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Nutrient status in soil of Ski runs in the sub-alpine belt of Uludag mountain, Bursa, Turkey

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Abstract: *Large areas of land are disturbed in sensitive bio-diverse mountain environments by Ski runs. Restoration of vegetation on such disturbed mountain sites may be hampered by soil degradation but the severity and nature of the constraints is not well understood. This study was designed to compare the water holding and nutritional status of soil in three Ski runs which had different construction dates and disturbance levels, and the adjacent undisturbed site in the Abies bornmuelleriana forest community in the sub-alpine belt of Uludag Mountain (Bithynian Olympus). The values of soil parameters were depressed in proportion to the disturbance level. Water holding capacity (WHC), total nitrogen (N), organic carbon (C) and calcium (Ca^{2+}), magnesium (Mg^{2+}) and potassium (K^{+}) contents (mg kg^{-1} dry weight) of soils in the Ski run which had the highest disturbance level were lower than that of the undisturbed adjacent sites. However, the results indicated that the soil parameters were less degraded when secondary vegetation was growing on the disturbed areas.*

Key words: *Abies bornmuelleriana, Forest soil, Ski runs, Sub-alpine, Soil nutrients*
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Introduction

The cumulative effects of persistent disturbances to soil and vegetation caused by anthropogenic activity have resulted in the decline of bio-diversity and ecosystem function in many parts of the world (Vitousek *et al.*, 1997; Chapin *et al.*, 2000). In alpine environments, natural or human-induced disturbances are fairly common and acknowledged as determining factors in pedogenesis and soil distribution (Scalenghe *et al.*, 2002). Human impact on alpine areas is continuously increasing as a result of development of resorts and recreational activities (Urbanska and Fattorini, 2000; Ruth-Balaganskaya and Myllynen-Malinen, 2000). The recovery of disturbed alpine sites proceeds at best very slowly and often does not occur completely if topsoil is destroyed (Urbanska and Fattorini, 2000). Especially, the machine grading for winter sports causes important problems such as erosion and therefore the biodiversity can be destroyed. In addition, composition and diversity of alpine plant communities is strongly determined by specific disturbance regimes (Chambers, 1995).

The mountainous landscapes of Turkey, with their remarkable bioclimatic, geomorphological and pedological diversity, support a great many different high mountain vegetation types, which have attracted botanists for more than 150 yr (Parolly, 2004). Uludag is the highest mountain in the Marmara region including Thrace and Northwest side of Anatolian peninsula. The climate of the mountain changes with elevation and causes high "biological diversity". Due to its natural plant communities and various geomorphologic structures, an area of 11,338 ha was established as a National Park in 1961 and then, this area was enlarged up to 12762 ha in 1998. The construction of Ski runs increased in Uludag in the last decade. These activities concentrated at the western Ski run between 1700 and 2150 m. Environmental problems arising from winter tourism activities and other facilities in the mountain have been determined previously through vegetation mapping studies (Güleryüz *et al.*, 1998; Arslan *et al.*, 1999).

The aims of this study were (i) to determine the impact of the Ski run construction on the soil nutrient levels, *viz*. phosphorus (P%), organic carbon (C%), total nitrogen (N%), C/N ratio, calcium (Ca^{2+}), magnesium (Mg^{2+}) and potassium (K^{+}) and on water holding capacity (WHC%), pH and $CaCO_3$ (%) and (ii) to compare the Ski runs according to the disturbance level and their re-vegetation processes. The results obtained from this study will provide the basis for designing the future rehabilitation practices on Mount Uludag.

Materials and Methods

Study area: The climate of the mountain changes with elevation, being of Mediterranean type in lower parts, near the city of Bursa at the NW-side of the mountain, and rainy, partially mild micro-thermic, with icy winters at higher altitudes. The climate could be included in the first family of East Mediterranean climatic group (Akman, 1990).

