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Impact of Visitors on Soil and Vegetation Characteristics in Urban Parks of Central Lithuania

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Urban parks are a major recreational feature attracting a large number of visitors. The aim of the study is to investigate the impact of visitors on vegetation and soil in urban recreational parks. The objects of the study were Alytus and Kaunas City Parks with different frequency of visitors. Soil parameters (pH, bulk density, and compaction) were measured, and the cover of vegetation and species number were determined. In order to assess the effects of frequencies of visitors on vegetation and soil characteristics, the correlation between these parameters was determined. The results indicated that activities of visitors caused a detrimental effect on soil and vegetation in the studied parks. The number of species and the cover of vegetation were significantly lower in the intensive recreation sites. Species diversity was significantly higher in the control sites than in the sites under intensive recreation. Soil properties (density, pH) of urban parks were significantly lower in the control sites in comparison with the intense use sites. In intensive trampling areas of Kaunas City Park, soil density was 26% higher than in Alytus City Park. Soil pH increased by 17% in Alytus City Park and by 6% in Kaunas Park compared with the control. The average pressure in the middle of the tracks increased by 7–8 times compared with the control. With an increasing number of visitors, the negative influence on soil characteristics as well as decreased number of species, vegetation cover and diversity was found.

Keywords: recreation, trampling, vegetation, soil, diversity.

Introduction

Urban green areas are important for recreation, and one of the benefits of green space and vegetation is improvements to public health (Lee and Maheswaran, 2010; Russel et al., 2013). Although effects at the individual level are small, the potential cumulative benefit at the community level highlights the importance of policies to protect and promote urban green spaces for well-being (White et al., 2013). While recreation provides well-being benefits, such green spaces in urban areas also help to mitigate the urban heat island effect, filter air and reduce runoff.

Recreation activities have the ecological impacts as threat to the integrity of those ecosystems (Young et al., 2005, Pickering, 2010, Marzano and Dandy, 2012). The physical disturbance by foot or tyre affects ecosystems. One of the possibilities to solve the problem is brief recommendations for management actions such as physical, spatial and temporal barriers and visitor education (Marzano and Dandy, 2012).

Studies on the ecological impacts of recreational activities in forests indicate that activities have direct and indirect impacts on ecosystem environment. Indirect impacts involve habitat change due to soil compaction and erosion (Deluca et al., 1998; George and Crooks, 2006). Trampling could reduce population densities of soil and litter dwelling invertebrates (Littlemore and Barlow, 2005). Soil compaction is the main factor influencing soil microbial activities (Kissling et al., 2009).

Direct effect of disturbance includes mechanical damage to plants, and indirect effects on vegetation are related to soil compaction. Changes in soil density and compaction cause changes in vegetation and a decrease in biodiversity and stratification of plant species (Andersen, 1995; Thurston and Reader, 2001; Andrés-Abellán et al., 2005; White et al., 2006). The changes in vegetation composition can be irreversible, and a low level of trampling can positively influence species diversity (Ikeda, 2003). Intense use is associated with the presence of nitrophilous plants and morphologically adapted to trampling species (Andrés-Abellán et al., 2005). Vulnerability to disturbance differs between plant communities due to distinction of resistance, resilience and tolerance (Roover et al., 2004). Therefore, management conservation plans should be explicated in order to limit recreational activities for the conservation of vulnerable communities (Littlemore and Barlow, 2005). The aim of the study was to investigate the effect of visitors on soil physical and chemical properties and vegetation composition.

Materials and methods

Study area and sampling methods

The investigations were conducted in 2 urban parks in central Lithuania. The first study area was the urban park in Alytus city. Alytus is the largest city of southern Lithuania and the sixth largest city of Lithuania (54°23’20’’N, 24°02’50’’E). The population of the city is 54,500. The City Park is in the centre of the city and is a usual place for the city people. The study area (approximately 5 ha) receives the mean annual rainfall of 662 mm. The study sites in Alytus City Park were situated in a deciduous stand (*Acer platanoides* L., *Betula pendula* Roth). During summer (June–April), the park is visited by about 71,289 people.

