

Comparing Soil Organic Carbon Contents in Three Usage Zones of Kızılcahamam Soguksu National Park, Turkey*

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ABSTRACT

This study aimed to compare the soil organic carbon (SOC) contents of the three different management and development zones of Soguksu National Park, Turkey: Controlled, Sustainable Use, and Precision Conservation. Ecotourism, recreational and leisure activities are allowed only in the Controlled Zone. The study was conducted using a 2 x 3 Factorial in Randomized Complete Block Design. Soil samples were taken from two soil depths: 0-5 cm and 6-10 cm. The chemical and physical properties that were analyzed include SOC concentration and bulk density. Results revealed that the soil bulk densities range from 0.88 g cm⁻³ for the Controlled Zone, 0.85 g cm⁻³ for the Sustainable Use Zone, and 0.79 g cm⁻³ for the Precision Conservation Zone. Mean SOC contents at 0-5 cm were: 12.82 Mg ha⁻¹, 15.23 Mg ha⁻¹, and 16.19 Mg ha⁻¹, for the Controlled Zone, Sustainable Use Zone, and Precision Conservation Zone, respectively. At the 6-10 cm soil depth, the mean SOC was 13.95 Mg ha⁻¹ for the Controlled Zone; 12.62 Mg ha⁻¹ for the Sustainable Use Zone, and 13.82 Mg ha⁻¹ for the Precision Conservation Zone. The mean total SOC concentration per gram was 3.06 % for the Controlled Zone, 3.35% for the Sustainable Use Zone, and 3.80% for the Precision Conservation Zone. The SOC contents significantly differed in the upper 5-cm depth, but not in the 6 to 10-cm depth. Mean separation analysis showed that SOC in the Controlled Zone differed significantly from the other two zones. However, there were no significant differences in the SOC contents between the Sustainable Use and Precision Conservation Zones. This finding suggests that human activities in the Controlled Zone introduced impacts to the SOC contents in the upper 5 cm only. Thus, to minimize soil disturbance, authorities should properly identify environmentally sensitive zones within the Controlled Zone in which human activities must be restricted.

Keywords: Soil Conservation, Preservation, Soil Organic Carbon, National Parks, Climate Change

I. INTRODUCTION

Climate change, which is largely attributed to the increasing level of greenhouse gases (GHG) in the atmosphere, is the most challenging issue in recent times. The GHG traps the longwave emissions from the Earth and reradiates it back to the planet's surface resulting in global warming [1, 2]. Forest ecosystems play an important role in mitigating climate change impacts through the sequestration of carbon dioxide (CO₂) in the above- and below-ground biomass components of plants. The CO₂ is utilized as the food of green plants through the photosynthesis process, producing inorganic products that are deposited in the different biomass components of the plants. Soil constitutes the biggest depository of

organic products in the form of soil organic carbon (SOC) [3, 4, 5]. Due to large deposits of SOC in the soil, any small changes in soil C pool result in the mass escape of CO₂. Soil disturbance, which is oftentimes attributed to human activities, is one of the drivers of SOC changes. Soil disturbance accelerates decomposition rates of SOC due to increased exposure of soil surface to oxygen, sunlight, and moisture – all of which are drivers of the decomposition process of soil organic matter.

In Turkey, the increased demands for outdoor recreation and ecotourism motivate government authorities to declare many forestlands and other environmentally significant areas as National Parks, which are intended to serve as venues of outdoor recreation, leisure, and educational activities; conservation and protection, and the showcase of sustainable resource use practices. One of these parks is the Soguksu National Park, which has a land area of about 1,187 hectares and is located within the boundaries of the district of Kizilcahamam and Camlidere in the Province of Ankara. To

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simultaneously achieve the objectives of conservation and protection, sustainable production, and outdoor recreation and ecotourism of the Park, the authorities divided the Park into three management and development zones: Controlled, Sustainable Use, and Precision Conservation (Table 1) [6]. The Controlled Zone is set aside for outdoor recreation and leisure activities, in which visitors are allowed to do camping, trekking, and many other related recreational activities. The Sustainable Use Zone is the area in which production forestry and agriculture are allowed, subject to compliance with regulations to ensure the sustainability of resources. In contrast, the Precision Conservation Zone is delineated for the conservation and protection of key biodiversity areas and serves as a genetic pool of indigenous flora and fauna thus human entry within the said area is prohibited, except for park management and research activities.

With the coming of millions of visitors in the Park every year, both local and foreign recreationists, it is possible that the resources of the Park, especially the SOC, are affected. It is possible that the recreation- and leisure-related activities, particularly those which are allowed in the Controlled Zone, have resulted in soil disturbance which has introduced SOC changes. This question remains to be a research gap that needs to be investigated.

