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URBAN GREEN SPACES IN BIODIVERSITY CONSERVATION

VÁROSI ZÖLDTERÜLETEK SZEREPE A BIODIVERZITÁS FENNTARTÁSÁBAN

Egyetemi doktori (PhD) értekezés

HÜSE BERNADETT

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DEBRECENI EGYETEM
Természettudományi Doktori Tanács
Juhász Nagy Pál Doktori Iskola
Debrecen, 2016

A doktori értekezés betétlapja

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Tanúsítom, hogy **Hüse Bernadett** doktorjelölt 2011-2016 között a fent megnevezett Doktori Iskola **Kvantitatív és Terresztris Ökológia** programjának keretében irányításommal végezte munkáját. Az értekezésben foglalt eredményekhez a jelölt önálló alkotó tevékenységével meghatározóan hozzájárult. Az értekezés elfogadását javasolom.
Debrecen, 2016.

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dr. Deák Balázs
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A doktori értekezés betétlapja

VÁROSI ZÖLDTERÜLETEK SZEREPE A BIODIVERZITÁS FENNTARTÁSÁBAN

Értekezés a doktori (Ph.D.) fokozat megszerzése érdekében
a Környezettudomány tudományágban

Írta: **Hüse Bernadett** okleveles Biológus-ökológus
Készült a Debreceni Egyetem **Juhász-Nagy Pál Doktori Iskolája**
(**Kvantitatív és Terresztris Ökológia** programja) keretében

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Introduction

Over the last millennium, extensive land use changes have induced fundamental and irreversible changes in the landscape composition and ecosystem functioning worldwide by altering natural ecosystems and forming new artificial habitats (Kiss et al. 2016; McKinney 2008; Magura et al. 2010a; Lososová et al. 2011; Valkó et al. 2016a; Deák et al. 2016a). Furthermore as a result of urbanisation and transformation of natural habitats into intensively used agricultural lands natural habitats became reduced in size and fragmented leading to a severe loss of biodiversity (Deák et al. 2015a, 2016b; Williams et al. 2015).

Urbanisation affects biodiversity in many ways: it alters the abiotic environment (such as temperature, soil characteristics, water availability; Sukopp 2004; Kühn & Klotz 2006; Csorba & Szabó 2012) and leads to considerable loss and isolation of natural habitats (McKinney 2006; LaPaix & Freedman 2010). Urban ecosystems are characterised by a fine-scale pattern of various habitat types, which are usually heavily disturbed and enriched in nutrients (Lososová et al. 2012a). Several anthropogenic disturbance regimes are associated with urban habitats, such as trampling, soil disturbance and pollution (Kowarik 1995; Sukopp 2004; LaPaix & Freedman 2010; Simon et al. 2011, 2013; Vince et al. 2014; Baranyai et al. 2015). Several studies have reported that land use intensity and the level of disturbances decrease from city centres towards peri-urban areas (McDonnell & Hahs 2008; Tóthmérész et al. 2011; Magura et al. 2013). Species diversity of urban habitats is considerably influenced by the various disturbance levels, which affect both the magnitude of the inter- and intra-specific competition and the ratio of disturbance adapted species (Connell 1978; Magura et al. 2004). For instance Magura et al. (2004) found that in urban environments species richness decreases with the increasing levels of disturbance; which was verified by their studies on rove beetles in East-Hungarian urban habitats. Beside the abovementioned factors in urban habitats, horticultural activity can considerably modify the natural flora by intensive management (e.g. mowing, fertilising, removal of woody vegetation, preferring grasses and herbs instead of woody species), and also by increasing the proportion of alien species by planting alien ornamental species (McKinney 2006; Lososová et al. 2012a, b; Huwer & Wittig 2013).

Despite this, urban habitats still play an important role in biodiversity conservation in cities. In many cities, urban green spaces preserve the remnants of the semi-natural habitats such as grasslands or forests, and they also have an important role in preserving at least a part of the regional species pool of semi-natural habitats (LaPaix & Freedman 2010). Urban areas can contain suitable habitats for numerous native plant species (McKinney 2006). In larger cities the number of native species is relatively high; for example half of the native flora of Germany, Belgium and the Netherlands occurs in Berlin, Brussels and in Maastricht respectively (Müller 2010). Various urban habitats, such as parks, vacant lots, rooftops, road verges and peri-urban grasslands can preserve and maintain urban biodiversity. Their species composition depends on their environmental characteristics, spatio-temporal dynamics, management and size (LaPaix & Freedman 2010; Cervelli et al. 2013). Furthermore urban habitats provide important ecosystem services for society such as purification of air and water, temperature regulation and water storage (Williams et al. 2009; Cervelli et al. 2013).

Urban grasslands are one of the most typical elements of urban habitats. They comprise either the remnants of semi-natural grasslands or, in a broader sense, urban parks, residential green areas, road verges, are integral parts of the urban green area (Klaus 2013, Deák et al. 2016a). The example of Berlin, where the 5% of urban habitats are grasslands (43% of them have been assigned to protected grassland types), demonstrates that urban grasslands can considerably contribute to biodiversity conservation and can compensate the loss of grassland habitats in peri-urban regions (Fischer et al. 2003). Even though the situation in most cities is less optimal for grassland species compared to Berlin, urban grasslands still have a great potential for harbouring a high plant and animal diversity (Klaus 2013). When assessing the biodiversity potential of urban grasslands it should be noted that the majority of them are novel ecosystems, driven by considerable current and past anthropogenic disturbances and by the specific urban biotic and abiotic conditions (Hobbs et al. 2006; Lososová et al. 2011). Generally, each urban habitat type can be characterised by a special combination of these factors (McDonnell & Hahs 2008). In their comparative study of 32 European cities, Lososová et al. (2011) studied the effects of climate and wide range of habitat types from historical city centres to early successional and mid-successional sites based on the species composition of vascular plants. They found that variation in the species composition of vascular plants is mainly related to the differences between habitat types (with different site history, age and level of isolation). This knowledge allowed future researches to focus on the differences between certain habitat types for a better understanding of mechanisms shaping urban vegetation. A better understanding of the effect of urbanisation on ecosystem functions can support the development of strategies for the preservation of natural ecosystems within urban areas and for mitigating detrimental environmental impacts on human populations (Magura et al. 2013; Williams et al. 2015).

Beside urbanisation habitat fragmentation is one of the most significant factors effecting biodiversity in intensively used landscapes. Habitat fragmentation reduces the connectivity between habitat patches by extending the distances between the remaining habitat stands, which leads to the loss of biodiversity in the long run (Lindborg et al. 2012; Bogyó et al. 2015a, b; Deák et al. 2015b, 2016b; Valkó et al. 2015). Thus preserving biodiversity, creation and maintenance of ecologically stable landscapes has a high priority in conservation (Zipkin et al. 2009). Habitat connectivity is an important factor that supports the preservation of biodiversity in fragmented anthropogenic landscapes by allowing gene flow and the movement of individuals between populations (Lindborg et al. 2012). In landscapes transformed by human activities, artificial elements can constitute barriers for species dispersal and hinder complex propagation processes, which can threaten the survival of the populations (Jaeger 2000; Szabó et al. 2012a, b).

Ecological networks are in the focus of ecological researches since the 1980s (Jongman and Kristiansen 2001). Exploration, designation and protection of ecological networks support the maintenance of biodiversity and reduce the isolation in intensively used fragmented landscapes. GIS-applications are suitable to explore ecological networks in fragmented landscape and estimate connectivity between habitat patches (Vuilleumier and Prélaz-Droux 2002; Nikolakaki 2004; Deák et al. 2015c, Singh et al. 2015; Szabó et al 2016). An ecological network can be described as a mosaic of functionally connected habitat patches, facilitating species dispersal and therefore, supporting biodiversity conservation (Boitani et al. 2007). It is crucial to ensure the coherence of ecological networks and to identify and eliminate the threatening barriers in order to support the survival of numerous species typical to natural and semi-natural habitats (Jordán et al. 2007; Ziółkowska et al. 2014). Greenway and green space planning have a long history; roots of the greenway idea are more than 100 years old (Zube 1995; Vasas et al. 2009). The first example of this kind of planning was the Adirondack Park Region Concept in the United States (Howard 1898). A catalogue of plant species suitable for urban greeningwas also prepared in Europe during the 20th century; such plans were also developed in Berlin, Budapest, and Prague (Kavaliauskas 1995). As a result of human impacts, such as increasing urban sprawl and land use changes formed barriers in natural environment; various barriers for example cities, industrial and transport areas as well as intensively cultivated agricultural lands decreased the area of semi-natural habitats. In these landscapes semi-natural habitat fragments are usually separated by degraded, transformed areas. Thus, the maintenance of biodiversity requires conscious planning in urban environments (Linehan et al. 1995).

In Europe, the idea of a continent-wide ecological network, the European Ecological Network (EECONET) was introduced in 1993, in the frame of an IUCN initiative (Jongman and Kristiansen 2001). The initiation aimed at preserving the natural values of Europe by identifying and sustaining the core and buffer areas of natural habitats, and also the ecological corridors (Madgwick and Jones 2002). The EECONET consists of several National Ecological Networks (NECONETs). Designation of the Hungarian NECONET was initiated in 1993; and the task was done at regional levels by the National Park Directorates, which resulted in detailed maps of the Regional Ecological Networks (rNECONETs) at a scale of 1:50000 (Nagy 2004). Although ecological networks can have a key role in sustaining biodiversity of a region, there is a considerable lack of information about the effectiveness of urban ecological networks in biodiversity conservation (Hüse et al. 2016). Even though urban green areas are generally small and have diverse utilization types; these areas can constitute a large-scale network supporting urban biodiversity (Lososová et al. 2011). Remaining semi-natural habitats such as forests or urban parks but even rooftops and road verges have the potential for preserving the species of the native flora and fauna (LaPaix and Freedman 2010; Török et al. 2013). The importance of the urban habitats in preserving biodiversity was proven by several studies; for example Müller (2010) found that great cities such as Berlin, Brussels and Maastricht harbour at least half of the regional flora.