The second study site, Kaunas oak-wood City Park, was chosen in the second largest city of Lithuania (54°53’50’’N 23°53’10’’E). The population of the city is 297,669. The site has a humid continental climate with an average annual temperature of 6.3°C and an average precipitation of 627 mm. The park covers about 84 ha and is the largest urban park of mature oaks in Europe. It is a popular recreational place for the citizens of Kaunas. The largest part of the stand is composed of old oaks with the age of 100–320 years.

The mean number of people visiting the park per hour was counted during the observation time (from 8 AM to 20 PM).

Sampling methods

The study sites were similar in the environmental conditions but different in the load of visitors. For sampling, 6 sites were chosen in each urban park: 5 trails (sites trampled by people) and one control site (natural vegetation not trampled by visitors). In each site, soil samples and vegetation parameters were measured on plots of 1 m^2. Vegetation quadrats were placed on the centre of the trail and 1 m from the centre to both sides of the trail. All plant species were recorded and percentage cover of plants was estimated visually. According to the projection cover of plants, the dominated indicator species were assessed. The Simpson diversity index was calculated to estimate diversity of species.

Soil samples were collected in each sample site. Every sample (approximately 500 g) was taken from the topsoil (25 cm). The soil bulk density was calculated as the weight of dry soil divided by the total soil volume. Soil exchangeable acidity (pH_{KCl}) was determined by the potentiometric method (inoLab 720). In order to determine soil compaction, values of unconfined compressive strength were obtained by using a cone penetrometer (model 16-T0163).

Data analysis

Spearman's rank correlation analysis was performed in order to identify the relationship between soil and vegetation parameters and the number of visitors per hour ($p < 0.05$). For the comparison of the difference between 2 means, the Mann-Whitney U test was used ($p < 0.05$).

Results and discussion

Effects of visitors on the vegetation and soil

The study showed that human trampling reduced the total cover of aboveground vegetation. The number of species was significantly lower in the trampled study sites in comparison with the control ($p < 0.05$, Figure 1).

The mean number of species in the sites intensively disturbed by human activities was 2.1, while the number of species of the control sites was 12.7.

The results showed that only one species was found in the middle of the trail (0 m distance) of both studied sites (Alytus Park: *Agrostis capillaris* L., Kaunas Park: *Plantago major* L.).

In Kaunas Park, the number of species was significantly lower in comparison with Alytus Park: at the distance of 1 m, three (*Plantago major, Leontodon hispidus* L., *Ranunculus acris* L.) and six (*Plantago major, Eriophorum vaginatum* L., *Leontodon hispidus, Agrostis capillaris, Convallaria majalis* L., *Hylocomium splendens* (Hedw.) Schimp.) species were found, respectively ($p < 0.05$; Figure 1).

Fig. 1

Number of species at different distances from the trails

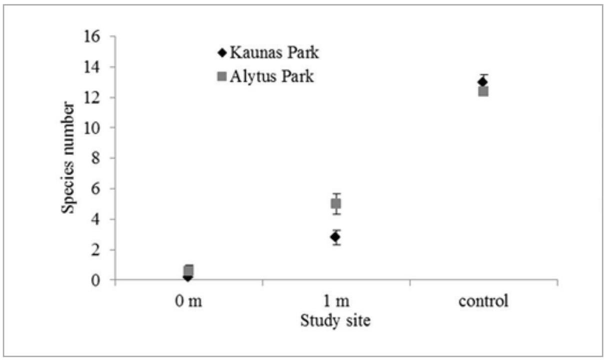
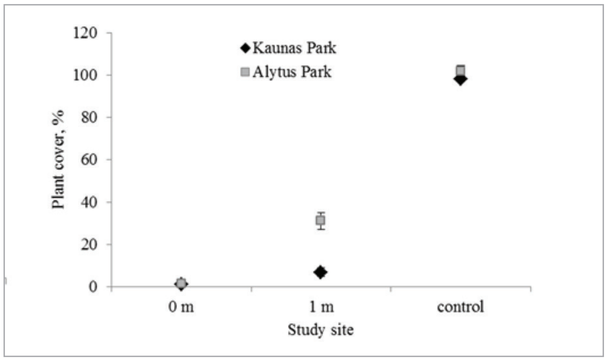


Fig. 2

Plant cover at different distances from the trails



Comparison of the results with other studies demonstrated a similar tendency of fewer plant species in the most frequented areas (Hylgaard and Liddle, 1981; Sun and Liddle, 1993). The study showed that plants could not survive due to the inability to absorb water and inorganic nutrients through lateral roots (Buckley, 2000) and also could not persist under the crush impact and weaken (Cole, 2004).