Table 1. The size of the regions within the National Park

Regions	Area (Ha)	Rate (%)
Precision Conservation Regions	1,090.95	91.90
Sustainable Use Regions	49.44	4.17
Controlled Use Regions	46.61	3.93
TOTAL	1,187	100

Thus, this study aimed to determine the SOC changes in these three management and development zones in the Park.

II. METHODS AND MATERIALS

Geographically, the Soğuksu National Park is situated between $40^{\circ} 27' 25''$ north latitudes and $32^{\circ} 36' 47''$ east longitudes (Figure 1). The average annual temperature in this area is 9.9°C and its mean annual precipitation is 542.1 mm. The highest precipitation is 78.2 mm in December and the lowest precipitation is 19.6 mm in July. The climate type of the National Park is “Step-Semi-Moist” based on De Martonne's climate classification. The average elevation of the Park is 1354 m with a slope ranging from 20 to 30 %. Moreover, conifers are the natural vegetation therein. These are dominantly composed of Black Pine (*Pinus nigra subsp. Nigra var. Caramanica*).

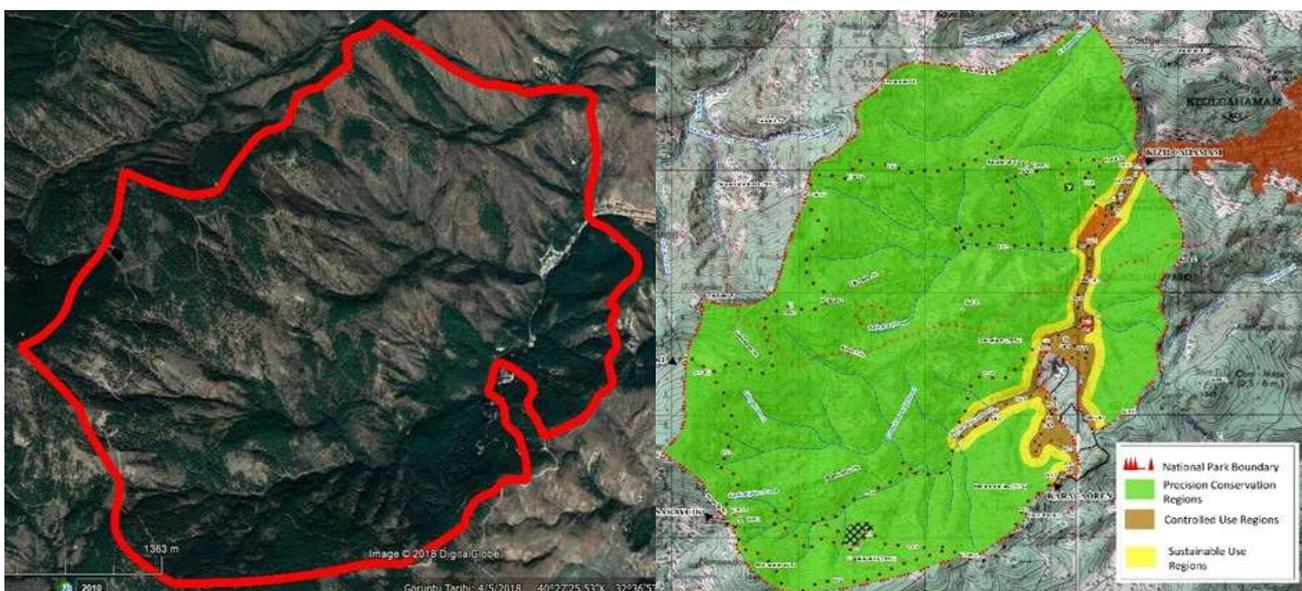


Figure 1. The location of the Soğuksu National Park

For purposes of this study, soil samples were collected from 10 measurement plots in each management zones. Two soil depths, 0-5 cm, and 6-10, cm were investigated. It is assumed that these depths are sensitive to soil disturbances which are likely to happen due to human activities. Soil cores (5 cm x 5-cm diameter) were collected from the two soil depths. Collected soil samples were oven-dried for bulk density, soil organic matter (SOM), and other physical and chemical analyses. The soil pH and EC were determined using soil-pure water suspension [7]. The soil texture was also analyzed using the hydrometer method [8] while the SOM by using the Black and Walkley method [9]. The SOM values were converted into SOC by multiplying the values by 0.58 [10]. ANOVA and Tukey HSD tests were used to determine the significant differences among treatment means.

