

Response of understory vegetation to enclosure in a heavily compacted forest recreational site

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Abstract

Objectives of this study were to investigate effect of enclosure on understory vegetation recovery and determine the time required for understory vegetation recovery in a forest recreational site. Recovery of understory vegetation in an enclosure was monitored for three growing seasons and plant density and vegetation cover were determined for each plant species. Enclosure was compared with control plot for the Shannon index of diversity. Results showed that a total of 33 (18 woody, 15 herbaceous) plant taxa were established in the enclosure while 42 (16 woody, 26 herbaceous) were encountered in the forest plot. *Quercus petraea* (Mattuschka) Liebl. subsp. *iberica* (Steven ex Bieb.) Krassiln. had the highest density both in the enclosure (30.37 plants m⁻²) and forest plot (25.75 plants m⁻²) and followed by *Hedera helix* L. (28.44 plants m⁻² in the enclosure, 23.33 plants m⁻² in the forest plot). Plant species recovered in the enclosure did not survive very long as growing season progressed, top soil dried, and canopy closure increased. *H. helix* L. was the major dominant plant species for vegetation cover in both enclosure (45.23 %) and forest plot (45.08 %). There was a significant difference between plots for species diversity and forest plot had diversity index of 1.01 while enclosure had a diversity index of 0.741.

Key words

Recreation, Trampling, Soil compaction, Herbaceous vegetation, Enclosure

Introduction

Importance of forests has increased for recreational use in the last century although forests have been used as a source of timber and wood fuel for many centuries (Amrein *et al.*, 2005). Especially in urban areas, population increase, rises in income and leisure time places huge pressure on the recreational use of forests and have increased demand for recreational use of urban forests (Waltert *et al.*, 2002; Malmivaara-Lämsä *et al.*, 2008; Hegetschweiler *et al.*, 2009). Because of excessive recreational use, human trampling has become a problem and causes extensive damages to soils and vegetations in the forest recreation sites. Therefore, human impact on vegetation in the recreational sites received attention from researchers (Cole, 1993; Whinam and Chilcott, 1999, 2003; Kutiel and Zhevelev, 2001; Talbot

et al., 2003; Dominik *et al.*, 2005; Sarah and Zhevelev, 2007; Kissling *et al.*, 2009; Mingyu *et al.*, 2009). These studies revealed that soil and vegetation were the most affected environmental factors on recreational sites and extent of the damage varied depending on the type and intensity of recreational use, soil and vegetation types, and the season of use (Thurston and Reader, 2001; Dominik *et al.*, 2005). According to Talbot *et al.* (2003), degradation of ground vegetation cover was increased with trampling intensity. Moreover, Kissling *et al.* (2009) reported that plant cover, height and species density decreased with increased trampling intensity. Vegetation types have also different resistant to trampling. Marion and Cole (1996) reported that open-canopy grassland vegetation was much more resistant to human trampling than forb-dominated forest vegetation in their study. Similar studies also showed that graminoids-

dominated grassland was less vulnerable and much more resistant to trampling damage than low shrub vegetation (Mingyu *et al.*, 2009), and shrub vegetation was more vulnerable to trampling damage than other vegetation types (Whinam and Chilcott, 1999).

Human originated trampling in the recreational sites causes soil compaction that reduces soil porosity, permeability, water holding capacity, productivity of soils, infiltration rate, increases soil bulk density, and leads to decreases in ground vegetation cover, plant height, and species richness (Sun and Walsh, 1998; Kutiel *et al.*, 1999; Kutiel and Zhevelev, 2001; Amrein *et al.*, 2005; Arocena *et al.*, 2006; Sarah and Zhevelev, 2007; Kissling *et al.*, 2009). Besides negative changes in the soil conditions, ecological changes such as losses of ground vegetation cover, litter biomass, and surface organic horizon, restriction in plant growth, poor soil aeration, and exposure of tree roots can take place because of recreational activities (Jim, 1998; Whitecotton *et al.*, 2000; Grieve, 2001; Waltert *et al.*, 2002; Talbot *et al.*, 2003; Sarah and Zhevelev, 2007). For instance, Lockaby and Dunn (1984) found that recreational activities increased number of exposed roots due to soil erosion and decreased number of underground roots.

Soil and vegetation conditions react rapidly to cessation of recreational activities (Marion and Cole, 1996). However, the time required for recovery of soil and vegetation characteristics varies depending on site conditions; type, intensity and frequency of recreational activities, degree of compaction, length of growing season, and vegetation and soil characteristics. Marion and Cole (1996) suggested that 6 years long period was significantly enough for recovery of soil and vegetation. However, in another study, one-year was not long enough for recovery of soil and vegetation conditions in the alpine environments of Tasmania (Whinam and Chilcott, 1999).

