RECREATIONAL USE IMPACTS ON HYDROLOGICAL PROPERTIES OF A DECIDUOUS FOREST ECOSYSTEM IN TURKEY

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Abstract

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Recreational use represents one of the major functions of the forest areas in Turkey. Owing to the fast and inappropriate urbanization trend and increasing population, Forest Service is going to face with a substantial increase in the recreational demand in the near future. In this paper impacts of recreational activities on some hydrological properties of a deciduous forest ecosystem have been evaluated. Soil samples were taken in addition to a 2 years water quality monitoring study. The water quality study on the creeks did not reveal a statistically significant deterioration in the stream water but the effects of trampling on some soil properties were evident. The bulk density values increased with the intensity of recreation and the percentage of sand fraction was also higher at the intensive recreation areas (75.15 > 72.19). The soils of the stream banks in the recreation area had fairly good saturated hydraulic conductivity (SHC) values, however affected from the intensity of recreation. In general, the recreational activities in the area found to be not conflicting with the water production function of the watersheds.

Key words: recreation, monitoring, water quality, trampling, stream bank

Introduction

Residents of Istanbul city faced with serious water supply problems in the last couple of decades. Although, it is a relatively humid region compared to the other parts of the country, a few subsequent dry summer seasons caused water shortages, especially in 1990s (Eroğlu et al., 2001). The government and the municipality went on planning and implementing costly pipeline projects in order to mitigate the problem. All water resources in a circle

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of 300 km in diameter were considered as a water supply for Istanbul (Sarıkaya, Eroğlu, 2001). However, the quality aspect of the problem was ignored and many reservoirs became polluted with human settlements and activities in the water producing watersheds. The overpopulation due to immigration from countryside also caused the recreation areas to become over-utilized.

Recreational use is one of the major functions of the forests ecosystems, and in some cases produces more value than timber (Swank, 1996). Vegetation cover, soil and water components of the forest ecosystems might be adversely affected from recreational activities. Nevertheless, stream bank is generally the most susceptible part of a fluvial system against degradation in a watershed (Volny, 1984), as erosion, in this zone could cause quick access of the sediments to the stream. Additionally, the stream bank either natural or artificial is mostly subject to flooding in at least a portion of the year, and it could also have gentle to steep inclination that promotes abrasion (Mitsch, Gosselink, 1993). Furthermore, in the reservoirs or watercourses that are used for recreational purposes, banks are among the most trampled zones by people. Therefore, emphasis is given to the stream banks in the soil survey part of this study.

Neşetsuyu recreation area in Belgrad forest reflects the typical recreation habits of Turkish people. Hiking, running and picnic are the most common activities. Almost 800 000 people visit Belgrad forest recreation areas each year and around 10% of them prefer Neşetsuyu. Some part of the forest is also assigned for educational (Güngör, 2007) and scientific use.

On the other hand, the importance of Neşetsuyu recreation area as a study site not only comes from its recreation potential but also its location which is just over a drinking water producing historical reservoir. The Büyükbent reservoir supplying 0.3 % f the water used in Istanbul was built 400 years ago in the Ottoman Empire era and due to favorable ecological conditions it supports an abundant aquatic biomass (plants and phytoplanktons).

In this study, the hydrological impacts of the recreation activities in Nesetsuyu picnic area after around 50 years of service have been evaluated by investigating the reservoir condition, stream water quality, and soil properties.

Material and methods

Site description

The Neşetsuyu forest recreation area is a part of Belgrad conservation forest, located on the northwestern part of the Trace Region in Turkey (Fig. 1). The recreation area (0.5 ha) which has been serving since 1956 (Pehlivanoğlu, 1987; Destan, 2001) is on the downstream of 2 adjacent forested catchments, on a flat landscape (0–5% slope) where two creeks meet. The coordinates of the water sampling points are 41°11'15'' N and 28° 58'04'' E while the elevation varies from 81 to 85 m. The climate of the region is described as 'humid, oceanic and some water shortage in summer' according to Thornthwaite method and classified as B3B1'sb4' (Serengil, Özhan, 2001).