III. RESULTS AND DISCUSSION

Texture, organic matter, bulk density, pH, electrical conductivity, carbon ratio and carbon content of the soil samples taken from the experimental areas and statistical analysis results are given in **Table 2**.

The bulk density ranged from 0.86 to 0.90 g cm⁻³, suggesting that the soils in all zones at the upper 10 cm are light to medium soils. It is evident, however, that the bulk density in the Controlled Zone had the highest value, which could be attributed to light compaction of the soil. Çetiner [11] stated that, depending on the type of soil, the average bulk density values of many soils in Turkey range between 1.07-1.43 g cm⁻³ in the upper 10-cm depth.

In the upper 5-cm depth, the results of the SOC contents showed the highest SOC concentration in the Precision Conservation Zone, which is significantly different from the Controlled Zone. Mean SOM concentration in the upper 5-cm depth ranged from 5.17 to 7.23% of the soil volume, which is within the range of values reported in the literature. Güner [12] found that the average SOM in upper 10-cm depth soil ranged from 5.59 to 9.73%. Kırış [13] reported that upper layers of the soil generally stored higher SOM than the lower layer. Furthermore, it was also observed that the amount of organic matter in the lower depth (6-10 cm) is about 5.09 to 5.87%. Upscaling these values into a hectare basis results in the following SOC values: 12.82 to 13.95 Mg ha⁻¹ in the Controlled Zone;

Table 2. The size of the regions within the National Park

Soil Properties		0-5 cm	Tukey HSD	6-10 cm	Tukey HSD
Bulk density (gr/cm ³)	1	0,86	ns	0,90	(1-3)
	2	0,83		0,86	
	3	0,77		0,81	
Organic matter (%)	1	5,17	(1-3)	5,35	ns
	2	6,47		5,09	
	3	7,23		5,87	
Carbon rate (%)	1	3,00	(1-3)	3,11	ns
	2	3,75		2,95	
	3	4,20		3,40	
Carbon content (ton/ha)	1	12,82	(1-3)	13,95	ns
	2	15,23		12,62	
	3	16,19		13,82	
Sand (%)	1	71,07	ns	65,15	ns
	2	69,74		70,00	
	3	78,87		72,43	
Clay (%)	1	18,58	ns	20,04	ns
	2	19,61		21,26	
	3	13,32		17,31	
Silt (%)	1	10,35	ns	14,81	(1-2)
	2	10,65		8,74	
	3	7,81		10,25	
pH	1	7,39	(1-2) (1-3) (2-3)	7,11	(1-2) (1-3) (2-3)
	2	7,05		6,83	
	3	6,84		6,55	
EC (µs/cm)	1	193,30	ns	169,10	ns
	2	131,40		140,82	
	3	172,69		136,88	

1: Controlled Use regions; 2: Sustainable Use regions; 3: Precision Conservation regions; ns: non-significant

15.2 to 12.62 in the Sustainable Use Zone; and 16.19 to 13.82 Mg ha⁻¹ in the Precision Conservation Zone.

Soil disturbance is one of the major drivers of SOC losses. This explains why the Controlled Zone showed relatively lower SOC than the other two zones. In contrast, the Precision Conservation Zone demonstrated the highest SOC contents, which could be largely attributed to the continuous deposition of SOM into the soil surface and lack of soil disturbance. Likewise, the Sustainable Use Zone also exhibited a high concentration of SOC in the upper 10-cm depth, which is not significantly different from the Precision Conservation zone. Though the Sustainable Use Zone is utilized for forestry and agricultural production which oftentimes results in soil disturbance, the application of sustainable land-use practices has led to high SOC concentration in the areas therein, which are comparable to that of the undisturbed zone. This suggests that human activities are not necessarily destructive to SOC as long as sustainable land-use practices are strictly enforced and complied with.

IV. CONCLUSIONS

Based on the results, it can be concluded that the upper 5-cm soil depth has been affected by the human activities in the Controlled Zone, which could be explained by the removal of SOM in camping sites and recreation activities area. Soil compaction due to traffic, the establishment of infrastructures, and fewer deposits of SOM in this zone are major contributors to decreased SOC concentration. It is surprising, however, that the utilization of forest areas for forest and agricultural production within the Sustainable Use Zone has not resulted in the degradation of SOC. This is probably due to the effective enforcement by authorities of regulations in this zone, such as requiring users to employ the best management and production practices. The Precision Conservation Zone showed the highest

amount of SOC deposits suggesting that the concept of soil conservation has been applied well in this zone. It is recommended that scientific investigation on the best soil conservation practices in the Controlled Zone should be conducted. Authorities should enact policies directed towards the reduction of impacts of ecotourism, recreation, and leisure activities on the natural resources, particularly the soil.

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