Researchers have tried to develop strategies such as permanently or temporary site closures, zoning sites to different type of users, locating recreational sites on most durable available surfaces, use limitation, visitor dispersal, rest-rotation, concentration of walkers on limited numbers of areas, containment, and site management to manage the intensity, distribution, and timing of recreational use (Marion and Cole, 1996; Marion and Farrell, 2002; Mingyu *et al.*, 2009). However, in most cases, all these strategies do not become a solution for recovery of soil and vegetation conditions in the recreational sites (Whinam and Chilcott, 1999).

Istanbul is the most populated industrial and cultural city in Turkey. The city has a few forest areas for recreational use. Belgrad forest is one of them and visited by about 851,000 people annually due to its proximity to the city (Destan, 2004). The site has been so heavily trampled for

many years by visitors that soil bulk density was measured to be 1.35 g cm^{-3} at the same recreational site (Özcan *et al.*, 2013). In order to determine the time required for herbaceous vegetation recovery in the recreational site and make appropriate management plans, objective of this study was to investigate effect of exclosure on the recovery of understory vegetation in a mixed broadleaf forest recreational site.

Materials and Methods

Study site: A mixed oak-hornbeam forest ecosystem was chosen as a study site in the Belgrad Forest of Istanbul ($41^{\circ} 13' - 41^{\circ} 14' \text{ N}$, $28^{\circ} 54' - 28^{\circ} 56' \text{ E}$). Two plots with a size of 400 m^2 ($20 \times 20 \text{ m}$), exclosure and forest, were placed in the recreational site with bare ground and in the adjacent forestland, respectively. Overstory vegetation in the site consists of mostly oak and hornbeam trees with a density of $240 \text{ trees ha}^{-1}$ and a canopy closure over 75 % (Özcan *et al.*, 2013) while understory species included mostly herbaceous plants and a few shrub species in the control plot (Table 1). Vegetation period begins in March and lasts until late-September, early October.

The study area is classified as a humid, mesothermal, and maritime climate with a moderate water deficit in summer months according to Thornthwaite method (Özyuvaci, 1999). Average annual precipitation is 1129.4 mm and mostly falls between October and March. Average annual temperature is around 12.3°C . August is the warmest month with a mean temperature of 21.7°C and February is the coldest month with a mean temperature of 4.2°C (Özcan *et al.*, 2013).

Soils of the study site developed mainly from Neocene deposits and Carboniferous clay schists. The soils developed from Carboniferous clay schists are generally moderately deep to shallow, gravelly, loamy clay with good permeability rates while the soils derived from Neocene deposits are deep, loamy clay in surface horizons and clay in the subsoil with medium permeability rates (Balci *et al.*, 1986). According to USDA (United States Department of Agriculture) taxonomic classification, soils of the study area are Vertic Xerochrept (USDA, 1996) and have a saturation capacity over 40 % in the topsoil and over 25 % in the subsoil (Özhan, 1977). Elevation varies from 94 to 100 m and topography is not steep.

Sample collection and laboratory analyses: Understory vegetation was sampled once in a month from April through August during the vegetation period for three years from 2005 to 2007. Sampling was done in the exclosure and forest control plot at 10 randomly selected locations every year at the same time during the vegetation period by using a quadrat with a size of $0.50 \times 0.50 \text{ m}$. Understory plant species were identified and categorized as trees, shrubs and herbs with using herbarium collection of Faculty of Forestry at

Istanbul University (ISTO) and some literature (Bean and Murray, 1980; Davis, 1965-1988). Plant density was estimated for each species and species diversities of exclosure and forest plots were also compared with using Shannon index of diversity (Zar, 1996).

Results and Discussion

Compared to the forest plot (Fig. 1a), recreational plot was a bare ground without any single plant species at the beginning of the study (Fig. 1b). A total of 33 (18 woody and 15 herbaceous) plant taxa established in the exclosure while 42 (16 woody and 26 herbaceous) were encountered in the forest plot (Table 1). More than half of the recovered plants (18) were woody species. Abundance of woody species among the recovered plants in the exclosure can be attributed to seed dispersal from the same species, which are present within the surrounding forest vegetation, and their seed size. Woody species had larger seed size than herbaceous species. Larger seeded species tend to have greater seedling emergence than smaller seeded species at most planting depth (Leishman and Westoby, 1994; Limbach and Call, 1995). Additionally, poor seedling recovery in the exclosure can be attributed to crust formation as a result of human trampling. Therefore, soil surface crust could have restricted the seedling emergence, especially in early study period when topsoil was compacted. Almost all of the woody species identified in this study were present in the adjacent forest ecosystem (Ister and Gokbulak, 2009). After exclosure establishment, some understory plant species established in the recreational plot (Fig. 1b). Exclosure and forest plots differed significantly for plant species diversity and forest plot had a greater Shannon index of diversity (1.01) than the exclosure (0.741).