Even though green areas of the cities are essential parts of the ecological network, their role has not been sufficiently evaluated till present day. One of the main reasons is that currently the rNECONETs have low resolution, thus, further efforts are needed for a complex evaluation of urban green areas. For instance, in the majority of the cities, only the larger parks are indicated as green areas in the rNECONETs. A detailed inventory of urban green areas would be essential for the complex evaluation of urban ecological networks. Such complex analyses could reveal the role of urban green areas in biodiversity conservation or could provide essential data for action plans against invasive species (Hunter 2007; Talley et al. 2007).

Aims of the study

For studying the role of urban green network in biodiversity conservation, the city of Debrecen provides unique research opportunity. Debrecen is the largest city in East-Hungary, harbouring several urban green areas with various land use types. In our study we aimed to investigate the effects of urban environment on the vegetation of three typical urban habitat types (vacant lot, urban park, and peri-urban grassland) characterised by species typical to semi-natural grasslands and ruderal assemblages (*Species composition of urban habitats*). Furthermore we studied the role of the urban green network in biodiversity conservation (*Urban green space system*).

Species composition of urban habitats

Concerning the factors which effect the vegetation of urban habitats we proposed the following hypotheses:

(i) The intermediate disturbance hypothesis assumes that diversity and disturbance have an unimodal relationship (Connell 1978); above a certain level of disturbance, in the declining slope of the unimodal curve, which is represented by our highly disturbed urban habitats, increasing level of disturbance results in a decreased diversity. Thus we expect lower species numbers and Shannon diversity in highly disturbed habitats of the city centres. As an indicator of disturbance we expect a higher proportion of weeds and disturbance-tolerant species in the more disturbed habitats.

(ii) Urban environmental conditions are among the main filters shaping the species pool of urban habitats (Williams et al. 2015). We expect an increase in the ratio of warm- and nitrogen-demanding species and a decrease in the ratio of moisture demanding species in habitats typical to city centres compared to the peri-urban grasslands.

(iii) According to the urban homogenisation hypothesis, urbanisation has a strong homogenisation effect on the species pool of the cities, making the vegetation in the cities across the globe more similar than would be otherwise expected (McKinney 2006). The intensity of homogenisation shows a positive correlation with the level of disturbance; thus, urban core areas are more affected in this respect than peri-urban areas (Kühn & Klotz 2006; LaPaix & Freedman 2010). We predict a larger proportion of cosmopolitan and alien species in the more disturbed habitats, resulting in a decrease in the proportion of species of the natural flora.

Urban green space system

Our aim was to identify urban green areas and their connections with the Regional Ecological Network surrounding the city. We especially focused on the composition of the urban flora, regarding the native species and adventive flora elements.

Materials and methods

Study sites

Debrecen is the second largest city, and one of the largest regional centres in Hungary (N 47.531000 E 21.625000) (Figure 1). Its administrative area is 461.65 km^2, its urbanized area is 109 km^2 and it has 207,594 inhabitants (Hungarian Central Statistical Office 2015). The climate is continental, the mean annual temperature is 10 C; the mean annual precipitation is 590 mm (Marosi and Somogyi 1991). The natural vegetation around Debrecen comprises Euro-siberian steppic woods (Mücke et al. 2013), sandy grasslands (Albert et al. 2013, 2014), alkali grasslands (Alexander et al. 2015, 2016; Burai et al. 2015; Deák et al. 2014a, b; Lukács et al. 2015; Török et al. 2012a; Valkó et al. 2014), wetlands (Deák et al. 2014c) and less grasslands (Tóth & Hüse 2014). The city has an extended agglomeration zone. The downtown is bounded by urban-suburban areas and urban settlement rings (Kozma 1999). Urbanization processes are similar to other large cities: increasing land use intensity, conversion of grasslands, forests and arable lands to residential and industrial parks with a dense traffic network. Land use of the peri-urban areas around Debrecen has been considerably altered in the past centuries. Many of the former agricultural areas were transformed to urban areas and the formerly extensively used agricultural areas (such as pastures) were replaced by intensively used arable lands (Kelemen et al. 2010; Török et al. 2011a; Valkó et al. 2010; Vida et al. 2010). As a result, the extension and diversity of the natural and semi-natural habitat patches have been considerably reduced in the region and many cosmopolitan and adventive flora elements appeared (Kelemen et al. 2016). In spite of the unfavourable changes the remnant semi-natural habitat patches still harbour a considerable diversity.

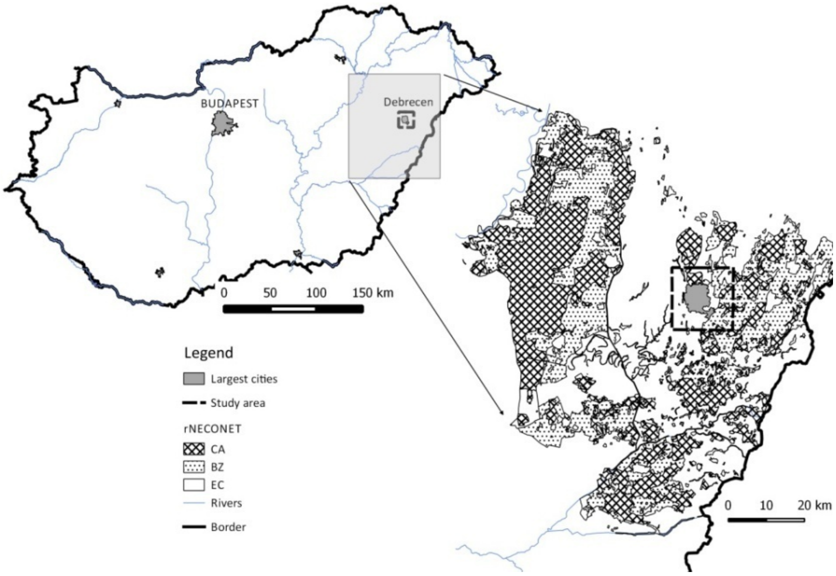

Figure 1. Debrecen city and its surroundings, with the map of the rNECONET. Abbreviations: CA – core area, BZ – buffer zone, EC – ecological corridor.

Species composition of urban habitats

We investigated three typical open urban habitat types that have the potential to harbour spontaneous grassland flora in the studied city. These habitats were vacant lots, urban parks and peri-urban grasslands (Appendix 1-3). These habitats have different site histories, current disturbance regimes and positions in the urban ecosystem of Debrecen. Vacant lots are unsealed surfaces in the city centre originating from the demolition of buildings (Figure 2). They are in an early successional stage and persist only for a few years (maximum 10 years) before being built on again. They are characterised by a high level of trampling, as the local population generally use them for recreation or as parking places. They generally harbour weedy vegetation composed of herbaceous species and are mown once or twice a year following the local weed control regulations. Urban parks are several decades old permanent green spaces that provide recreational space for citizens. They are characterised by open vegetation, predominantly grassland and scattered woody vegetation. The most significant disturbance factor is high intensity trampling and frequent mowing. They have a highly disturbed, unstructured soil. These places are mown at least once during the vegetation period, but typically they are mown several times a year. Peri-urban grasslands are large, persistent habitats around the inbuilt areas of the city. They are old-fields or levelled abandoned industrial spaces in a mid-successional stage (Albert et al. 2014). Their typical age is between 10-30 years, and characterised by spontaneously recovering grassland. Mainly due to financial limitations, they are mown only once a year. While vacant lots and urban parks are isolated from semi-natural grasslands by urban surfaces that are hostile to plant life, the level of isolation is lower in case of peri-urban grasslands. Based on our experiences and information from the literature, we assumed that habitats of the city centres are characterised by a higher level of disturbance compared to the habitats located outside the heavily urbanised area. As suggested by Lososová et al. (2011) we studied the effects of the different disturbance levels indirectly by concentrating on the differences between the distinct habitat types.

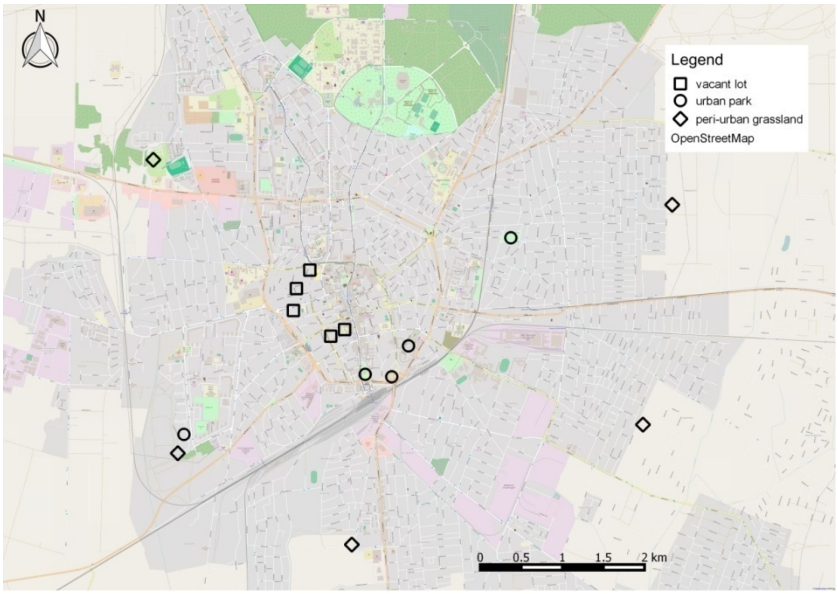

Figure 2. Map of Debrecen with the position of the studied habitat patches. The urban area is indicated by a darker grey colour. Source of the map: © Open Street Map contributors.