Study watersheds are located on Neocene material that generated deep, acidic, coarse textured and graveled soils. The region is located in the Castanetum-Fagetum vegetation zone (Özhan, 1977).

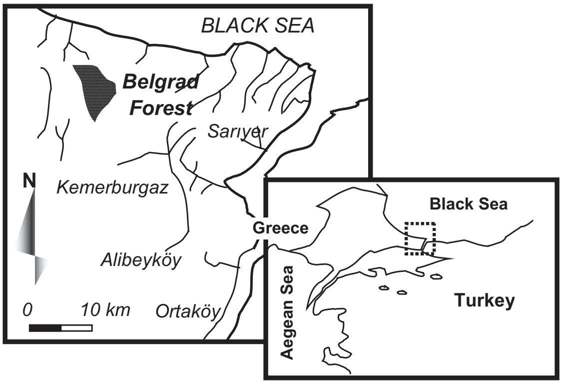

Fig. 1. Location of Belgrad forest.

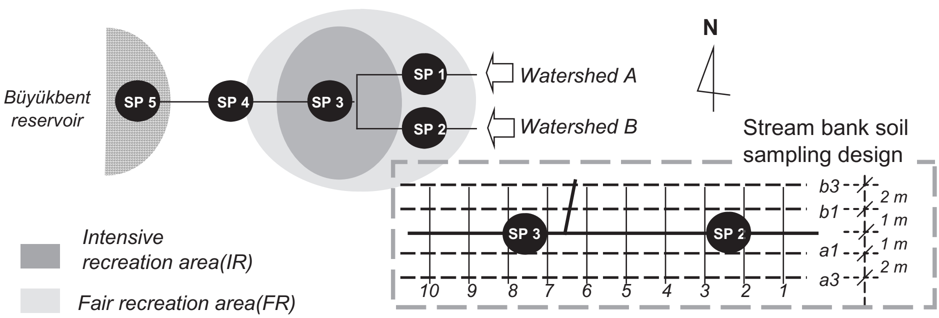

Fig. 2. Schematic representation of the water sampling points. Numbered black circles are water sampling points (SP 1, 2…5), and solid lines represent the creeks. The stream bank soil sampling points are taken on the transects (1, 2…10), 1 and 3 m away from the channel on both sides (a1, a3, b1, b3).

Sampling and analyses

Five sampling points (SP) were determined on the creeks to monitor water quality in a period of two hydrologic years (1999–2000 and 2000–2001) (Fig. 2), and sampling was performed manually for 15-day intervals except for some extraordinary situations (for instance, sampling was not done in case of no- flow in some dry summer months and was made more frequent during heavy storm events).

The total number of stream water samples was 51 on each sampling point. The analyzed water quality parameters were pH, turbidity, electrical conductance (EC), dissolved oxygen concentration (DO) and saturation, water temperature, Mg^{2+}, K^{+}, Na^{+}, $NO3^{-}$, $NH4^{+}$, $PO4^{-,2-,3-}$ and Cl^{-}.

To make a comparison two (1st and 2nd SPs) of the five sampling points were taken above the recreation area on both creeks and water quality parameters were compared with the ones below (3rd, 4th and 5th). Mean water quality values of the SPs were compared with ANOVA followed by Duncan t test.

The water quality data of the 1st and the 2nd SPs were combined with the impact ratios calculated with the equation below;

$$a_i\, t_i + b_i\, k_i = c_i \qquad (i=1,2...51)$$

where,

ai: ith Electrical conductance (EC) value of SP1,
bi: ith EC value of SP2,
ci: ith EC value of SP3,

This equation was solved for the 51 EC measurements and 50 values have been computed for *t* and *k* coefficients. Then the mean values were calculated with the below formula and symbolized as γt and γk. EC was used to determine the impact ratios as it is thought to be the simplest and most reliable water quality parameter.