28 out of 33 species in the exclosure had a density less than 1 plant m^{-2} while 29 out of 42 species in the forest plot had a density less than 1 plant m^{-2} . Among the tree species, *Quercus petraea* (Mattuschka) Liebl. subsp. *iberica* (Steven ex Bieb.) Krassiln. had the highest seedling densities both in exclosure and forest plot and followed by *Carpinus betulus* L. (Table 1). *Q. petraea* (Mattuschka) Liebl. subsp. *iberica* (Steven ex Bieb.) Krassiln. had densities of 30.37 plants m^{-2} in the exclosure and 25.75 plants m^{-2} in the forest plot while *C. betulus* L. had densities of 21.74 plants m^{-2} in the exclosure and 13.53 plants m^{-2} in the forest plot. *Hedera helix* L. was another woody perennial plant species that had very high densities in the both study plots. On the other hand, woody plants had greater densities than herbaceous plant species in the exclosure and forest plots except for *Crataegus monogyna* Jacq., *Clematis vitalba* L., and *Ruscus hypoglossum* L.

In the exclosure, all herbaceous plant species had a density less than 1 plant m^{-2} . In the forest plot, *Ranunculus ficaria* L. (24.21 plants m^{-2}) had the highest density and rest



(a)



(b)

Fig. 1 : Study plots (a) forest plot, (b) exclosure (back side of the fence) and recreational site (front side of the fence)

of the herbaceous plants species had densities lower than 1 plant m^{-2} except for *Poa annua* L., *Ranunculus constantinopolitanus* L., *Cardamine bulbifera* (L.) Crantz. and *Ornithogalum sigmoideum* Freyn. et Sint. (Table 1).

Vegetation cover also showed similar trend to plant densities. Woody plants had greater vegetation cover than herbaceous species in the both plots. Among the tree species, seedlings of *Q. petraea* (Mattuschka) Liebl. subsp. *iberica* (Steven ex Bieb.) Krassiln. had the highest vegetation cover (40.04 %) in the exclosure while *Fraxinus angustifolia* Vahl. had (30.65 %) in the forest plot (Table 1). *H. helix* L. had density less than some tree species (e.g., *Q. petraea* (Mattuschka) Liebl. subsp. *iberica* (Steven ex Bieb.) Krassiln.) but had the highest vegetation cover in both plots. On the other hand, *H. helix* L. had similar vegetation cover (about 45 %) values in both exclosure and forest plots (Table 1; Fig. 1).

Compared to woody species, herbaceous species had lower vegetation cover in the plots and among the herbs;

Table 1 : Average density and cover values of plant species identified in enclosure and forest plots

