86	2.34	2.96	2.28	3.85	4.55
TP (mg/l)	0.151	0.097	0.115	0.091	0.097	0.092
Ca^{++} (mg/l)	30.94	22.26	36.69	44.96	16.12	21.86
Mg^{++} (mg/l)	1.24	1.13	1.41	1.38	1.19	1.09
K^{+} (mg/l)	1.53	0.84	1.19	1.08	0.72	0.74
Na^{+} (mg/l)	1.47	1.49	1.46	1.23	1.38	1.29



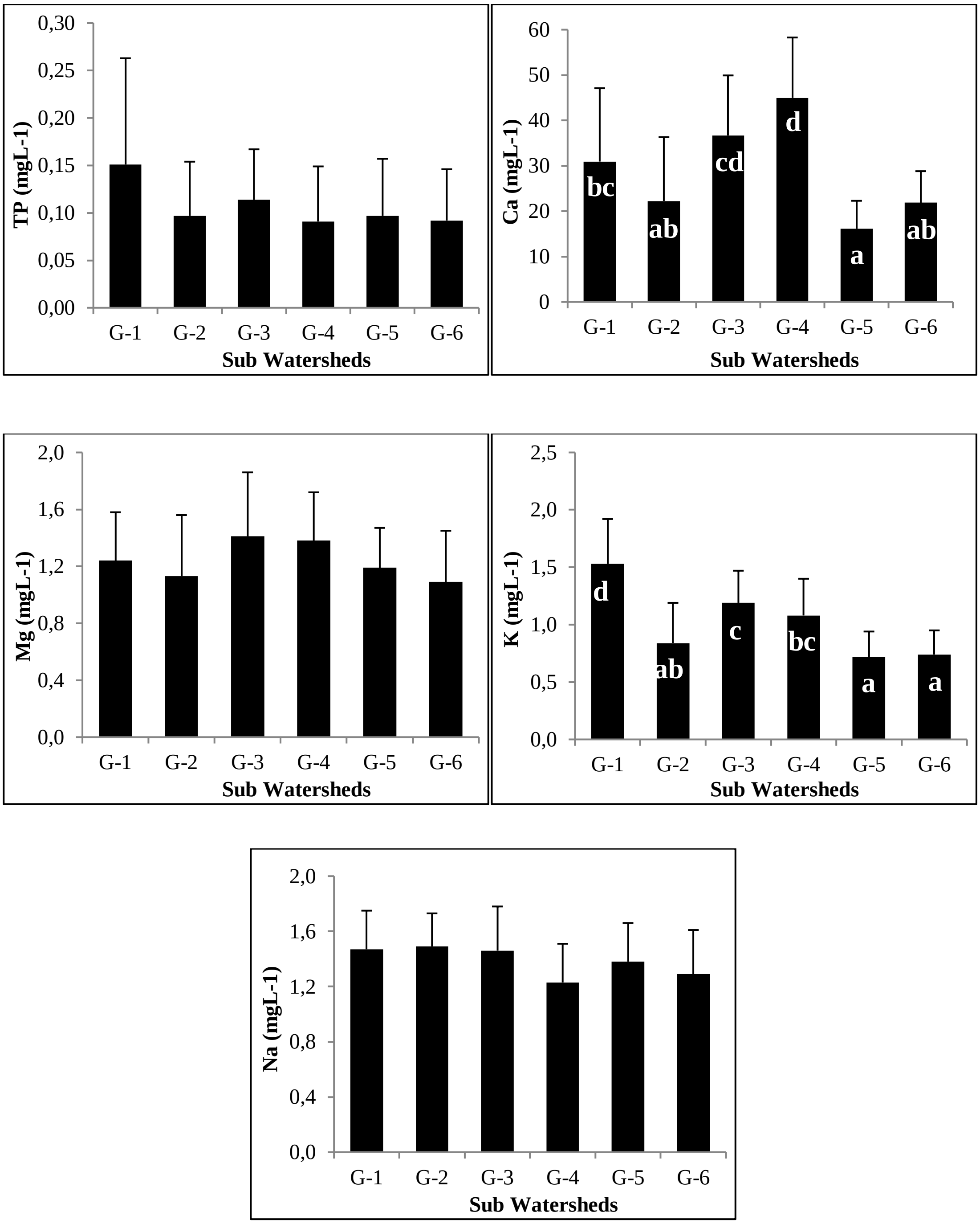


Figure 3. Water quality parameters of sub-watersheds

Table 3. Pearson correlation coefficients between land uses and water quality parameters