Urban green space system

The Regional Ecological Network (rNECONET) in the region (Hajdú-Bihar County) was designated by the Hortobágy National Park Directorate (Figure 1). The rNECONET consists of core areas, ecological corridors and buffer zones and also includes the local sites of the Natura 2000 network and protected areas. For instance the protected "Nagyerdő" forest site which is located nearby the city and partly inside the suburban area is one of the core areas of the ecological network (Magura et al. 2010b, 2013; Mücke et al. 2013). On the one hand, Debrecen city has a considerable barrier-effect in this network; on the other hand, there are many urban green areas inside the city which may reduce the barrier effect and contribute to the connectivity of the ecological network. As there is a large environmental load in and around the city; green areas also have an important role in providing healthy living environment in the city (Simon et al. 2014, 2016). Beside the mapping of rNECONET we also studied the spontaneous flora and planted species of 9 urban parks (please find the general description of urban parks above).

Sampling design and spatial informatics

Species composition of urban habitats

Using the Urban Atlas (European Environmental Agency 2014) and aerial photographs we chose five representative sites of each of the three studied habitat types (vacant lots, urban parks, and peri-urban grasslands); altogether we studied 15 sites. We designated five random sampling plots of 5×5 metres in every site, thus we surveyed 25 plots in each habitat type and a total of 75 plots. The mean area of the sites was 2 667.4 m^2 ± 1 161.5 SE in vacant lots, 21 969.6 m^2 ± 8 248.9 SE in urban parks and 5 003.8 m^2 ± 1 446.5 SE in peri-urban grasslands. In the sampling plots we recorded the percentage cover of vascular plants in 2013. For the calculations we used only the records of natural and spontaneous vegetation including garden escapes and spontaneously established woody species, we excluded the planted species as we aimed to represent the natural responses of the vegetation.

Urban green space system

We studied the spontaneous flora and planted species of 9 urban parks in Debrecen in 2012. For studying the spontaneous flora, we designated two 10×10 m sampling plots in each urban park. In the plots we recorded the species list and percentage cover of all vascular plants of the spontaneous vegetation including garden escapes. We excluded the planted species from the plot level survey. Besides surveying the spontaneous flora, we also surveyed the planted ornamentals in the whole area of the studied parks. The nomenclature of plant species names follows Király (2009).

Our goal was to provide a finer-scale map of the green space system of the city than the rNECONET or even the official green areas map of Debrecen. As a first step we determined the actual land use categories in accordance with the Development Plan of Debrecen (ERDA, 2003). We vectorized the land use objects using Google Maps (satellite images of 2011), and prepared the actual land use layer of Debrecen. For this, we used the Open Layers 1.3 plugin of the QGIS 2.12 (Quantum GIS Development Team, 2016). We also used the Urban Atlas (EEA, 2002) and the rNECONET map to fine-tune our results. Based on the Built Environment and Conservation Law (1997) we considered functional green space of the city (for example urban parks), undeveloped areas (arable lands, meadows, treeless and wooded grasslands and gardening culture), and forest patches as potential green spaces of the ecological network. For the categorisation we used the categories suggested by Wittig (1991).

Data analysis

Species composition of urban habitats

We calculated species numbers and Shannon diversity for each plot, and we calculated total species numbers on the site level as a sum of species encountered in all plots. Species were assigned to four groups: alien species, weeds, disturbance-tolerant species and species of natural habitats using the categories of the social behaviour type general classification system (Borhidi 1995). As the social behaviour system contains 10 categories, we simplified it by aggregating groups of the main functional types. Adventive competitors

(AC), invasives (I) and adventives (A) were considered as alien species. Ruderal competitors (RC) and weeds (W) were considered as weeds. Disturbance-tolerants (DT) and natural pioneers (NP) were considered as disturbance-tolerant species. Generalists (G), competitors (C) and specialists (S) were considered as species of natural habitats. We considered species as cosmopolitans based on the classification of Borhidi (1995). We calculated both relative species number and relative cover scores for social behaviour type groups and for cosmopolitan species for each plot. We used cover weighted scores of Ellenberg ecological indicator values for temperature, water, and nitrogen adapted to the Hungarian conditions (Borhidi 1995). We digitalised the borders of each site using ortho-photos provided by the open layers plug-in of the Quantum GIS 1.8 and calculated their area (Quantum GIS Development Team 2012).

We compared the vegetation characteristics of the habitat types using General Linear Models (GLM) and Tukey-tests (Zuur et al. 2009). As suggested by Sokal & Rohlf (1981) we used a nested design with habitat type, and sites were nested in habitat type as predictors and vegetation characteristics as dependent variables (total species number, Shannon diversity, relative species number and relative vegetation cover of the social behaviour types, ratio of the cosmopolitan species and cover weighted scores of Ellenberg ecological indicator values). For the calculations we used the plot data (n=75). ANOVA and GLM analyses were calculated using Statistica 7.0 program. For comparing the vegetation of vacant lots, urban parks, and peri-urban grasslands we used Detrended Correspondence Analysis (DCA) based on specific cover scores. We used the cover weighted relative ecological indicators values TB (temperature), WB (moisture) and NB (nitrogen) as an overlay for the ordination (CANOCO 4.5; Lepš & Šmilauer 2003). The nomenclature follows Király et al. (2011) for taxa.

Urban green space system

Functional connectivity of green spaces was determined using our green space map. Effective spreading distance of open habitat species was reported to be less than 100 m by Novák and Konvička (2006). However considering that species movements do not depend only on the inter-patch distances itself, but can be described by occurrence probabilities (Adriaensen et al. 2003; Saura and Pascal-Hortal 2007) in certain distance ranges, we examined a 200 m wide range divided by 10 meter buffer zones and counted the number of disjunct areas (i.e. individual habitats). We also determined the minimum distances between the patches.

We categorised the species based on their social behaviour types (SBT) using the categories of Borhidi (1995) and their origin based on Terpó et al. (1999), Mihály and Botta-Dukát (2004) and Pinke et al. (2011). Classification of SBTs is based on the model of Grime (1979) and was adapted for the Hungarian conditions. SBT express the role of individual species in the plant communities and provide information about the community regarding its stability, regeneration ability, naturalness and degree of disturbance. Species were assigned to six functional groups: competitors, generalists, natural pioneers, disturbance-tolerants, weeds and ruderal competitors. These categories represent a gradient from the species typical of natural habitats (for example competitors and generalists) to the species typical of degraded habitats (for example ruderal competitors). We also studied and analyzed the origin of species of the spontaneous and planted flora. Species were classified into the following groups: native, archaeophytes, neophytes, invasive, naturalized and casual neophytes.

Results

Species composition of urban habitats

We found altogether 140 species in the studied sites; there were 90 species in vacant lots, 44 in urban parks and 96 in peri-urban grasslands (Appendix 4-6). Total species numbers of the three habitat typesdiffered significantly (ANOVA, F=7.68, p=0.007); urban parks harboured significantly fewer species compared to vacant lots and peri-urban grasslands (mean ± SE=23.6 ± 1.47; 34.6 ± 2.50 and 34.4 ± 2.66 species/site, respectively). Species number and Shannon diversity of the plots were the lowest in urban parks and the highest in the peri-urban grasslands (Table 1). Both relative species number and relative cover scores of alien species were the highest in vacant lots and peri-urban grasslands and the lowest in urban parks. Weeds and disturbance-tolerant species were the most typical groups in each habitat types. The number of weed species was higher in vacant lots and urban parks compared to peri-urban grasslands, but we did not detect significant differences in cover scores. The number of disturbance-tolerant species was higher in vacant lots and peri-urban grasslands than in urban parks; however, their relative cover was the highest in urban parks. Both the relative number of species and cover of species typical for natural habitats were the highest in peri-urban grasslands. Both the relative species richness and relative cover of cosmopolitan species were the highest in urban parks. We detected no difference in the cover-weighted TB scores of the three studied zones. Cover-weighted WB scores were the highest in the peri-urban grasslands. Cover-weighted NB scores were the highest in vacant lots (Table 1).