Name of the plant species	Life forms	Distribution	Density (plants m ⁻²)		Cover (%)	
			Exclosure	Forest	Exclosure	Forest
<i>Fraxinus angustifolia</i> Vahl.	Deciduous tree ¹ up to 30 m	West, South and Inland Anatolia	0.42	8.55	0.47	30.65
<i>Carpinus betulus</i> L.	Deciduous tree up to 25 m	North Turkey, West of Central Anatolia	21.74	13.53	7.04	5.27
<i>Quercus petraea</i> (Mattuschka) Liebl. subsp. <i>iberica</i> (Steven ex Bieb.) Krassiln	Deciduous tree up to 30 m	Thrace, North and Middle-West Anatolia	30.37	25.75	40.04	20.31
<i>Quercus frainetto</i> Ten.	Deciduous tree up to 25 m	North-West Turkey	1.83	12.55	13.09	10.44
<i>Quercus robur</i> L.	Deciduous tree up to 25 m	North-West Turkey, Middle and South Anatolia	1.44	0.11	0.77	0.11
<i>Acer campestre</i> L.	Deciduous tree up to 12-25 m	West-North-Middle Anatolia	0.88	1.19	1.83	1.49
<i>Acer pseudoplatanus</i> L.	Deciduous tree up to 30 m	Exotic (not native)	0.44	— ²	<0.1 ³	—
<i>Tilia tomentosa</i> Moench	Deciduous tree up to 40 m	West and North Anatolia	0.27	1.51	0.10	0.72
<i>Ulmus minor</i> Miller	Deciduous tree up to 30 m	West Turkey, South Anatolia	0.33	0.83	0.54	5.12
<i>Aesculus hippocastanum</i> L.	Deciduous tree up to 25-30 m	Exotic (not native)	0.11	—	3.33	—
<i>Robinia pseudoacacia</i> L.	Deciduous tree up to 25 m	Exotic (not native) Naturalized	0.55	—	2.86	—
<i>Pinus sylvestris</i> L.	Deciduous tree up to 5-15 m or more	North Anatolia, Central and East Anatolia	0.11	—	0.05	—
<i>Crataegus monogyna</i> Jacq.	Deciduous shrub or small tree up to 10 m	North, Northwest, West and Southwest Anatolia	<0.1	0.22	<0.1	0.22
<i>Sorbus torminalis</i> (L.) Crantz.	Deciduous tree up to 25 m	Cosmopolite	0.14	0.12	<0.1	<0.1
<i>Rubus hirtus</i> Waldst. et Kit.	Shrub with long trailing turions	North Turkey, South and Northeast Anatolia	0.11	0.05	<0.1	<0.1
<i>Daphne pontica</i> L.	Erect shrub sparingly branched	North Turkey	—	<0.1	—	<0.1
<i>Clematis vitalba</i> L.	Woody climbers	Out of Anatolia	<0.1	—	<0.1	—
<i>Ruscus aculeatus</i> L.	Evergreen shrub	North Anatolia	0.22	0.88	1.22	7.55
<i>Ruscus hypoglossum</i> L.	Evergreen shrub	North and Northwest Anatolia	—	<0.1	—	<0.1
<i>Hedera helix</i> L.	Woody perennial, stems creeping or climbing	Thrace, Out of Anatolia	28.44	23.33	45.23	45.08
<i>Smilax excelsa</i> L.	Tall, climbing shrub up to 20 m	Southeast and South Anatolia	—	0.22	—	0.94
<i>Poa annua</i> L.	Annual herb	Cosmopolite	<0.1	2.66	<0.1	1.79
<i>Poa nemoralis</i> L.	Perennial herb	Turkey (Except Southeast Anatolia)	0.66	<0.1	1.02	<0.1
<i>Carex sylvatica</i> Hudson	Perennial herb	North Turkey	0.66	0.66	1.44	1.55
<i>Arum italicum</i> Miller	Tuberous perennial herb	North Anatolia	0.22	0.83	0.77	2.32
<i>Viola odorata</i> L.	Acaulous perennial herb	Out of Anatolia	0.33	0.92	0.66	0.68
<i>Ranunculus constantinopolitanus</i> L.	Perennial herb	North Turkey, West, South, Central and East Anatolia	—	6.47	—	12.68

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<i>Ranunculus ficaria</i> L.	Perennial herb	North and South Anatolia	0.83	24.21	8.19	18.03
<i>Cardamine bulbifera</i> (L.) Crantz.	Perennial herb	North Turkey	—	1.77	—	1.94
<i>Ornithogalum sigmoideum</i> Freyn. et Sint.	Bulbous perennial herb	North Anatolia	0.72	1.32	1.49	0.82
<i>Urtica dioica</i> L.	Perennial herb	Cosmopolite	0.94	<0.1	2	<0.1
<i>Carex flacca</i> Schreber	Perennial herb	Thrace, North, Central and South Anatolia	0.11	<0.1	2.77	<0.1
<i>Tamus communis</i> L.	Herbaceous climbers	Out, East and Inland Anatolia	—	<0.1	—	<0.1
<i>Brachypodium pinnatum</i> (L.) Beauv.	Perennial herb	Northwest Turkey, Out of Anatolia	—	<0.1	—	<0.1
<i>Carex pendula</i> L.	Perennial herb	Thrace, Out of Anatolia	—	<0.1	—	<0.1
<i>Euphorbia stricta</i> L.	Annual herb	Thrace, Out and Central Anatolia	—	<0.1	—	<0.1
<i>Rubia peregrina</i> L.	Perennial clinging climber herb	Northwest Turkey	—	0.22	—	<0.1
<i>Geranium asphodeloides</i> Burm.	Perennial herb	North, Central, West and South Anatolia	—	<0.1	—	<0.1
<i>Geum urbanum</i> L.	Rhizomatous perennial herb	Turkey (Except South east Anatolia)	<0.1	<0.1	<0.1	<0.1
<i>Alliaria petiolata</i> (Bieb.) Cavara et Grande	Biennial herb	Thrace, North, South, Central and East Anatolia	<0.1	<0.1	<0.1	<0.1
<i>Oenanthe pimpinelloides</i> L.	Tuberous perennial herb	Cosmopolite	—	<0.1	—	<0.1
<i>Orobanche minor</i> Sm.	Herbaceous root-parasites	Northwest Turkey, Out of Turkey	<0.1	<0.1	<0.1	<0.1
<i>Rumex obtusifolius</i> L. subsp. <i>subalpinus</i> (Schur) Čelak	Perennial herb	West and North Anatolia	<0.1	—	<0.1	—
<i>Epimedium pubigerum</i> (DC.) Moren et Decaisne	Perennial rhizomatous herb	North Turkey	—	<0.1	—	<0.1
<i>Scrophularia scopolii</i> (Hoppe ex) Pers.	Biennial or perennial herb	West, Northeast and South Anatolia	<0.1	—	<0.1	—
<i>Sonchus asper</i> (L.) Hill. subsp. <i>glaucescens</i> (Jordan) Ball	Annual or biennial herb	Turkey (Except Southeast Anatolia)	<0.1	—	<0.1	—
<i>Stellaria holostea</i> L.	Perennial herb	North, West, Central Anatolia	—	<0.1	—	<0.1
<i>Lamium purpureum</i> L.	Annual herb	Northwest Turkey	—	0.11	—	0.11
<i>Veronica chamaedrys</i> L.	Perennial herb with rhizome	Northwest Turkey, North and Central Anatolia	—	<0.1	—	<0.1
<i>Veronica cymbalaria</i> Bodard.	Annual herb	Thrace and Out of Anatolia	—	<0.1	—	<0.1