	Agricultural Land	Grassland	Coniferous Forest	Broad-Leaved Forest
T (°C)	0.084	0.069	-0.061	-0.024
pH	0.334[a]	0.641[a]	-0.306[a]	-0.278[b]
EC (µscm^{-1})	0.165	0.616[a]	-0.621[a]	0.056
TN (mg/l)	-0.278[b]	-0.591[a]	-0.208	0.647[a]
TP (mg/l)	0.047	-0.152	-0.168	0.218
Ca (mg/l)	0.224	0.425[a]	-0.549[a]	0.098
Mg (mg/l)	0.168	0.178	-0.236[b]	0.019
K (mg/l)	0.201	-0.047	-0.587[a]	0.440[a]
Na (mg/l)	0.188	-0.125	0.051	-0.029

a Significance at 0.01 probability level. b Significance at 0.05 probability level

Table 4. Stepwise multiple regression models for water quality parameters and land uses

Parameters	Independent variables	Regression equations	R^2	Adjusted R^2
pH	Grassland	7.632+0.012*GR	0.410	0.402
EC	Coniferous Forest, Grassland	223.881-2.356*CF+2.981*GR	0.649	0.639
TN	Broad-Leaved Forest	0.493+0.063*BLF	0.419	0.411
Ca	Coniferous Forest, Grassland	31.043-0.403*CF+0.358*GR	0.413	0.396
K	Coniferous Forest	1.280-0.013*CF	0.345	0.336

Stepwise multiple linear regression showed that no single land use type was able to describe the overall water quality, but most water quality parameters could be sufficiently predicted using one or two land use types (Table 4). pH (R^2: 0.402) could be predicted by grassland, EC (R^2: 0.639) and Ca (R^2: 0.396) by coniferous forest and grassland, TN (R^2=0.411) by broad-leaved forest, K (R^2: 0.336) by coniferous forest, respectively.

4. Discussions

Statistically significant results were obtained between measured water quality parameters (pH, EC, TN, Ca, Mg and K) according to correlation analysis, and land uses.

Liming reduces soil acidity and increases the availability of nutrients in the soil. However, with high rainfall and slopped areas, as is the case in the Black Sea region, calcium is quickly leached from the soil, and soils are commonly acidic (Demiryurek and Ceyhan 2008). For this reason, both pH of soil and pH of stream waters can increase with given agricultural lime against acidification and given fertilizers in the basic character in order to increase both nut farm and grass yield. The emergence of a statistically positive relationship between EC ($p<0.01$, 0.616) and Ca ($p<0.01$, 0.425) amounts of grassland and stream waters also support it. Although there is no a positive relationship between EC and Ca values of agricultural lands and stream waters, there is a positive trend (Table 3). Indeed, a large part of the grasslands (75.0 ha) according to management map was noted earlier as private ownership area (agricultural area) (Table 1). Increase of agricultural lands (Tong and Chen 2002) and grasslands (Jabbarian and Nakane 2009) in the watersheds can increase pH value of stream waters.

It was obtained statistically negative relationship between pH value of stream waters and both coniferous forest areas ($p<0.01$, -0.306) and broad-leaved forest areas ($p<0.05$, -0.278). It is stated that increase of forest cover in water production watersheds decreases pH value of stream waters (Tong and Chen 2002; Jabbarian and Nakane 2009).

The increase of algae population depending on the amount of nutrients, it shows its impact on especially lakes, river mouths or dam reservoirs (Mcmahon and Harned 1998). It was stated that being higher than 0.3 mg/l of TN concentration shows the algal growth potential (Vollenweider 1971). Additionally, it was stated that there needs to be lower than 0.1 mg/l of TP concentration in order to the prevention of algae explosion in stream waters (Mackenthum 1969; Harned et al. 1995). In this study, TN values in the sub-watersheds ranged from 2.28 to 6.86 mg/l, TP values in the sub-watersheds ranged from 0.091 to 0.151 mg/l. The highest values of average of TN and TP values have been measured in G-1 watershed (Table 2). Measured TN and TP values will be able to increase algae growth in stream waters and thus eutrophication. Work in sub-watersheds close to dam increases one more time the significance of it.