Table 1. Effect of habitat type and site on vegetation attributes (GLM and Tukey test; mean ± SE; N = 75). Notations: UP – urban parks, VL – vacant lots, PA – peri-urban grasslands. RS – relative species number; RC – relative vegetation cover; ***p < 0.001; **p < 0.01; *: *p*<0.05; n.s.: non-significant. Different letters in superscript indicate significant differences between the three habitat types (Tukey test).

	mean ± SE			Effect of habitat type		Effect of site	
	UP	VL	PA	F	p	F	p
Total species number/plot	11.8±0.5[a]	14.6±0.9[b]	17.0±0.8[c]	20.57	***	4.82	***
Shannon diversity	1.6±0.1[a]	1.8±0.1[b]	2.2±0.1[c]	26.88	***	3.63	***
Social behaviour types							
RS of alien species	3.0±1.0[a]	10.3±2.3[b]	10.7±1.7[b]	11.65	***	6.06	***
RS of weeds	39.6±2.5[a]	43.0±2.1[a]	32.3±1.9[b]	9.86	***	4.40	***
RS of disturbance-tolerants	55.3±3.0[a]	43.4±2.5[b]	46.9±1.9[b]	9.61	***	4.63	***
RS of natural habitats	2.2±0.7[a]	3.4±0.8[a]	10.1±1.2[b]	30.47	***	4.02	***
RC of alien species	2.3±1.6[a]	7.9±3.3a[b]	12.4±3.6[b]	5.04	**	5.52	***
RC of weeds	38.3±4.9	34.3±3.8	30.1±2.5	2.04	n.s.	6.11	***
RC of disturbance-tolerants	57.6±4.9[a]	55.4±3.3[ab]	46.8±3.7[b]	4.37	*	7.96	***
RC of natural habitats	1.8±1.2[a]	2.5±1.1[a]	10.7±2.4[b]	10.9	***	2.39	*
Cosmopolitan species							
RS of cosmopolitan species	57.6+2.0[a]	32.0+2.7[b]	27.5+1.8[b]	70.14	***	2.68	**
RC of cosmopolitan species	69.2+4.1[a]	33.0+4.5[b]	25.6+2.4[b]	61.50	***	4.54	***
Ecological indicator values							
TB	5.6±0.1	5.3±0.1	5.3±0.1	2.40	n.s.	0.96	n.s.
WB	4.3±0.1[a]	4.6±0.1[ab]	4.9±0.2[b]	5.42	**	4.24	***
NB	5.4±0.2[a]	6.0±0.1[b]	5.3±0.2[a]	6.67	*	3.36	***

In the DCA ordination, plots of the three habitat types were well separated (Figure 3). Urban parks composed the most compact group which was characterised by *Carex hirta, Convolvulus arvensis, Cynodon dactylon, Geranium pusillum* and *Poa compressa*. Plots of vacant lots had a more heterogeneous pattern, typical species of this habitat were *Arctium lappa, Bromus tectorum, Chelidonium majus, Medicago lupulina*, *Trifolium pratense* and *T. repens.* Two alien invasive species *Ailanthus altissima* and *Solidago canadensis* were plotted here as well. *Taraxacum officinale* and *Lolium perenne* were typical both for urban parks and the vacant lots. Plots of peri-urban grasslands were scattered and characterised by species mainly typical for oldfields such as *Achillea collina, Cirsium arvense, Daucus carota, Plantago lanceolata, Poa pratensis, Rumex acetosella, Vicia grandiflora* and *V. villosa*. Typical alien species of this group were *Solidago gigantea* and *Erigeron annuus*. High cover-weighted WB values were typical for peri-urban grasslands and high cover-weighted NB values for the vacant lots.

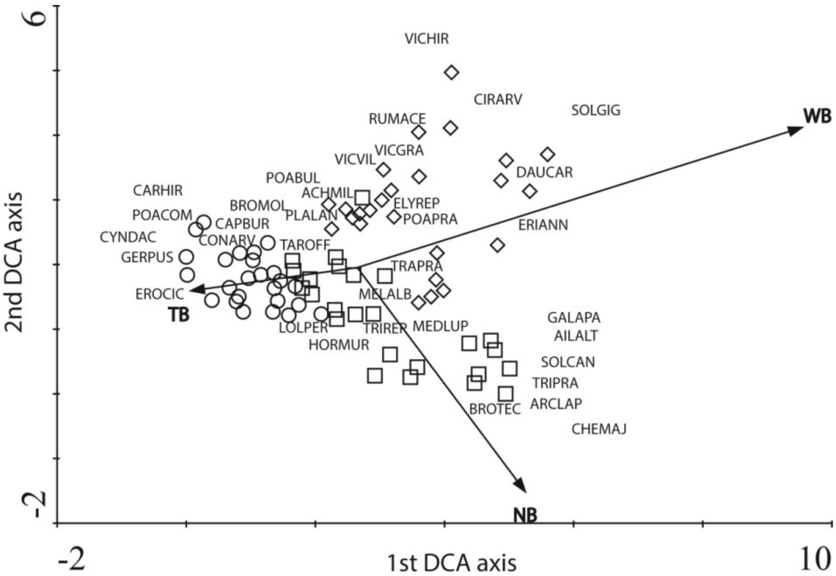

Figure 3. DCA plot of the species composition of the studied habitats. Indicator values for temperature (TB), moisture (WB) and nitrogen (NB) scores were included as overlay. The first 35 species with highest cover scores are plotted. Notations: circle – urban park; square–vacant lot; diamond–peri-urban grassland. Abbreviations of species names: ACHMIL – *Achillea millefolium*, ELYREP – *Elymus repens*, AILALT – *Ailanthus altissima*, ARCLAP – *Arctium lappa*, BROMOL – *Bromus mollis*, BROTEC – *Bromus tectorum*, CAPBUR – *Capsella bursa-pastoris*, CARHIR – *Carex hirta*, CHEMAJ – *Chelidonium majus*, CIRARV – *Cirsium arvense*, CONARV – *Convolvulus arvensis*, CYNDAC – *Cynodon dactylon*, DAUCAR – *Daucus carota*, EROCIC – *Erdodium cicutarium*, GALAPA – *Galium aparine*, GERPUS – *Geranium pusillum*, HORMUR – *Hordeum murinum*, LOLPER – *Lolium perenne*, MEDLUP – *Medicago lupulina*, MELALB – *Melandriumalbum*, PLALAN – *Plantago lanceolata*, POABUL – *Poa bulbosa*, POACOM – *Poacompressa*, POAPRA – *Poa pratensis*, RUMACE – *Rumex acetosella*, SOLCAN – *Solidagocanadensis*, SOLGIG – *Solidago gigantea*, ERIANN – *Erigeron annuus*, TAROFF – *Taraxacum officinale*, TRAPRA – *Tragopogon pratensis*, TRIPRA – *Trifolium pratense*, TRIREP – *Trifolium repens*, VICGRA – *Vicia grandiflora*, VICHIR – *Vicia hirsuta*, VICVIL – *Vicia villosa*.

Urban green space system

We identified altogether 26 land use types in the green space system of Debrecen (Table 2). We selected the elements of functional green spaces and elements of potential green spaces of the city. We identified the current elements of the green spaces (GS); furthermore, we involved further categories which also have relevant ecological functionality but not included into the system (PGS). The resulted land use map (Figure 4) shows both the green spaces (GS) and the potential green spaces (PGS) in Debrecen city, together with the elements of the Regional Ecological Network (rNECONET) surrounding the city (Patches 1-15). Elements of green spaces (GS) of the city were as follows: zoo and amusement park, botanical garden, cemetery, urban public park and residential public park. Elements of potential green spaces (PGS) consisted of the suburban residential areas, villas, institutes with large green space, rural residential areas, mixed land, undeveloped land, forest and water surface. We found whilst industrial areas, airport and mixed land covered a relatively large area, parks and other functional green spaces had relatively small extent (Table 2).

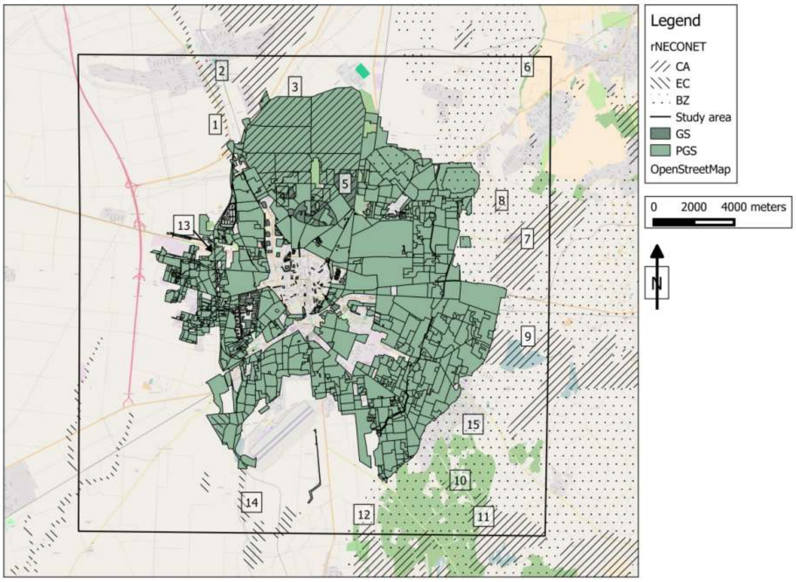

Figure 4. Map of the green spaces (GS), potential green spaces (PGS) and the patches of rNECONET surrounding the city (patches 1-15).

Table 2. The identified 26 land use types in Debrecen city.

Land Use Type	Total area (ha)
Suburban residential	2497.9
Undeveloped land	1870.6
Forest	1744.5
Rural residential	1393.0
Industrial areas	821.2
Airport	441.3
Mixed land	434.9
Panel housing	240.4
Small-town areas	220.7
Other service facilities	218.5
Villas	194.0
Urban residential	129.8
Residential public parks	112.7
Commercial-service areas	97.2
Cemeteries	87.1
Railway facilities	83.4
Urban public parks	76.9
Modern residential	68.4
Landfill	58.2
Traffic areas	36.9
Wastewater	31.0
Zoo and amusement park	12.8
Botanical gardens	10.7
Thermal power plant	10.7
Waterworks	5.3
Water surface	1.6

We analysed the relation between green areas of the city and patchesof rNECONET surrounding Debrecen. In the studied area rNECONET consisted core areas (Figure 4; Patches 1-13), buffer zones (Patch 15) and ecological corridors (Patch 14) (Table 3). Urban green areas of the city were adjacent or overlapping with several patches of rNECONET (Patches 1; 3-5; 7; 9; 13; 15).