The middle of the trail was covered by only 1.5% of the vegetation layer (Figure 2). In the intensively trampled zone (0 m and 1 m distance), the mean cover was significantly lower (about 25%) in Kaunas Park than in Alytus Park: 4.2 and 16.4, respectively ($p < 0.05$). Vegetation cover of the trampled study sites was statistically lower in comparison with the control ($p < 0.05$).

The study showed that the negative effect of trampling begins quickly when soil is affected. The study in a campsite (Oregon, USA) indicated as much as 87% loss of vegetation cover (Cole, 1985). In a Californian sand dune, the remnant vegetation covered only 5%, and the usage of transport was the reason for the vegetation loss (Luckenbach and Bury, 1983). Man-made and natural dunes were observed to be most vulnerable in a study of Danish coastal communities under the influence of human trampling (Andersen, 1995).

Compared with the undisturbed site, human trampling altered composition and diversity of species. According to the Simpson diversity index, the diversity was very low: 0.09 in Alytus Park and 0.01 in Kaunas Park in the middle of trails (Figure 3). At the distance of 1 m, the diversity index was similar in both parks (0.29). Compared with the control (Simpson index 0.67 and 0.73 in Kaunas and Alytus parks, respectively), the diversity was significantly lower in the intense trampling zone ($p < 0.05$). The species diversity was lower in Kaunas Park than in Alytus Park.

In the trampled study sites, species tolerant to trampling were found: *Leontodom hispidus* L., *Eriophorum vaginatum* L., *Carex elongata* L., *Poa annua* L., *Lolium perenne* L., *Agrostis capillaris* L. Plant cover of *Plantago major* and *Hylocomium splendens* composed a large proportion of the soil.

In the trampled sites, soil density was significantly higher than in the control ($p < 0.05$; Figure 4). Soil density of Kaunas Park increased by 79% (0 m distance) and 64% (1 m distance), while in Alytus Park it increased by 51% and 39%, respectively, in comparison with the control. The highest soil density was 1.65 g cm^{-3} in Kaunas Park and 1.21 g cm^{-3} in Alytus Park, while in the control site soil density was 0.86 g cm^{-3} (Figure 4).

The highest soil density was recorded in the soil with the highest visitor frequency (Figure 4). Such soil density (1.24 g cm^{-3}) was higher by almost 65% than the one which is optimal for plant growth (0.8 g cm^{-3}). Other studies also showed that trampling caused soil to be more compacted and increase in hardness (Kozlowski, 1999). An increase in density would cause a decrease in soil aeration, air humidity, content of organic matter and change in bacteria flora (Manning, 1979). Soil density is related not only with its particles but also with its structure and water content. The more compact the soil structure is, the higher the water level and the deeper the density of soil.