Due to its altitude (2543 m) and various geological conditions, Uludag has a rich flora containing numerous endemic species and forms several well-distinguished vegetation types, which vary from Mediterranean to Euro-Siberian and Alpine type with altitude. There are humid forests on the NW and SE slopes of the mountain. Because of high plant diversity, Uludag mountain is one of the Important Plant Areas (IPAs) of Turkey (Uludag, IPA 18) (Güleryüz *et al.*, 2005). *Juniperus communis-Vaccinium myrtillus* dwarf shrub, *Plantago holosteum* and *Plantago atrata* mat and *Nardus stricta* meadow

Fig. 1: Satellite image of Ski runs (Source: Google Earth®)

communities are dominant in the sub-alpine belt and *Festuca cyllenica*, *Festuca punctoria* and *Acontholimon ulucinum* hard cushion communities were dominant in the alpine belt (Rehder *et al.*, 1994).

The study was performed on three Ski runs which have different construction date and disturbance level. They were placed on the north and east slopes of Fatin hill in Uludag (Fig. 1). Each Ski run (inside) and adjacent natural site (undisturbed sites) was considered as one sampling site. While the width of the Ski runs was approximately 150 m, the length ranged from 250 to 750 m (Fig. 1). The parent material is granite and the slope of the Ski runs is approximately 15-20%. The natural plant cover of the Fatin hill is an *Abies bommuelleriana* forest community. *Fagus orientalis* is found in the *A. bornmuelleriana* community on east-facing slopes and *J. communis* and *V. myrtillus* dwarf shrubs are the main components of the plant cover under forest on north-facing slopes.

Ski run I was constructed in 1968. This site is continuously subjected to machine grading and is thus heavily affected by erosion. For this reason, the plant cover is low (Fig. 1).

Ski run II was constructed at the same time with the Ski run I. Ski run II has not been disturbed for a long time. Thus, natural revegetation occurred on this site. Although *Festuca cyllenica* is dominant on this Ski run, the species composition is mixed. For example, *Juniperus communis*, *Vaccinium myrtillus*, and *Genista lydia* dwarf shrub species are dominant on some places of this Ski run. The percentage of plant cover on this site is 80% (Fig. 1).

Ski run III was constructed in 1991 and it has not been subjected to machine grading repeatedly since then. However, the plant cover is poor on this Ski run. The ruderal plant species is *Verbascum olympicum* and rarely *Carduus olympicus*, *Thymus bornmuelleri*, *Anthemis cretica*, *Urtica dioica* species are spread on this site. In addition, the commercial grass *Lolium perenne* is sparsely found (Fig. 1).

Soil sampling and analysis: The sampling was carried out in July 2001. Totally six soil samples (n=6) were taken from each Ski run (inside) and each adjacent site (undisturbed sites). Half of them were sampled from the upper altitude; the others were collected from the lower altitude of each Ski run and undisturbed adjacent site. The soil samples were taken from 15x15x15 cm pits and separated into 0-5 cm and 5-15 cm depths. Soils were sieved through a standard 4 mm sieve and weighed. Approximately 200-300 g soil samples were brought to the laboratory and stored in paper bags.

The water holding capacity (WHC%) of the soil samples was calculated using the differences between the saturated and dry weights of materials, after respective samples were dried at $80^{o}C$ until constant weight. The pH was measured with a soil:water ratio of 1:2.5 (in saturated paste) (Stuebing, 1965). Total nitrogen (N%) was determined by a Kjeldahl method using salicylic-sulfuric acid and selenium (Stuebing, 1965). Total phosphorus (P%) was analyzed with vanado-molibdophosphoric acid method by spectrophotometer (APHA, 1975). The $CaCO_3$ (%) and organic carbon (C%) contents of soils were determined by the Scheibler method and wet digestion method (digestion with concentrated sulphuric acid and titration by $K_2Cr_2O_7$) (Stuebing, 1965). Ammonium acetate extraction was used for determining the exchangeable cation contents in the soils (APHA, 1975). Cations [calcium (Ca^{2+}), magnesium (Mg^{2+}) and potassium (K^{+})] were analyzed with an atomic absorption spectrophotometer in the scientific and technological research council of Turkey (TUBITAK), Bursa Test and Analytical Laboratory (BUTAL).

Statistical analysis: The differences among the sample sites (Ski run I, II, III and undisturbed adjacent sites) in relation to the soil parameters (P, C, N, C/N ratio, Ca, Mg, K, WHC, $CaCO_3$ and pH) were tested by analysis of variance. Differences between groups were determined by the Tukey HSD test. All of the tests were performed at the significance level of α=0.05 (Zar, 1984) with the Statistica version 6.0 (StatSoft Inc. 1984-1995) program.