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$$\gamma t = \frac{\sum_{i=1}^{50} t_i}{n} \qquad \gamma k = \frac{\sum_{c=1}^{50} k_i}{n}$$

Hence, relative contribution coefficients of each creek in the conjunction point have been determined and in this way the water quality data of the SP1 and SP2 has been combined and represented as SPC (Sampling point combined). For example the SPC value for dissolved oxygen concentration could be found as;

$$SP1DO\ \gamma t + SP1DO\ \gamma k = SPCDO$$

Soil properties were also investigated in order to interpret the results of water quality monitoring study. Firstly, double soil sampling was performed on transects perpendicular to stream channel. As a second method, soils taken from stream banks were compared with the ones taken in (IR and FR areas) and outside the recreation area (forested).

The analyses performed on the soil samples were EC, pH, saturated hydraulic conductivity (SHC), bulk density, organic matter percentage (OM) and texture. Topsoil samples (0–10 cm) were taken from 72 points in the watersheds (24 at each IR, FR and forested areas) with intensive systematic grid sampling pattern and from 40 points on the stream bank. Stream bank soil sampling points were taken on 10 cross sections along the creek (Fig. 2). Four sampling points were taken on each transect named according to their side and distance to the creek (a1, a3, b1, b3).

Laboratory analytical methods

Nitrate, K^+, and Na^+ were measured using Orion ISE multimeter (ion selective electrode technique). $PO4^{-,2-,3-}$, Mg^{2+} and $NH4^+$ were analyzed with DrLange digital photometer (Ewing, 1975). Chloride with titrimetric methods (APHA-AWWA-WPCF, 1975) and pH, temperature DO and EC with WTW Multiline pH meter. Turbidity was measured with Hellige turbidimeter. Soil pH and EC measurements were performed on filtered soil solutions of 1/5 using again the same Multiline pH meter. Bulk densities of the bulk soil samples were calculated with dividing the oven dry weights to the sample volume. OM percentages of the soil samples were determined with Walkley-Black method (Irmak, 1956), SHC (saturated hydraulic conductivity) according to Darcy Law, with procedure in Özyuvacı (1976) and texture with hydrometer method (Irmak, 1956). To determine the SHC values of the soil samples, bulk soil samples were saturated with distilled water and the discharge was measured under a constant hydraulic load. This was achieved by a mechanism prepared for this purpose.

Results and discussion

Reservoir condition

Büyükbent reservoir is one of the historical water supply structures of Istanbul with a surface area of 0.26 km^2, and a cret length of 84.5 m. It has a storage capacity of 1.318.000 m^3. After 350 years of service, today, observations around the lake point out a slow increase in the aquatic and riparian vegetation cover. Due to adequate temperature and moisture conditions the reservoir and the surrounding forest ecosystems are quite fertile, and thus, the human activities in the region might be a factor to promote the slow natural process of eutrophication. The SP 5 was taken on the reservoir to represent its water quality. The average annual temperature and electrical conductance of the reservoir were 11.75 °C and 201.60 μS/cm respectively, during the monitoring period.

The DO concentration of the reservoir was highly influenced by water temperature. It increased in winter months with decreasing water temperature. The lowest concentrations were recorded in late autumn (October November). The measured values distributed between 2.68 mg/L and 8.49 mg/L (mean = 5.65 mg/L, median = 5.61 mg/L). However, 50% of the measured DO values (51 measurements in 2 years) distributed between 4.8 mg/L and 6.4 mg/L which indicates a fairly favorable condition for the fish population of the reservoir.

The pH of the reservoir was not an effective factor on DO and ranged between 6.2 and 7.4 during the 2 years of monitoring period. Although, very acidic precipitation (pH < 4.0), particularly in winter months, falls in the region, not even any serious episodic acidification event was observed in the lake (Serengil, 2002).

Mean values of water quality parameters measured at the reservoir are given in Table 1. The pH of the reservoir water was favorable and fertile for the aquatic flora and plants during the whole monitoring period. The measured water quality parameters were compared with the data given by Biswas (1996) based on the quality criteria of Russia and Canada for the aquatic life, and recreational purposes. It was even in good quality and suitable for a drinking water supply according to WHO, USEPA and Canada regulations (Ryding, 1989).

T a b l e 1. Mean water quality values of Büyükbent reservoir.