Table 3. Habitat types of the Regional Ecological Network surround Debrecen city.

Patch ID	Characteristic land use type	Urbanized habitats	Function in ecological network
1	croplands and grasslands	highway	core area
2	rural settlement, croplands, treeless grasslands	-	core area
3	forest area (nature reserve)	-	core area
4	forest area	botanical garden, other service facilities	core area
5	forest area	urban public park, cemetery	core area
6	cropland	-	core area
7	forest area, croplands, grasslands, wooded grassland, homesteads	-	core area
8	cropland and grassland	-	core area
9	arboretum, forest areas, wooded grasslands, reservoirs, croplands, homestead	-	core area
10	forest area and afforestation	-	core area
11	forest patches, afforestation, pond, croplands, homesteads	-	core area
12	grassland	-	core area
13	rural residential, undeveloped green space	railway facilities, commercial-service areas, suburban and modern residential	core area
14	treeless and wooded grasslands	-	ecological corridor
15	forest area, wooded grassland, croplands, rural residential, homesteads and hobby gardens	-	buffer zone

We found that in the studied urban ecosystem inter-patch distances ranged between 6 m to 2664 m. Western and northern part of the city is mostly connected, while in the eastern and southern green areas are isolated or form smaller set of habitats considering a 200 m threshold distance (Figure 5). The lower quartile was 16 m, the median was 40 m, and the upper quartile was 195 m. 65% of the data was below 100 m. Three fourth of the green spaces were closer than 200 m and only 10% of the nearest distances were higher than 500 m (Figure 6). Due to the close nearest neighbour patches, number of disjunct areas (as clusters of green space areas within a given distance) decreased in a relatively fast pace, i.e. within a 10-20-30 m buffer there were only 193, 128 and 98 clusters, while the original number of patches were 303. The 100 buffer distance involved a set of 38 clusters, and the 200 m buffer had 9 (Figure 7).

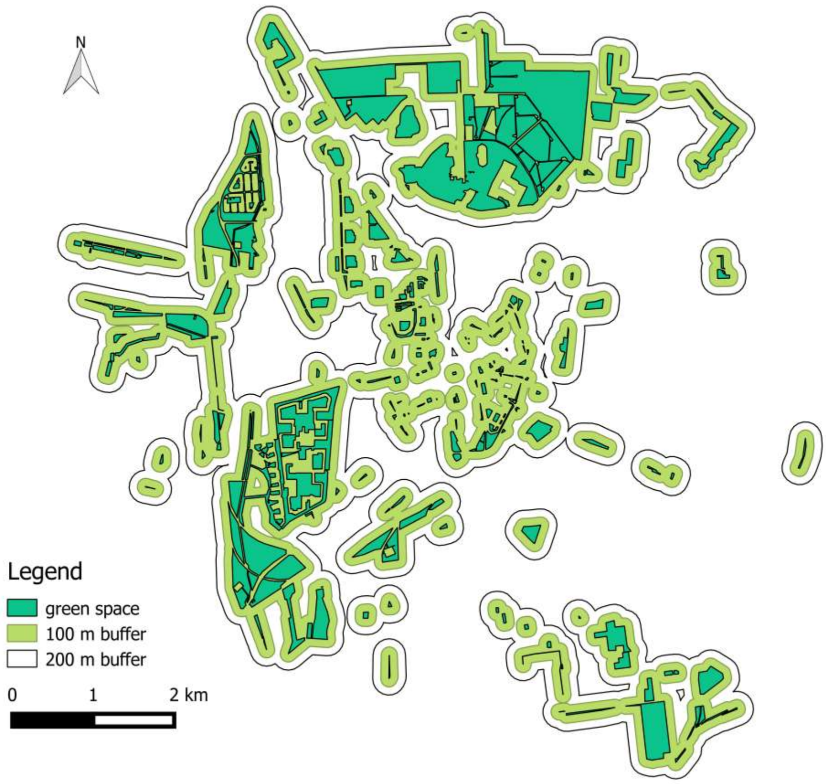

Figure 5. Functional connectivity of green space areas in Debrecen.

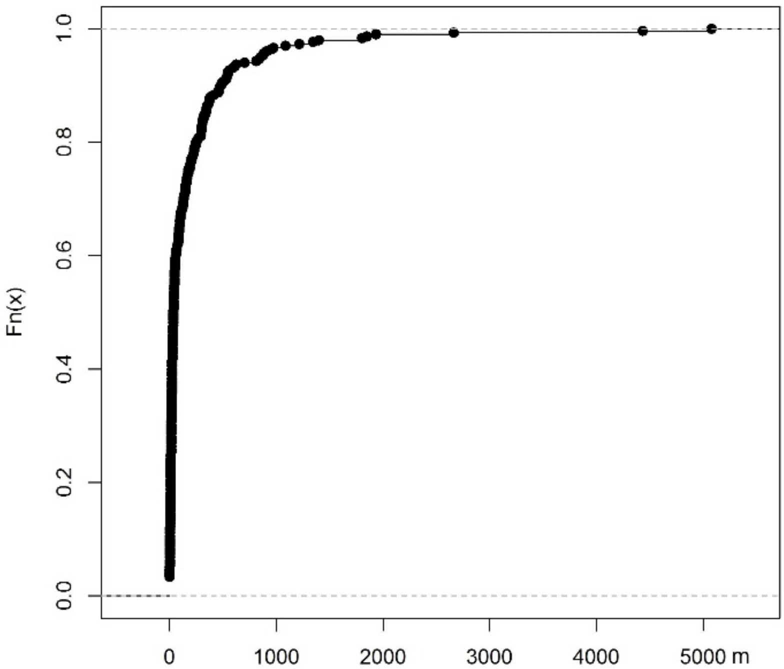

Figure 6. Cumulative relative frequency of the nearest neighbour distances between the green spaces.

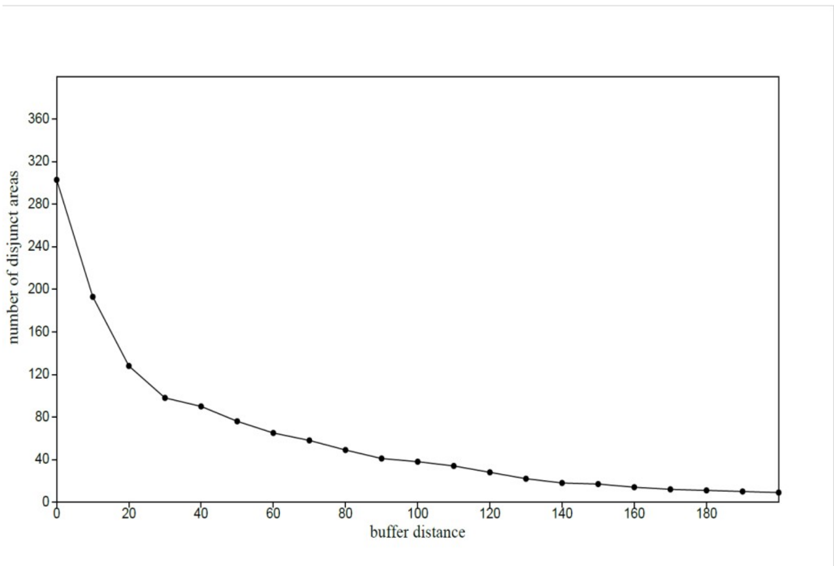

Figure 7. Number of disjunct green spaces in the function of 10 m buffer zones from the patch edges (0 means the original number of green space areas).

We found that mostly species typical to ruderal habitats (disturbance-tolerants, weeds and ruderal competitors) had the highest proportion in the spontaneous flora of the surveyed urban parks (Table 4). The most frequent disturbance-tolerant species were *Trifolium repens, Lolium perenne, Plantago lanceolata, Poa angustifolia, Lotus corniculatus* and *Stellaria media*. The most typical weed species were *Capsella bursa-pastoris, Erodium cicutarium, Plantago major* and *Hordeum murinum*. Frequent ruderal competitors were *Agropyron repens, Polygonum aviculare, Taraxacum officinale* and *Poa annua*. We also found species typical to habitats in a good nature conservation status such as *Poa pratensis* and *Violaodorata*.

Table 4. Social Behaviour Types of plant species in the spontaneous flora.

Social Behaviour Type	Mean±SD
Competitors	1.4±2.4
Generalists	3.4±4.3
Natural pioneers	0.5±1.5
Disturbance-tolerants	33.3±6.2
Weeds	29.9±8.3
Ruderal competitors	22.1±5.8
Adventives	0.5±1.4
Introduced alien species	1.7±2.1
Alien competitors	6.3±4.5

In the spontaneous flora of the studied urban parks, native species were the most typical (with a cover above 50%), although the ratio of archaeophytes and neophytes were also high (Table5). Among ornamental plants, both the proportion of native species and neophytes were considerable in each park, and the proportion of archaeophytes were low (Table6). Invasive neophytes had the highest proportion in spontaneous flora, ornamental species were represented mainly by casual neophytes. However, we also found several invasive species such as *Acer negundo, Ailanthus altissima, Phytolacca americana, Robinia pseudoacacia, Solidago canadensis* and *S. gigantea*.