Results and Discussion

Soil pH was one of the main soil parameters which was affected by the vegetation disturbance. The soil pH was higher in 0-5 cm depth of Ski runs than that of undisturbed adjacent sites (Table 1). This high pH can be associated with the plant cover. Since the natural plant cover is *Abies bornmuelleriana* community, the pH of the soil is lower in the undisturbed site. The continuous soil destruction with machine grading on the Ski run I resulted in high pH values due to the losses of organic matter and topsoil in this Ski run. $CaCO_3$ content was higher in the Ski runs than that of undisturbed adjacent sites, however the difference among the sites was not significant ($p>0.05$). Water holding capacity of soils was changed by the construction of Ski runs. While the lowest water holding capacity values were found in both soil layers of Ski run I (43% ± 6), they were highest in both soil layers of undisturbed adjacent sites (Table 1). Ski run I was continuously subjected to machine-grading. Since organic matter content was increased by growing secondary vegetation at Ski run and undisturbed adjacent sites, the higher WHC values were found in 0-5 cm depth layer of soil in the undisturbed adjacent sites and the Ski run II and III. Re-vegetation processes on Ski run II, which is on the non-machine graded site, might help to restore soil properties such as water holding capacity. High water holding capacity values in both soil layers of undisturbed site and low water holding capacity values in both soil layers of Ski run I are the implications of the human land-use effects on soil properties. Such environmental impacts of anthropogenic activities include loss of vegetation, reduction in depth of organic horizon, loss of surface organic matter, increased soil bulk density, and

Table - 1: The comparison of undisturbed adjacent outside and the Ski runs in terms of pH, $CaCO_3$ and WHC in two soil layers

Soil depth (cm)	Ski run No.	Site	pH	$CaCO_3$ (%)	WHC (%)
0-5	I	inside	6.1 ± 0.7^{a}	0.06 ± 0.04^{a}	43 ± 6^{bc}
		outside	5.3 ± 0.1^{b}	0.04 ± 0.01^{a}	60 ± 11^{ab}
	II	inside	5.8 ± 0.4^{ab}	0.08 ± 0.05^{a}	69 ± 14^{a}
		outside	5.2 ± 0.1^{b}	0.05 ± 0.01^{a}	64 ± 7^{ab}
	III	inside	5.6 ± 0.3^{ab}	0.06 ± 0.02^{a}	48 ± 2^{b}
		outside	5.4 ± 0.3^{b}	0.07 ± 0.02^{a}	67 ± 14^{a}
			$p<0.05$	$p>0.05$	$p<0.05$
5-15	I	inside	6.2 ± 0.8^{a}	0.05 ± 0.01^{a}	43 ± 6^{b}
		outside	5.1 ± 0.3^{b}	0.03 ± 0.01^{b}	59 ± 11^{ab}
	II	inside	5.6 ± 0.6^{ab}	0.07 ± 0.02^{a}	63 ± 14^{a}
		outside	5.0 ± 0.2^{b}	0.06 ± 0.02^{a}	61 ± 5^{a}
	III	inside	5.4 ± 0.2^{ab}	0.06 ± 0.02^{a}	51 ± 7^{ab}
		outside	5.1 ± 0.5^{b}	0.06 ± 0.01^{a}	59 ± 9^{a}
			$p<0.05$	$p<0.05$	$p<0.05$

Table - 2: The comparison of the sites in terms of P, C, N, C/N in two soil layers