Fig. 3

Species diversity at different distances from the trails

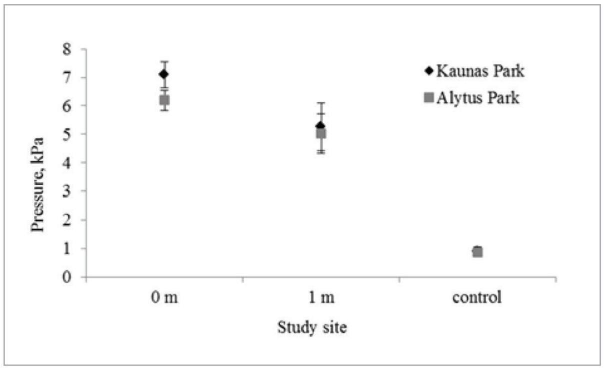


Fig. 4

Soil density at different distances from the trails

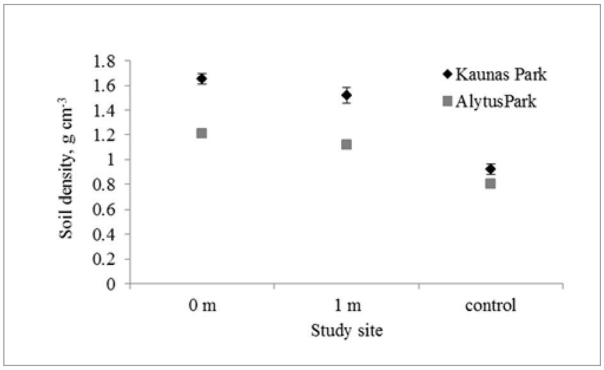
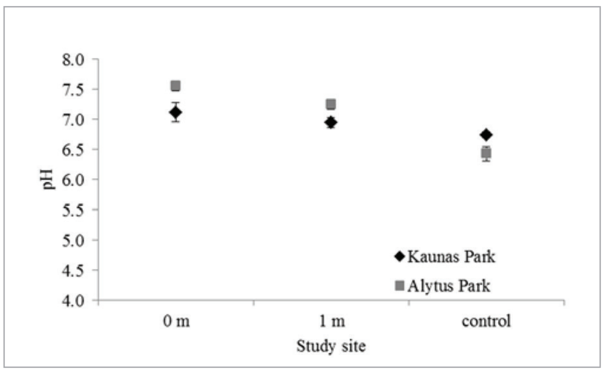


Fig. 5

Soil acidity (pH) at different distances from the trails



Soil pH is often referred to as the key variable of soil, which affects the spectrum of chemical reactions and processes. The soil pH value directly affects nutrient availability. For many plant species, soil medium at pH 5.8–6.8 is the most favourable. The results showed that pH was between 6.02 and 7.87 in Alytus Park (Figure 5). The data show that the results are statistically significantly ($p < 0.05$) different from the control area. In the control site, pH was 6.33, which indicates that the soil is moderately acid (plants grow best at the soil pH between 5.8 and 6.8).

Thus, in the analysed area, the conditions for the plant growth were suitable. In the middle of the track, pH was around 7. The soil of the treated heavily trampled sites was weak alkaline, had low organic matter content, sparse vegetation and was degraded. A high number of visitors resulted in higher pressure on soil density and existing vegetation. Meanwhile, the anthropogenic pressure in the control location was optimal for vegetation to grow.

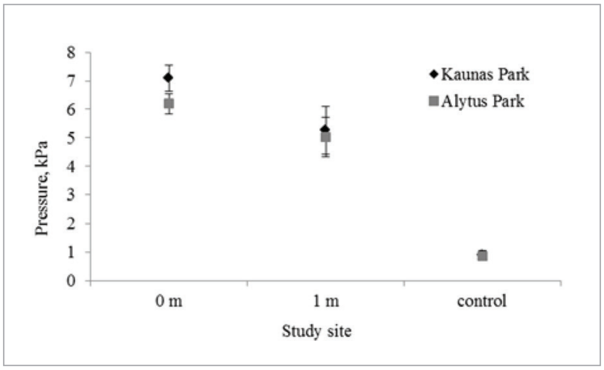
Some authors suggest that soil would be more acid in the trampling zones due to removal of organic matter (Burden and Randerson, 1972; Monti and Mackintosh, 1979). In contrast, other authors argue that the higher soil pH should be due to the fact that it becomes denser and reduces infiltration. It is suggested that deeper layers approach the calcareous bedrock due to soil erosion and depletion (Burden and Randerson, 1972; Monti and Mackintosh, 1979).

The data show that soil compaction was significantly increased in the trampling tracks. The average pressure in the middle of the track was 6.2 kPa in Alytus Park and 7.1 kPa in Kaunas Park, and 5.03 kPa and 5.27 kPa, respectively, at 1 m distance, while the soil pressure was significantly lower in the control sites (0.85 kPa). Higher pressure results in higher soil compaction along with higher density and pH. Plants are unable to absorb soil water and nutrients because air circulation of heavily compacted soil is declining. Higher density interferes with the penetration of roots inhibiting the growth of plants. This is in accordance with our results: vegetation was scarce in the heavily trampled sites.