Although it wasn't emerged a statistically significance relationship between coniferous forest areas and

values of TN, it was determined a significance positive relationship ($p<0.01$, 0.647) between broad-leaved forest areas and values of TN. Similarly, there are also studies emphasizing that forest areas affected the amount of TN (Coulter et al. 2004; Ahearn et al. 2005; Li et al. 2008). It was found the highest average amount of TN in G-1 sub-watershed. G-1 watershed is covered with 92.5% broad-leaved forest areas and 7.5% agricultural lands. According to management map, alder stands generate approximately 60% of broad-leaved forest areas in G-1 watershed (Table 1). Alder stands can influence N concentrations of adjacent streams and lakes (Goldman 1961; Binkley et al. 1982; Stottlemyer and Toczydlowski 1999). Both nitrogen emerged from decomposition of alder litter and surplus nitrogen in the soil in research areas, by reaching to stream waters with the subsurface flow of rainwaters, can increase nitrogen concentration in water (Volk et al. 2003; Stieglitz et al. 2003; Cairns and Lajtha 2005). Ca is an important basic cation and it increases the hardness of the stream waters with Mg. It was found that there was statistically difference in among sub-watersheds according to amount of Ca^{++} in the stream waters (Fig. 3). The highest values of Ca^{++} was measured in G-4 (44.96 mg/l) and G-5 (16.12 mg/l) sub-watersheds compared to other sub-watersheds. In statistical analysis, a positive correlation was obtained between percentage of grassland and values of Ca^{++} ($p<0.01$, $r= 0.425$), a negative correlation was obtained between percentage of coniferous forest and values of Ca^{++} ($p<0.01$, $r= -0.549$). Effectiveness of percentages of grassland and coniferous forest in correlation analysis shows that there are contributions of these ecosystems on Ca^{++} concentration in the stream water. As stated earlier, made liming and fertilizing activities, in order to increase efficiency in agricultural lands and especially low-elevation grasslands, can increase amount of Ca^{++} in stream waters.
The highest values of Mg^{++} was measured in G-3 (1.41 mg/l) sub-watershed compared to other sub-watersheds. In statistical analysis, a negative correlation was obtained between percentage of coniferous forest and values of Mg^{++} ($p<0.05$, $r= -0.236$). It was found that there was statistically difference in among sub-watersheds according to amount of K+ in the stream waters (Fig. 3). The highest values of K^+ was measured in G-1 (1.53 mg/l) sub-watershed compared to other sub-watersheds. In statistical analysis, a negative correlation was obtained between percentage of coniferous forest and values of K^+ ($p<0.01$, $r= -0.587$), a positive correlation was obtained between percentage of broad-leaved forest and values of K^+ ($p<0.01$, $r= 0.440$). As will be seen, coniferous and broad-leaved forests can affect directly away in terms of statistical on water quality parameters. Also, correlation analysis revealed an interesting result. As shown in Table 2, statistically significant negative relationships were obtained between pH, EC, Ca, Mg, K and coniferous forest areas in the sub-watersheds. Positive relationships were obtained between TN, K^+, except for pH, and broad-leaved forest areas. This situation can stem from plenty of nutrients given to soil with rapid decomposition of litter of species (alder, beech, hornbeam etc.) in broad-leaved forest. Indeed, the highest values of TN (6.86 mg/l) and K^+ (1.53 mg/l) in stream waters in the sub-watersheds were determined in G-1 sub-watershed. G-1 has 92.5% broad-leaved forest areas according to QBird satellite imagery. And according to management map, dominant species are alder (64%) and hornbeam (36%) in broad-leaved forest areas. Litter of Alder can increase the concentration of nutrients in the environment by easily decomposing with effect of high level of nitrogen in Alder areas (Homann et al. 1992; Giardina et al. 1995; Yilmaz and Usta 2015).

4. Conclusions

Sub-watersheds were covered with vegetation composed of areas with anthropogenic effects and dominated by broad-leaved forests. Being close to the dam reservoir studied the sub-watersheds may significantly impact to water quality parameters and so drinking water.
The dominant tree species in broad-leaved forests is beech in the sub-watersheds in the study area. Beech tree species is followed by respectively alder and hornbeam. Alder may enter the mixture with other broad-leaved tree species except in the case place where the dominant. The existence of alder in the land may increase decomposition in the soil (C/N ratio) and therefore nutrient concentration. In this study, it was seen that increase in the broad-leaved forest areas enhance especially TN values in the stream water. This may increase the eutrophication which may negatively impact the quality of the stream water. Measures to be taken by the administration (silviculture, afforestation, etc.) are also important besides raising the awareness of local people in the planning studies held in watershed.

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