Soil depth (cm)	Ski run No	Site	P (%)	N (%)	C (%)	C/N (%)
0-5	I	inside	0.12 ± 0.04^{ab}	0.06 ± 0.02^{c}	0.9 ± 0.6^{cb}	14 ± 7^{bc}
		outside	0.10 ± 0.02^{b}	0.17 ± 0.04^{ab}	3.0 ± 0.7^{cb}	18 ± 3^{b}
	II	inside	0.14 ± 0.02^{a}	0.25 ± 0.09^{a}	6.8 ± 1.5^{a}	29 ± 6^{a}
		outside	0.13 ± 0.01^{ab}	0.21 ± 0.04^{ab}	5.6 ± 1.7^{ab}	28 ± 7^{ab}
	III	inside	0.10 ± 0.01^{b}	0.13 ± 0.02^{bc}	4.3 ± 0.7^{b}	33 ± 6^{a}
		outside	0.11 ± 0.01^{b}	0.23 ± 0.09^{a}	7.1 ± 2.0^{a}	31 ± 5^{a}
		$p<0.05$	$p<0.05$	$p<0.05$	$p<0.05$	
5-15	I	inside	0.13 ± 0.03^{a}	0.05 ± 0.03^{c}	1.3 ± 0.4^{bc}	26 ± 6^{b}
		outside	0.08 ± 0.02^{b}	0.13 ± 0.02^{b}	2.8 ± 0.5^{b}	22 ± 5^{cb}
	II	inside	0.14 ± 0.04^{a}	0.22 ± 0.05^{a}	6.5 ± 2.2^{a}	29 ± 7^{b}
		outside	0.12 ± 0.02^{ab}	0.16 ± 0.04^{ab}	4.6 ± 1.8^{ab}	29 ± 13^{b}
	III	inside	0.11 ± 0.01^{ab}	0.12 ± 0.03^{bc}	5.2 ± 1.0^{a}	47 ± 11^{a}
		outside	0.09 ± 0.04^{ab}	0.14 ± 0.07^{b}	4.9 ± 0.8^{ab}	40 ± 12^{ab}
			$p<0.05$	$p<0.05$	$p<0.05$	$p<0.05$

Table - 3: Comparison of the available Ca, Mg and K contents of the sample sites

Soil depth (cm)	Ski run No.	Elements ($mg\ g^{-1}$ dry wt.)			
		Site	Ca	Mg	K
0-5	I	inside	0.55±0.32[b]	0.02±0.01[cb]	0.06±0.02[b]
		outside	0.43±0.18[b]	0.03±0.01[b]	0.08±0.02[ab]
	II	inside	0.81±0.39[ab]	0.06±0.01[ab]	0.11±0.02[a]
		outside	0.61±0.36[ab]	0.05±0.02[b]	0.10±0.03[ab]
	III	inside	0.33±0.11[b]	0.03±0.01[b]	0.08±0.03[ab]
		outside	1.24±0.66[a]	0.08±0.04[a]	0.12±0.04[a]
			$p<0.05$	$p<0.05$	$p<0.05$
5-15	I	inside	0.59±0.43[a]	0.02±0.01[b]	0.05±0.02[a]
		outside	0.29±0.10[a]	0.02±0.01[b]	0.06±0.01[a]
	II	inside	0.49±0.33[a]	0.05±0.03[a]	0.08±0.02[a]
		outside	0.22±0.21[a]	0.02±0.01[ab]	0.08±0.01[a]
	III	inside	0.28±0.19[a]	0.03±0.01[ab]	0.07±0.02[a]
		outside	0.28±0.12[a]	0.03±0.01[ab]	0.08±0.03[a]
			$p<0.05$	$p<0.05$	$p>0.05$

reduced infiltration rates (Marion and Cole, 1996; Hammit and Cole, 1998). Hence, soil microbial communities and processes, nutrient status, and water holding capacity are directly and indirectly affected by these physical and chemical impacts (Lal and Stewart, 1992; ZabinSki and Gannon, 1997).

The removal of the plant cover resulted in decreased organic carbon content (%) of soil (Table 2). A significant difference was found among Ski runs with regard to organic carbon of both soil layers ($p<0.05$). Although organic carbon in the soil layers of Ski run II and Ski run III was high (respectively; 6.8% and 4.3% in 0-5 cm), it was low in both soil layers of Ski run I (0.9%). Organic carbon content was highest in the soil of undisturbed adjacent sites of Ski run III (7.1%) as well. The C/N ratio of the soils was lowest in the Ski run I (14 ± 7) and highest in the both layer of undisturbed adjacent sites and the Ski run III (Table 2). The soil organic matter is a critical component that enables the parent material of soil to release the nutrients in the ecosystems and to form the soil structure, water holding capacity which decreases the soil erosion (Matson *et al.*, 1997).