Table 5. Origin of spontaneous flora of urban parks.

Urban parks	Species number	Native species (%)	Archeo-phytes (%)	Neo-phytes (%)	Uncertain (%)
No.1	23	52.2	17.4	21.7	8.7
No.2	27	55.6	29.6	7.4	7.4
No.3	10	70.0	20.0	0.0	10.0
No.4	13	61.5	23.1	7.7	7.7
No.5	45	68.9	11.1	13.3	6.7
No.6	20	60.0	25.0	5.0	10.0
No.7	23	56.5	26.1	13	4.3
No.8	30	60.0	26.7	13.3	0.0
No.9	34	50.0	26.5	14.7	8.8

Table 6. Origin of ornamental plants of urban parks.

Urban parks	Species number	Native species (%)	Archeo-phytes (%)	Neo-phytes (%)
No.1	8	62.5	12.5	25.0
No.2	7	42.9	14.3	42.9
No.3	41	53.7	2.4	43.9
No.4	16	43.8	6.3	50.0
No.5	28	50.0	7.1	42.9
No.6	26	46.2	3.8	50.0
No.7	18	61.1	0.0	38.9
No.8	11	45.5	0.0	54.5
No.9	5	40.0	0.0	60.0

Discussion

Species composition of urban habitats

Effect of disturbance intensity – The findings supported our hypothesis; we found that the urban parks characterised by a high level of urbanisation and disturbance harboured the lowest number of species and the lowest Shannon diversity. Mid-successional peri-urban grasslands characterised by a low disturbance regime were the most species-rich among the studied habitat types. This is in line with the findings of other studies where they found that intensively managed recreational sites had the lowest species numbers compared to any other habitat types (Sukopp 2004; LaPaix and Freedman 2010). In their study, Lososová et al. (2011) also found that species richness increased from the city centres towards the less urbanised urban peripheries. Continuous high-intensity disturbance in city centres supports weeds and disturbance-tolerant species but suppresses species of natural habitats (Williams et al. 2015). We detected a high proportion of weed species in all habitat types, however their cover scores were the highest in habitats of the city centre (vacant lots and urban parks). This was due to the frequent and intensive human disturbance such as trampling and soil disturbance which allows the establishment of these species (Cervelli et al. 2013). Weed species can establish in these sites also by their enhanced dispersal potential (e.g. wind dispersal) or can germinate from their persistent seed bank (Lososová et al. 2011; Valkó et al. 2011, 2013; Török et al. 2012b). Based on the results of the GLM it should be noted that vegetation of the sites showed a high level of variance, thus even though the observed trends are valid, the proportion of certain vegetation functional groups can vary due to the specific local conditions that we could not partial out in our model.

There was a marked difference in the species composition of the habitats; the species composition of urban parks, and the early- (vacant lots) and mid-successional (peri-urban grasslands) were well separated (see also the results of Lososová et al. 2011; Figure 3). Urban parks and vacant lots were characterised by species typical to disturbed and ruderal habitats in an early successional stage, such as *Erodium cicutarium, Hordeum murinum, Melandrium album* and *Taraxacum officinale*. Moreover, we detected ruderal species such as *Convolvulus arvensis* and *Cynodon dactylon* which are highly resistant for trampling. High ratio of trampling-tolerant species is typical in urban habitats in Europe (Lososová et al. 2011; Lundholm 2011).

We detected considerable differences in the species composition of peri-urban grasslands compared to the vacant lots and urban parks due to their different origin and landscape context. Peri-urban grasslands were mostly characterised by segetal weed species absent from urban habitats but typical for old-fields (*Cirsium arvense, Elymus repens,Lepidium ruderale, Papaver rhoeas* and *Vicia villosa*) which likely immigrated from the neighbouring arable fields and from the residual seed bank (Cervelli et al. 2013; Májeková and Zaliberová 2014; Valkó et al. 2016b). In case of disturbance-tolerant species we found a similar pattern: several species typical for the adjacent semi-natural grasslands were present in peri-urban grasslands, such as *Achillea collina, Daucus carota* and *Plantago lanceolata*.

Changes in environmental factors – The so-called "urban heat island effect" assumes that urban habitats are characterised by a higher temperature compared to their environments, which is mainly due to the higher rate of artificial surfaces (Kowarik 1995; McKinney 2006; McDonell & Hahs 2008). However, we did not find differences between the cover-weighted TB scores of the studied habitat types. The cover-weighted WB scores were the lowest in the urban parks and highest in peri-urban grasslands. This is in line with the findings of other studies, where they found that plant species of city centres are more drought-tolerant compared to peri-urban grasslands (Godefroid and Koedam 2007; Williams et al. 2015). This can be explained by the lack of asphalt surfaces, drainage and soil levelling in peri-urban grasslands (Dolan et al. 2011; Williams et al. 2015). Thus, surface water can be retained and species typical to habitats with moist or wet soils (such as *Carex vulpina, Calystegia sepium, Juncus* spp. and *Phalaris arundinacea*) can establish in smaller depressions of peri-urban grasslands. Furthermore, invasives typical for peri-urban grasslands (especially *Solidagocanadensis* and *S. gigantea*) are confined to mesophilous habitats. Species preferring high soil fertility are typical in urban habitats (Pyšek 1995). In our study, species with high nitrogen (NB) score were the most typical for the vacant lots; corroborating reports of high nitrogen deposit and low depletion in city centres (Lososová at al. 2006; Williams et al. 2015). However, it should be taken in consideration as well, that ruderal species favouring soil disturbances are generally characterised by high NB values, thus the effect of nitrogen influx and disturbance cannot be perfectly separated in this case.

Homogenisation – Several studies found that relative cover of alien species increased in city centres (Olden & Poff 2003; Kühn &Klotz 2006; Cervelli et al. 2013). Lososová et al. (2012a) proposed that increased levels of disturbance, nutrient flux and alien propagule pressure are the main drivers of plant invasions. In our study we found that the ratio of alien species in the spontaneous flora were high both in the early-successional vacant lots with a high disturbance level and mid-successional peri-urban grasslands, which represented the lowest disturbance regime. Urban parks harboured the fewest alien species. Even though most studies found that strongly disturbed habitats are the most prone to plant invasions (Chytrý et al. 2008; Lososová et al. 2012a), in our case likely the key factor was the successional stage of habitats, not the level of disturbance. This is in line with the findings of Albert et al. (2014), who found that the ratio of alien species is higher in younger habitats. In vacant lots the co-occurrence of early-successional age, the high levels of disturbance and the vicinity of potential propagule sources was likely responsible for the high proportion of the alien species. In this habitat *Ailanthus altissima, Celtis occidentalis* and *Solidago canadensis* were the most typical alien species. These species could establish in the habitat patches with a disturbed surface, their existence was supported by the low competitive ability of other species present (Fenesi et al. 2015; Kelemen et al. 2015, 2016). The propagules of *A. altissima* and *C. occidentalis* most likely originated from the neighbouring areas. In peri-urban grasslands beside *Solidago gigantea, Erigeron annuus* and *Medicago sativa* were present making up large proportions of the vegetation. The presence of *E. annuus,* which is a typical species of old-fields in the region (Albert et al. 2014), and *M. sativa* might be a result of former agricultural cultivation and spontaneous immigration from neighbouring agricultural areas and old-fields. The proportion of cosmopolitan species was high in all studied habitat types similar to urban habitats situated in other European cities (Lososová et al. 2012a). In contrast to the proportion of alien species, the proportion of cosmopolitan species was significantly higher in the most disturbed urban parks compared to the vacant lots and peri-urban grasslands. This is in line with the findings of Lososová et al. (2012b) who found that more disturbed habitats are more affected by biotic homogenisation. Cosmopolitan species were represented mainly by species such as *Capsella bursa-pastoris, Convolvulus arvensis, Erodium cicutarium* and *Poa compressa,* which are fast growing and short-lived and well adapted to disturbed habitats (Sukopp 2004).

Several studies found that the high ratio of cosmopolitan and alien species together with the continuous human disturbance puts native species at a competitive disadvantage, suppressing species typical to natural habitats (Sukopp 2004; McKinney 2006; Huwer and Wittig 2013; Williams et al. 2015). Our results confirmed this pattern; we found the lowest proportion of species typical for the natural habitats in vacant lots and urban parks. These results partly contradict the findings of Lososová et al. (2012a) who found that in spite of the low species richness of parks they harbour a small proportion of alien species. Even in our case, the ratio of alien species was low, likely because the high level of isolation did not allow the species of natural grasslands to persist or re-establish due to the depleted soil seed banks and limited dispersal ability of grassland species (Novák and Konvička 2006). Only some species such as *Agrostis stolonifera, Poa pratensis, Potentilla recta* and *Veronica prostrata* were present in a few sites with low cover. As was also found by Lososová et al. (2012a) the ratio of species typical to natural habitats were significantly higher in mid-successional peri-urban grasslands where the studied sites harboured several species typical for semi-natural dry and mesophilous grasslands, such as *Achillea collina, Agrostis stolonifera, Astragalus cicer, Poa pratensis* and *Potentilla recta*.