¹Seedlings of the tree species; ²Not encountered in the sampling site; ³These values were taken as 0.1 for the estimation of the Shannon index of diversity

Ranunculus ficaria L. had the greatest vegetation cover with a value of 8.19 % in the exclosure and 18.03 % in the forest plot.

Although 33 plant taxa established in the exclosure, majority of them did not survive very long. Except for *Hedera helix* L. and *Ruscus* species, seedlings of the understory plant species did not survive until end of the growing season and mortality was very high as growing season progressed, shading effect of canopy closure increased, top soil dried, and competition for resources increased. This case can be related to several environmental factors. One of them is the soil moisture deficit in the topsoil (0-10 cm) in summer

months. Another one is the shading effect of overstory canopy for high seedling mortality in the exclosure. As vegetation period progresses, canopy cover of the overstory vegetation reaches about 75-100% in the exclosure (Özhan *et al.*, 2005) and prevents sunlight reaching understory vegetation. The other factor was the soil compaction. Because soil was so heavily compacted (with a bulk density value of 1.35 g cm⁻³) that about 1 cm-thick crust was formed in the recreational site (Özcan *et al.*, 2013). Compacted soil conditions could have restricted root development, elongation and branching of root system that influence leaf and tiller development (Aguirre and Johnson, 1991) and hence survival of the understory vegetation in

the enclosure. Finally, competition could be also important factor for seedling mortality in the enclosure. After enclosure construction, *H. helix* L., an invasive evergreen plant species, appeared in the plot and its aboveground cover reached the same level as in the forest plot within the three years. It covered almost half of the study plot, shaded other emerged seedlings, and gained superiority in the access for resources. Therefore, understory plant species had to also compete with *H. helix* L. plants in addition to tree species for sunlight, soil moisture and nutrients and *H. helix* L. plants suppressed understory herbaceous vegetation. As a consequences of competition, *H. helix* L. plants and trees from overstory forest vegetation caused seedling mortality in the enclosure.

This study monitored effect of enclosure on the recovery of understory vegetation in a forest recreational site for three years and results showed that 3 years of enclosure was not effective for recovery of understory vegetation except for *H. helix* L. Based on results of present and earlier studies, it is hard to reach a conclusion and make generalization about the time required for vegetation recovery in this forest recreational site because recovery of the understory vegetation depends not only cessation of trampling but also recovery of physical soil conditions. The time required for recovery of site characteristics may be too long depending on site conditions, intensity of compaction, length of growing season, and vegetation and soil properties. This study also revealed that shade tolerant invasive species (e.g., *H. helix* L.) gained superiority in the recovery and suppressed herbs. Seedlings of larger seeded woody species also established but not survived until end of the growing season every year. In conclusion, it can be said that enclosure was not a good strategy to be used for recovery of understory vegetation in the forest recreational site because of presence of overstory canopy. When overstory vegetation exists, recovery of understory vegetation in the forest recreational site may not be successful due to shading, intercepting rainfall, and limiting soil resources for understory vegetation.

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