Parameter	Unit	Reservoir water	Parameter	Unit	Reservoir water
pH	NU	6.89	Na	*mg/L*	9.74
EC	*microS/cm*	201.6	Mg	*mg/L*	4.35
Temperature	*°C*	11.75	Al	*mg/L*	0.01
PO_4	*mg/L*	3.17	Fe	*mg/L*	0.66
SO_4	*mg/L*	9.0	K	*mg/L*	2.53
Cl	*mg/L*	4.74	Turbidity	*mg/L* SiO_2	31.15
NO_3	*mg/L*	2.94	Color	*unit*	20
DO	*mg/L*	5.65			

T a b l e 2. The mean concentrations of the measured water quality parameters at the sampling points. SPC is the combination of SP1 and SP2 as explained above.

	EC	pH	T	DO	Na	Mg	K	NH_4	SO_4	NO_3	PO_4	Cl	Tur
	microS/cm	*NU*	*°C*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*SiO_2*
SPC	220.12	6.86	10.92	6.34	10.73	3.39	2.83	0.22	7.54	2.90	3.21	5.68	37.59
SP3	218.48	6.97	11.01	6.65	10.30	4.04	2.59	0.24	9.33	2.41	3.21	5.28	42.23
SP4	230.38	6.90	10.86	6.13	10.77	3.56	2.52	0.29	8.90	2.66	3.23	5.42	42.83
SP5	201.60	6.89	11.75	5.65*	9.74	4.35	2.53	0.32	9.00	2.94	3.17	4.74	31.85

* Statistically significant according to Duncan t test ($p < 0.05$).

Spatial variations

The spatial variations of all water quality parameters among the SPs are given in Table 2. The values are the average of 51 measurements during the whole monitoring period.

According to ANOVA test no statistically significant difference was found among the SPs for the whole analyzed water quality parameters except DO concentration. For DO concentration, ANOVA F value was 3.173 with a 2 tailed significance of 0.026. The difference found by both tests was caused by the low DO concentration of the reservoir (DO concentration of the reservoir was expected to be lower than the stream, naturally). The lowest average EC, turbidity K^+, DO, Cl^- and Na^+ values were measured for the 5th SP, representing the reservoir water quality.

When a general evaluation is made including all parameters, it is quite apparent that the differences between SPs for water quality parameters are very slight and quite far from being considered as a deterioration. The values for SP1 and SP2 were little different particularly for turbidity, DO, and EC but it was even normal as they were on the two different creeks. On the other hand the data belonging to SP3 and SP4 were almost identical.

Effects of recreational activities on the soil properties

The first (1st) and the last (10th) transects were taken just outside the fair picnic area and the trampling intensity gradually increased in the central transects (5th and 6th). The changes in the soil organic matter and bulk density values are given in Table 3. Bulk density increased at the heavily trampled parts inversely proportional with soil organic matter. It reached the highest values (1.4 g/cm^3) in the middle transects and decreased to 1.22 g/cm^3 at the 10th one. The average bulk densities of the soils from the forested upper portion of the watersheds were 1.12 g/cm^3 and in the IR areas it was 1.29 g/cm^3. Hence, higher values than the IR area and lower values than the forested area were determined on transects taken on the stream banks. SHC decreased passing through the heavily trampled part of the recreation area while pH, EC and the texture composition did not show a certain trend.

T a b l e 3. The change in the soil organic matter and bulk density values of the soils taken on the stream bank. The values are the average of 4 points on each transect (8 samples with replicates). To make a comparison, the mean bulk density values calculated for the intensive recreation, fair recreation, and forested areas were 1.29 g/cm^3, 1.18 g/cm^3, and 1.12 g/cm^3, respectively.

Transect No.	1	2	3	4	5	6	7	8	9	10
OM (%)	5.18	5.44	5.49	3.72	4.75	3.82	5.46	4.54	4.20	5.55
BD (g/cm^3)	1.03	1.11	1.08	1.26	1.27	1.40	1.37	1.36	1.36	1.22

On the other hand the distance to the channel also influenced some soil properties. As explained above, soil sampling was done at two distance rows on the transects (Fig. 2). The average values for some soil properties are computed according to the distance to the channel (Table 4).