Urban green space system

We found that 65% of the functional green spaces are potentially connected, thus, there is a possibility for species typical to semi-natural open habitats to disperse between the green spaces of the city. However, the 200 m buffer distance of the habitat patches resulted in 9 disjunct areas, which means that the complete patch level connectivity is not ensured within Debrecen, southern and eastern areas represent isolated regions based on our present approach. On the one hand, the high level of connectivity is favourable for sustaining biodiversity (Lososová et al. 2011) which is shown by the relatively high ratio of native species. On the other hand, it can be problematic, as it can also support the spread of invasive species (Lososová et al. 2012). We found that the even the ratio of native species was relatively high in the studied urban parks, these habitats were predominantly characterised by disturbance-tolerant species of natural habitats. It suggests that the studied urban habitats have some biodiversity conservation potential, however they mostly harbour species which can cope with unfriendly environmental conditions such as increased temperature, drought and nutrient enrichment (Godefroid 2001; Lososová et al. 2011). Altered environmental conditions together with the continuous high-intensity disturbance are responsible for the spread of neophyte species as was found also in case of other large cities (Lososová et al. 2012; Williams et al. 2015). As our results pointed out, the spread of neophytes are also supported by the gardening activity of the city like in other Central-European settlements (Huwer and Wittig 2013). We found similar patterns of vegetation as was reported by Kowarik (1990) from Berlin; urban conditions promote colonization and survival of disturbant-tolerant and invasive species.

The most successful invasive species in the green areas of Debrecen included *Acer negundo*, *Ailanthus altissima* and *Robinia pseudo-acacia*, which are also widespread in European cities, for instance in the urban areas of Berlin (Kowarik 1990). Lososová et al. (2012) also reported the presence of *Ailanthus altissima* from several European cities. These species were often used as ornamental plants in the studied parks. Surveying invasive species is especially important in urban environments, because many plants are able to escape from cultivation and can easily spread to other habitats due to their good dispersal ability (Lososová et al. 2012).

In Hungary, green space planning is regulated by the Requirements of Urban Planning and Building (Decree 253/1997 and 10/2016) as the part of the urban territorial planning. Our general observation was that the area of the green spaces shrank in the city centres due to the denser building-up, i.e. green spaces had larger area in the outskirts. Minimal green space ratio is present only in private plots and public parks (see also Jámbor 2008). There is no regulation for the quality of the green spaces, for instance there are no criteria about the species used in gardening activities. Unfortunately the current legislation does not support the introduction of native species to urban green areas, thus, in many cases, invasive species are introduced because of their wide disturbance-tolerance or rapid growth.

Conclusions

In our study we found that species composition of urban habitat types was considerably affected by the specific disturbances and site histories associated with the certain habitats (see also Lososová et al. 2012a). The studied habitats were affected by various disturbance factors such as trampling, soil disturbances and mowing, which resulted in lower species diversity and a higher proportion of weeds and disturbance-tolerant species. In addition, in urban habitats the dry and nutrient-rich environment proved to be an important driver of the vegetation composition. The special conditions in urban habitats led to a homogenisation of the vegetation. In the vacant lots and urban parks we observed a significantly higher proportion of cosmopolitan species and a considerably lower proportion of species typical for the natural habitats compared to peri-urban grasslands. Although the studied urban habitat patches did not contribute considerably to the preservation of rare or endangered plant species, they still play an important role in preserving last remnants of grasslands in an intensively used landscape, and providing essential ecosystem services for the society. Moreover, even the smallest fragment of grasslands may contribute to the support of diversity of macro-invertebrates as pointed out by Horváth et al. (2009, 2012, 2015).

Our study reveals that in many cities there is an urgent need for a conceptual naturalizing plan for the urban habitats by introducing species typical for natural habitats and providing proper management for them (Deák et al. 2011; Kelemen et al. 2014; Tälle et al. 2016). Mowing of the grasslands and the removal of the hay and litter strongly influence the species composition (Török et al. 2010, 2011; Valkó et al. 2012; Miglécz et al. 2013). As Klaus (2013) points out, grassland restoration projects in urban environments have a considerable advantage compared to ones in agricultural landscapes, namely that in urban ecosystems there is no interest in maximizing the yield and long-term management is more feasible. We suggest using perennial, disturbance tolerant, competitor species of the local flora which can cope with the special urban conditions in such projects (Deák & Valkó 2013; Miglécz et al. 2015). Preferably the seeds should be originated from a local provenance to conserve the regional gene pool (Török & Tóthmérész 2015; Valkó et al. 2016c).

In the planning of green spaces we suggest starting with a botanical survey, focusing on invasive species. We demonstrated that urban parks, even being the most important and most extent elements of the green space system, are highly infested with invasive species. It is reported by several authors as a global threatening factor in urban areas (Alexis 2006; McKinney, 2008). Consequently, the first step of the maintenance of urban biodiversity should be to facilitate the presence of native species in the urban parks and eliminate the non-native ones. As McKinney (2008) pointed out, introduced non-native species can be the major factor of influencing the species richness, which is just a pseudo-diversity from the ecological point of view. An important step could be whether instead of planting invasive ornamental plants, horticulturists would prefer native species from the already existing "green lists" (Dehnen-Schmutz 2011). It also should be taken into account that urban areas have a great potential for grassland restoration projects, which could effectively contribute to increase both the floral and faunal diversity of the cities (Klaus 2013).

It is important to involve ecologists in the planning process of urban development. This suggestion is in accordance with the suggestions of Alexis (2006), who emphasized the responsibility of city planners in the recognition that urban areas are potential refugees of biodiversity in urban environments. For example in Berlin, which is one of the biggest cities of Europe, 5% of the urban area is covered by grasslands of which 43% is under a legal protection due to its high nature conservation value. Even decision-makers usually focus on parks and forest remnants, it should be noted that they are not the only green space systems in the cities. Gardens, suburban and rural residential areas may also provide valuable habitats for plant and animal species (Rudd et al.2002). Green space system can be a network of potential habitats for plants and animals, thus, it is important to ensure connections with the neighbouring nature close habitats, in this way, species typical to natural habitats can immigrate into urban green areas and enhance their biodiversity.

It is crucial to increase the area of green spaces to decrease the negative effects of extreme urban conditions both on the livelihood of citizens and also on the biota of remaining habitat fragments. Connected green spaces (green space system) provide essential ecosystem services, such as climate regulation, by providing cooler and more humid conditions, and also by venting and refreshing effect. Plants can filter the dust and pollutants, preserve urban soils against drying and erosion and decrease noise pollution.

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Appendix

Appendix 1. Vacant lot (Hatvan street, Debrecen).

Appendix 2. Urban park (Wesselényi street, Debrecen).

Appendix 3. Peri-urban area (Tócó-liget, Debrecen).

Appendix 4. Mean cover scores, frequency, relative indicator values for temperature (TB), moisture (WB) and nitrogen (NB), social behaviour type (SBT) and the flora element type (FLE) of the detected species in vacant lots (cover > 0.5%). Abbreviations of social behaviour types: adventive competitors (AC), adventives (A), disturbance-tolerants (DT), generalists (G), invasives (I), ruderal competitors (RC), weeds (W). Abbreviations of flora element types: Adventive (ADV), Circum-boreal (CIR), Cosmopolitan (COS), Eastern- Sub-Mediterranean (SMO), Eurasian (EUA), European (EUR), Sub-Mediterranean (SME).

Species name	TB	WB	NB	SBT	FLE	Mean cover	Frequency
Achillea millefolium	5	6	5	DT	COS	1.8	6
Ailanthus altissima	8	5	8	AC	ADV	3.8	2
Anchusa officinalis	8	3	5	DT	EUR	1.2	5
Arctium lappa	5	6	9	W	EUA	3.5	6
Ballota nigra	6	5	8	W	SME	1.2	3
Bromus tectorum	6	3	4	DT	EUA	20.1	23
Capsella bursa-pastoris	6	5	7	W	COS	0.7	14
Celtis occidentalis	5	5	5	I	ADV	0.8	2
Chelidonium majus	6	5	9	W	EUA	2.4	5
Cirsium arvense	5	4	7	RC	EUA	2	9
Convolvulus arvensis	6	4	4	RC	COS	1.9	8
Elymus repens	5	5	7	RC	CIR	4.8	7
Erodium cicutarium	6	4	4	W	COS	0.9	6
Galium aparine	5	7	9	W	COS	1.3	8
Geranium pusillum	6	3	6	DT	EUR	0.5	7
Hordeum murinum	7	4	6	W	ADV	2.1	12
Lolium perenne	5	5	7	DT	COS	9.2	18
Malva sylvestris	6	4	8	W	COS	0.5	5
Medicago lupulina	5	5	4	DT	EUA	0.5	6
Melandrium album	5	4	7	W	EUR	1.8	13
Parthenocissus quinqefolia	5	5	5	A	ADV	0.8	1
Poa annua	5	6	8	RC	COS	1	4
Poa pratensis	5	6	5	G	COS	1.6	5
Solidago canadensis	6	7	6	AC	ADV	3.8	4
Taraxacum officinalis	5	5	7	RC	EUA	3.6	18
Tragopogon pratense	5	4	6	DT	EUA	1.2	4
Trifolium pratense	5	6	5	DT	EUA	1.9	4
Trifolium repens	5	5	7	DT	COS	5	11
Urtica dioica	6	7	9	DT	COS	1.3	5
Vicia angustifolia	7	3	5	DT	EUA	0.6	4
Vicia grandiflora	7	4	4	DT	SMO	2.8	8

List of species with a mean cover lower than 0.5%. Frequency scores are given in brackets.