The significant difference was found among the sites in terms of N and P contents in both soil depths of ($p<0.05$). The lowest P values were determined in both sides of the Ski run I (0.12 ± 0.04 and 0.10 ± 0.02). The highest ones were determined in both sides of Ski run II (0.14 ± 0.02 and 0.13 ± 0.01). The disturbance inside the Ski runs I and III caused important losses of N. For example, although total N is 0.05% in the inside of Ski run I, it is 0.30% for the outside of Ski run III and inside of the Ski run II. It was indicated that drastic soil disturbance reduces plant growth through the reduction of soil nitrogen levels (Bradshaw and Chadwick, 1980; Reeder and Sabey, 1987; Munshower, 1994). Claassen and Hogan (2002) suggested that soil disturbance often results in depletion of soil nitrogen reserves and that the remaining substrates may be unable to provide adequate N for re-vegetation.

A significant difference was found among sample sites regarding exchangeable Ca, Mg and K levels of the 0-5 cm depth of soil ($p<0.05$). We determined that Ca content was 1.24 $mg\ g^{-1}$ dry weight in control sites, but only 0.33 $mg\ g^{-1}$ dry weight on Ski runs. Mg content was 0.8 $mg\ g^{-1}$ dry weight in control sites, whereas it was 0.03 $mg\ g^{-1}$ dry weight in Ski runs. K content was 0.12 $mg\ g^{-1}$ dry weight in control sites, whereas it was 0.08 $mg\ g^{-1}$ dry weight in Ski run III (Table 3). These results indicate that Ca, Mg and K were decreased by soil disturbance occurring on Ski runs.

Increased water holding capacity (%), phosphorous (%), total nitrogen (%), total organic carbon (%), C/N ratio, calcium (Ca^{2+}), magnesium (Mg^{2+}) and potassium (K^{+}) values in the soils of undisturbed adjacent sites and on Ski run III compared to other Ski runs indicates the effects of vegetation on soil properties. Plants seem to have a key role in the restoration system and they facilitate recovery of some soil properties such as soil organic carbon, and soil structure (Gros *et al.*, 2004). But some researchers indicate that recovery is slow at high elevation sites, where short growing seasons, shallow soils, and low temperatures limit re-vegetation success (Cole and Ranz, 1983). However, it can be seen that re-establishment of indigenous plant species began naturally on some Ski runs in the alpine belt of Uludag National Park. Some plant species prefer the degraded sites exposed to anthropogenic pressure. These species become dominant on such secondary sites and they are the pioneer species of disturbed sites. They are tolerant to extreme temperatures, soil disturbances and nutrient depletion (Bowman *et al.*, 1993). Such species prepare the soil for later succession of perennial grasses through stabilizing soil structure, increasing soil organic matter and nutrient pools, restoring soil moisture and biological functions (Munshower, 1994). Spontaneous re-vegetation of disturbed areas on Uludag begins with the growth of pioneer species such as *Verbascum olympicum* which have high biomass productivity (Rehder *et al.*, 1994; Güleryüz and Arslan, 2001). Also *Rumex olympicus*, *Festuca punctoria*, *Festuca cyllenica, Thymus bornmuelleri* and *Trifolium repens* var. *orphanideum* are among the main accompanying species in secondary vegetation on these areas (Rehder *et al.*, 1994).

Water holding capacity (%), $CaCO_3$ (%) and pH values of soils on Ski runs of Uludag National Park were changed relative to adjacent undisturbed areas. Also losses of phosphorous (%), total organic carbon (%), total nitrogen (%), calcium (Ca^{2+}), magnesium (Mg^{2+}) and potassium (K^+)] occurred in these areas. The extent of change in physical and chemical properties of soils in these areas was proportional to the level of disturbance and inversely to the growth of vegetation on the Ski runs. Habitat restoration is needed in the destroyed areas of Uludag National Park. Native and endemic pioneer species on degraded areas in this belt (*e.g. Carduus olympicus* subsp *olympicus, Festuca punctoria, Festuca cyllenica* subsp *uluana, Verbascum olympicum*) can be useful tools in development of vegetation cover and ecosystem function. However, Ski runs should not be established in areas where the alpine vegetation has a high conservation value (Wipf *et al.*, 2005).

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