T a b l e 4. The soil properties on the transversal cross section of the channel bank. The letters a, and b indicates the side, and 1, and 3 shows the sampling distances to the channel. The values are the average of 20 measurements each (10 sampling points with replicates).

	Soil properties					
	SHC	BD	Clay	pH	EC	OM
	cm/hr	*g/cm^3*	*%*		*microS/cm*	*%*
a3	4.92	1.27	14.36	5.77	76.80	5.36
a1	10.20	1.29	12.36	6.23	102.10	4.71
b1	56.74	1.20	10.53	6.21	119.80	4.15
b3	23.75	1.22	11.96	6.05	95.00	5.05

Key: BD – bulk density, OM – organic matter, SHC – saturated hydraulic conductivity, EC – electrical conductance.

As seen from the table above, clay and organic matter content of the soil decreased while electrical conductance, pH, and saturated hydraulic conductivity of the soil increased approaching to the channel. The non-parametric Kruskal Wallis test was used to compare means (as the number of variables in each group was 10) and no significant difference was found among the sampling rows (a1, a3, b3, b1) on the transects. The increase in the coarse fraction of the soil could have promoted the infiltration at the a1 and b1 rows (high SHC values at these 2 rows).

Soils taken from the stream banks were also compared with those taken from upper watershed areas and other parts of the recreational area.

In Table 5 some soil properties are given to make a comparison between the creek banks, heavy and fair recreation areas and the non-recreational forested areas. OM percentage of the recreation area -intensive or fair- was half of the forested part of the watershed. On the other hand EC decreased to 80.25 μS/cm at the IR areas but did not change with the intensity of recreation on the stream bank. Recreational activities affected the pH of the soils. pH values of the recreation areas were higher than forested areas especially on the stream bank. Unexpectedly, textural compositions of the soils were not significantly variable and sensitive to the degree of recreation. Statistical difference was found just for clay percentage (arcsinus transformation was made for percentage values). Bulk density values were in a homogenous group while SHC values were quite variable according to mean comparison test results. The lower value was measured at IR areas while the highest at the FR stream bank.

Table 5. The comparison of soils properties taken from various parts of the recreation area.

	SHC	Bulk density	Clay fraction	Sand fraction	pH	Electrical conductance	Organic matter
	cm/hr	gr/cm^3	%	%		microS/cm	%
Bank IR	15.00	1.28[a]	10.92[a]	77.66[a]	6.34	111.25[a]	4.35[a]
Bank FR	61.17	1.18[a]	12.24[a]	73.58[a]	6.03[a]	110.50[a]	4.54[a]
IR	6.45	1.29[a]	13.53[a]	75.15[a]	5.90[a]	80.25	4.91[a]
FR	26.17[a]	1.18[a]	12.61[a]	72.19[a]	5.92[a]	94.38[a]	5.64[a]
Forested	26.90[a]	1.12[a]	16.00	73.50[a]	5.45	96.37[a]	11.36

Key: IR – intensive recreation, FR – fair recreation, SHC – saturated hydraulic conductivity,
[a] In the same group according to Duncan t test ($p < 0.05$).

Conclusions

The recreational use demand of the public has increased substantially in recent years in Turkey, especially around Istanbul. The main reason is the insufficiency of green areas in the city. Therefore, a sound recreational planning approach has become compulsory to sustain this function of forests under high human pressure. The main challenge to develop and implement a sustainable recreation management plan is the data requirement. The forestry functions conflicting with recreational use have to be identified in order to enable multiple purpose forestry. This study was an effort towards this objective.

The hydrological effects of recreational activities (mainly composed of picnic and trekking) in a forested area have been investigated with a water quality monitoring, and soil survey study. The topsoil horizons were compacted and litter layer was mostly disappeared due to trampling in the intensive used areas. However, the water quality of stream passing through the recreation area was in good condition to support aquatic life and quite similar with the Büyükbent reservoir.

However, further studies are needed for different recreation area sizes, types, and ecological conditions to assess recreational use and forest hydrology interaction.

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