Alopecurus pratensis (2), *Ambrosia artemisifolia* (2), *Anthriscus cerefolium* (1), *Apera spica-venti* (1), *Aquilegia vulgaris* (1), *Artemisia vulgaris* (2), *Asperugo procumbens* (2), *Astragalu scicer* (1), *Calystegia sepium* (1), *Carex hirta* (4), *Cerastium semidecandrum* (7), *Chenopodium album* (2), *Clematis vitalba* (1), *Dactylis glomerata* (2), *Daucus carota* (1), *Descurainia sophia* (2), *Duchesnea indica* (1), *Echium vulgare* (1), *Erigeron annuus* (8), *Euphorbia cyparissias* (1), *Galium verum* (2), *Geum urbanum* (2), *Glechoma hederacea* (1), *Hypochoeris radicata* (1), *Lamium purpureum* (7), *Leontodon hispidus* (1), *Lotus corniculatus* (1), *Medicago sativa* (1), *Oxalis corniculata* (5), *Parthenocissus tricuspidata* (1), *Phytolacca americana* (3), *Plantago lanceolata* (5), *Plantago major* (5), *Poa angustifolia* (3), *Poa bulbosa* (1), *Poa compressa* (4), *Polygonum aviculare* (3), *Potentilla recta* (1), *Ranunculus repens* (1), *Rosa canina* (2), *Rubus caesius* (3), *Rumex acetosa* (1), *Rumex crispus* (2), *Rumex obtusifolius* (1), *Salix alba* (1), *Sambucus nigra* (2), *Scorzonera cana* (1), *Solidago gigantea* (1), *Sonchus oleraceus* (1), *Stellaria media* (9), *Verbascum phoeniceum* (1), *Veronica chamaedrys* (2), *Veronica hederifolia* (2), *Veronica polita* (4), *Veronica verna* (4), *Vicia hirsuta* (1), *Vicia villosa* (2), *Viola arvensis* (1), *Viola sororia* (6).

Appendix 5. Mean cover scores, frequency, relative indicator values for temperature (TB), moisture (WB) and nitrogen (NB), social behaviour type (SBT) and the flora element type (FLE) of the detected species in urban parks (cover > 0.5%). Abbreviations of social behaviour types: disturbance-tolerants (DT), generalists (G), invasives (I), natural pioneers (NP), ruderal competitors (RC), weeds (W). Abbreviations of flora element types: Adventive (ADV), Atlantic-Sub-Mediterranean (AsM), Circum-boreal (CIR), Cosmopolitan (COS), Eurasian (EUA), European (EUR), Sub-Mediterranean (SME), Turanian (TUR).

Species name	TB	WB	NB	SBT	FLE	Mean cover	Frequency
Achillea millefolium	5	6	5	DT	COS	1.0	14
Bellis perennis	5	5	5	DT	AsM	1.0	4
Bromus mollis	6	5	5	DT	COS	1.7	6
Capsella bursa-pastoris	6	5	7	W	COS	3.8	19
Carex hirta	6	7	5	DT	EUR	2.7	4
Cerastium semidecandrum	7	2	2	NP	SME	1.2	5
Convolvulus arvensis	6	4	4	RC	COS	5.9	10
Cynodon dactylon	7	3	5	RC	COS	3.2	6
Erodium cicutarium	6	4	4	W	COS	9.4	10
Geranium pusillum	6	3	6	DT	EUR	4.2	14
Hordeum murinum	7	4	6	W	ADV	2.0	11
Lepidium draba	7	3	4	W	EUA	0.7	3
Lolium perenne	5	5	7	DT	COS	21.6	21
Plantago lanceolata	5	4	5	DT	COS	2.6	19
Poa bulbosa	8	2	1	NP	TUR	0.9	3
Poa compressa	6	2	2	DT	COS	4.4	10
Poa pratensis	5	6	5	G	COS	1.7	6
Polygonum aviculare	5	4	5	RC	COS	1.4	14
Potentilla argentea	5	2	1	DT	CIR	1.2	6
Stellaria media	5	5	8	DT	COS	0.5	14
Taraxacum officinale	5	5	7	RC	EUA	6.0	17
Trifolium repens	5	5	7	DT	COS	1.9	11
Veronica verna	6	1	1	NP	TUR	1.3	16
Viola sororia	5	5	5	I	EUA	1.3	2

List of species with a mean cover lower than 0.5%. Frequency scores are given in brackets.

Ambrosia artemisifolia (1), *Bromus tectorum* (1), *Cynoglossum officinale* (1), *Dactylis glomerata* (1), *Elymus repens* (5), *Erigeron annuus* (3), *Erigeron canadensis* (1), *Lamium purpureum* (2), *Malva neglecta* (2), *Malva sylvestris* (3), *Medicago lupulina* (5), *Medicagosativa* (1), *Melandrium album* (4), *Oxalis corniculata* (2), *Plantago major* (5), *Tragopogon pratensis* (3), *Veronica hederifolia* (1), *Veronica polita* (5), *Veronica prostrata* (1), *Viciagrandiflora* (2).

Appendix 6. Mean cover scores, frequency, relative indicator values for temperature (TB), moisture (WB) and nitrogen (NB), social behaviour type (SBT) and the flora element type (FLE) of the detected species in peri-urban grasslands (cover > 0.5%). Abbreviations of social behaviour types: adventive competitors (AC), adventives (A), disturbance-tolerants (DT), generalists (G), invasives (I), ruderal competitors (RC), weeds (W). Abbreviations of flora element types: Adventive (ADV), Circum-boreal (CIR), Cosmopolitan (COS), Eastern- Sub-Mediterranean (SMO), Eurasian (EUA), European (EUR), Sub-Mediterranean (SME).

Species name	TB	WB	NB	SBT	FLE	Mean cover	Frequency
Achillea millefolium	5	6	5	DT	COS	1.8	6
Ailanthus altissima	8	5	8	AC	ADV	3.8	2
Anchusa officinalis	8	3	5	DT	EUR	1.2	5
Arctium lappa	5	6	9	W	EUA	3.5	6
Ballota nigra	6	5	8	W	SME	1.2	3
Bromus tectorum	6	3	4	DT	EUA	20.1	23
Capsella bursa-pastoris	6	5	7	W	COS	0.7	14
Celtis occidentalis	5	5	5	I	ADV	0.8	2
Chelidonium majus	6	5	9	W	EUA	2.4	5
Cirsium arvense	5	4	7	RC	EUA	2	9
Convolvulus arvensis	6	4	4	RC	COS	1.9	8
Elymus repens	5	5	7	RC	CIR	4.8	7
Erodium cicutarium	6	4	4	W	COS	0.9	6
Galium aparine	5	7	9	W	COS	1.3	8
Geranium pusillum	6	3	6	DT	EUR	0.5	7
Hordeum murinum	7	4	6	W	ADV	2.1	12
Lolium perenne	5	5	7	DT	COS	9.2	18
Malva sylvestris	6	4	8	W	COS	0.5	5
Medicago lupulina	5	5	4	DT	EUA	0.5	6
Melandrium album	5	4	7	W	EUR	1.8	13
Parthenocissus quinqefolia	5	5	5	A	ADV	0.8	1
Poa annua	5	6	8	RC	COS	1	4
Poa pratensis	5	6	5	G	COS	1.6	5
Solidago canadensis	6	7	6	AC	ADV	3.8	4
Taraxacum officinalis	5	5	7	RC	EUA	3.6	18
Tragopogon pratense	5	4	6	DT	EUA	1.2	4
Trifolium pratense	5	6	5	DT	EUA	1.9	4
Trifolium repens	5	5	7	DT	COS	5	11
Urtica dioica	6	7	9	DT	COS	1.3	5
Vicia angustifolia	7	3	5	DT	EUA	0.6	4
Vicia grandiflora	7	4	4	DT	SMO	2.8	8

List of species with a mean cover lower than 0.5%. Frequency scores are given in brackets.

Alopecurus pratensis (2), *Ambrosia artemisifolia* (2), *Anthriscus cerefolium* (1), *Apera spica-venti* (1), *Aquilegia vulgaris* (1), *Artemisia vulgaris* (2), *Asperugo procumbens* (2), *Astragaluscicer* (1), *Calystegia sepium* (1), *Carex hirta* (4), *Cerastium semidecandrum* (7), *Chenopodium album* (2), *Clematis vitalba* (1), *Dactylis glomerata* (2), *Daucus carota* (1), *Descurainia sophia* (2), *Duchesnea indica* (1), *Echium vulgare* (1), *Erigeron annuus* (8), *Euphorbia cyparissias* (1), *Galium verum* (2), *Geum urbanum* (2), *Glechoma hederacea* (1), *Hypochoeris radicata* (1), *Lamium purpureum* (7), *Leontodon hispidus* (1), *Lotus corniculatus* (1), *Medicago sativa* (1), *Oxalis corniculata* (5), *Parthenocissus tricuspidata* (1), *Phytolacca americana* (3), *Plantago lanceolata* (5), *Plantago major* (5), *Poa angustifolia* (3), *Poa bulbosa* (1), *Poa compressa* (4), *Polygonum aviculare* (3), *Potentilla recta* (1), *Ranunculus repens* (1), *Rosa canina* (2), *Rubus caesius* (3), *Rumex acetosa* (1), *Rumexcrispus* (2), *Rumex obtusifolius* (1), *Salix alba* (1), *Sambucus nigra* (2), *Scorzonera cana* (1), *Solidago gigantea* (1), *Sonchus oleraceus* (1), *Stellaria media* (9), *Verbascum phoeniceum* (1), *Veronica chamaedrys* (2), *Veronica hederifolia* (2), *Veronica polita* (4), *Veronica verna* (4), *Vicia hirsuta* (1), *Vicia villosa* (2), *Viola arvensis* (1), *Viola sororia* (6)