The environmental impact of recreational locations showed spatial distribution, which is closely related to visitors and their activities. In the most frequently visited places, severe damage and vegetation degradation effects of soil trampling were observed. Assessment of these factors is important for management.

Fig. 6

Soil compaction at different distances from the trails



Relationship between number of visitors and environmental parameters

The study results showed a positive and significant correlation between visitor frequency and soil variables: the higher the number of visitors per hour, the lower the soil acidity and the higher the soil density and compaction (Table 1).

An increase in pH with frequency of visits has also been found in the recreational area (Andrés-Abellán et al., 2005).

The positive effect of trampling on higher soil density has been observed as one of the most studied aspects in other impact studies (Liddle, 1975; Manning, 1979; Cole and Fichtler, 1983; Lockaby and Dunn, 1984; Hammitt and Cole, 1987; Mortensen, 1989; Gómez-Limón and de Lucio, 1995; Marion and Cole, 1996).

The vegetation parameters of the frequently visited sites negatively correlated with visitor frequency, especially number of species (Table 1).

Similar results were obtained by Cole (1985) who found a linear relationship between the loss of vegetation cover and trampling intensity, while other studies have shown a non-linear correlation (Hylgaard and Liddle, 1981; Liddle and Thyer, 1986).

In summary, it could be concluded that species richness would be lower if trampling was higher because the number of species was significantly lower in the trampled study sites in comparison with the control ($p < 0.05$).

Table 1
Correlations between visitor frequency and soil and vegetation parameters

	Mean number of visitors per hour	
	Kaunas City Park	Alytus City Park
1	2	3
	Soil parameters	
pH	0.51*	0.46**
Density	0.58*	0.32*
Compaction	0.55*	0.52*
	Vegetation parameters	
Number of species	-0.50*	-0.37**
Coverage	-0.24*	-0.47**
Diversity	-0.32*	-0.44*

Notes: $p < 0.05$ (*), $p > 0.05$ (**)

Conclusions

The results of the present study showed that soil properties of the treated sites were affected by trampling. Human trampling increased soil pH, soil compaction and density. This type of disturbance, particularly changes in soil physical conditions, affected the vegetation: a shift in species composition and diversity. Stress tolerant species occurred more frequently in the disturbed sites in comparison with the control (undisturbed) site.

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Miesto parko lankytojų poveikis dirvožemio savybėms ir augalijai centrinėje Lietuvoje

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Darbo tikslas - ištirti lankytojų poveikį miestų rekreacinių vietų augalijai ir dirvožemiui. Tyrimo objektai – Alytaus ir Kauno miesto parkai su skirtingu lankytojų dažniu. Siekiant ištirti lankytojų poveikį dirvožemiui ir augalijai, buvo apskaičiuotas lankytojų skaičius, tiriamas dirvožemio tankis, pH, matuojamas dirvožemio slėgis, nustatomas augalijos padengimas, rūšių skaičius ir įvairovės indeksai. Rūšių skaičius Alytaus miesto parke ir Kauno Ąžuolyno parke buvo patikimai didesnis kontrolinėje vietoje nei intensyvios rekreacijos tiriamosiose vietose. Apskaičiavus visų tiriamųjų vietų augalijos padengimą, Alytaus miesto parke jis siekė 44,87%, o Kauno Ąžuolyno parke – 35,53%. Kontrolinės vietos augalų rūšių įvairovės indeksas buvo patikimai didesnis ($p<0,05$) nei intensyvios rekreacijos tiriamosiose vietose. Dirvožemio parametrai (tankis, pH) Alytaus miesto parke ir Kauno Ąžuolyno parke buvo patikimai mažesni kontrolinėje vietoje nei intensyvios rekreacijos tiriamosiose vietose ($p<0,05$). Dirvožemio slėgis Alytaus miesto parke buvo padidėjęs 7 kartus, o Kauno Ąžuolyno parke - 8 kartus (lyginant su kontroline vieta). Didėjant lankytojų skaičiui, didėja neigiama įtaka dirvožemiui, taip pat didėjant lankytojų skaičiui, mažėja rūšių skaičius, augalijos padengimas ir augalijos įvairovė.