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IMPACT OF SECONDARY LANDSCAPE STRUCTURE ON THE PRESENCE OF NON-NATIVE PLANT SPECIES IN THE CADASTRAL AREA OF THE TOPOĽČANY TOWN

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Abstract

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This study characterises an impact of secondary landscape structure on the introduction of non--native plant species during the years 2008 and 2010–2012. The field mapping was realised in the cadastral area of the Topoľčany town. The area of study consists of built-up area with surrounding agricultural land. During the period of our research, we identified the presence of total 55 non--native plant species, including 21 invasive, 11 casual and 23 naturalised. The highest dominance occurred in elements of ruderal vegetation without trees (22) and in the vegetation protection of aquatic dams (15). Several species were observed in a wide range of landscape elements. The occurrence in many structurally different types of habitats confirmed the ability of non-native species to tolerate a wide range of biotic and abiotic conditions.

Key words: secondary landscape structure, non-native plant species.

Introduction

Intensive anthropic activity affects the landscape structure and is an important factor in determining its dynamics (Baudry, Tatoni, 1993; Goudie, 2005). Non-native plant species have been an integral part of our native vegetation for several decades. Many of them pose a serious global threat, have significant environmental impacts and cause economic losses at the local, regional and national scales (Marinelli, 2004; Rejmánek et al., 2005; Vilá, Pujadas, 2001; Meiners, Cadenasso, 2005). They also decrease the biodiversity of affected areas (Mlíkovský, Stýblo, 2006; Nentwig, 2007) and displace many native species (Callaway, Aschehoug, 2000), which can lead to the complete replacement of native populations (Huxel, 1999). Many experts consider them to be one of the leading negative impacts on natural and agricultural systems of the world (Wittenberg, Cock, 2001; Pimm et al., 1995). Important factors allowing the introduction, dispersion and also naturalisation of non-native plant species in the area include the strong anthropic pressure on vegetation (eutrophication of the environment, soil erosion, urbanization, etc.). Disturbance of the soil surface increases invasibility of the area because of the removal of natural species, destroys the relations between species and increases the availability of abiotic resources such as light, water and nutrients (Davis et al., 2000). Introduction itself and subsequent spread is carried out by the support of landscape structure, which has undergone many changes over various time periods.

The speed of dispersion and success of the introduction in the area may be significantly determined not only by the representation of different types of landscape structures and their spatial relations (localisation, interaction or isolation) but also by its changes (Eliáš, 2001). Impact of secondary landscape structure on the occurrence of non-native plant species was evaluated in the cadastral area of Topoľčany town. This study area is defined by the cadastral boundaries and consists of heterogeneous landscape elements and is an important centre of transport, trade and industry. The dispersion of non-native plant species is largely realised by the corridors. As a linear element of landscape structure, it provides the movement between habitats (Rosenberg et al., 1997) in a relatively short time (Nentwig, 2007). Major national transport routes and corridors cross our study area. Based on these factors, attention has been given to increasing occurrence of non-native plant species especially in their surroundings. This assumption is highlighted by the fact that the contact area between the boundary of the urban and rural area acts as the filtering zone where species penetrate from built-up areas to the environment and back (the so-called edge effect). Based on these arguments, this paper aims to evaluate the impact of secondary landscape structure and importance of landscape elements on the introduction of non-native plant species in the

Material and methods

A survey was realised in the cadastral area of Topoľčany town, which is situated in the south-west part of the Slovak Republic and in the northern part of the Nitra Region (Fig. 1). The research consisted of two parts. The first part is represented by the evaluation of groups of elements of secondary landscape structure and it includes groups of forest and shrubs vegetation, grasslands, agricultural crops, raw land, water area, built-up area and other areas. The second part is focused on the occurrence of non-native plant species in the study area in various elements of landscape structure. The composition of the current landscape structure was processed using the software Quantum GIS 1.7.2. The individual landscape elements were determined in the context of the work of Petrovič et al. (2009). The current landscape structure was digitised by the vectorisation of orthophotos from 2003 and topographic maps. The correction of landscape elements was carried out on the basis of field mapping in the years 2008 and 2010–2012.

The occurrence of non-native plant species was recorded by the inventory of study area with approximately 2707 ha. Non-native species were identified during the flowering seasons because of the simpler determination. Identified species were also evaluated in relation to non-originality (invasive, naturalized, casual), according to the list of non-native plants in the Slovak Republic published by Medvecká et al. (2012). The size and number of individuals were recorded according to the evidentiary letter for mapping invasive plant species, where based on the number, it is possible to divide the found values into groups: I, individual; GI, group of individuals; SG, small groups; LIV, large involved vegetation. The abundance of localities of non-native plants was derived by using the semi-quantitative scale of Pyšek et al. (2002): 1 = 1–4 localities, 2 = 5–14 localities, 3 = 15–49 localities, 4 = 50–499 localities, 5 = more than 500 localities. The frequency of plants and their occurrence were observed in three forms: point, line and area incidence. Finally, we also determined the type of vegetation (expansive, cultivation, without specifying the origin); the GPS location of occurrence in the landscape; the distance to the corridors (road, railway, watercourse); the Ellenberg values for light, heat, moisture, pH and nutrients; and the degree of hemeroby within the landscape elements. The influence of selected corridors on the species distribution was analysed by identifying the number of populations located within selected buffers of 5, 10 and 50 m around rivers, roads and railways (according to Mahy et al., 2006).

For the landscape structure, we calculated and established the following indicators: the number of patches, the mean patch size and the coefficient of landscape ecological stability (Oláhová et al., 2013). The quantification and changes of individual landscape elements were identified using GIS tools (Oláhová et al., 2012). Shannon's diversity and evenness indices were used to establish diversity of non-native species in landscape elements. For the correlation analysis of data, we used the software Canoco (Ter Braak, Šmilauer, 2002). Input data (data matrix) consisted of the number of identified non-native plant species related to the elements of secondary landscape structure. For the multivariate analysis of coenoses, we used DCA (detrended correspondence analysis), and the relation of non-native species and environmental characteristics was analysed by the direct linear RDA analysis (redundancy analysis).

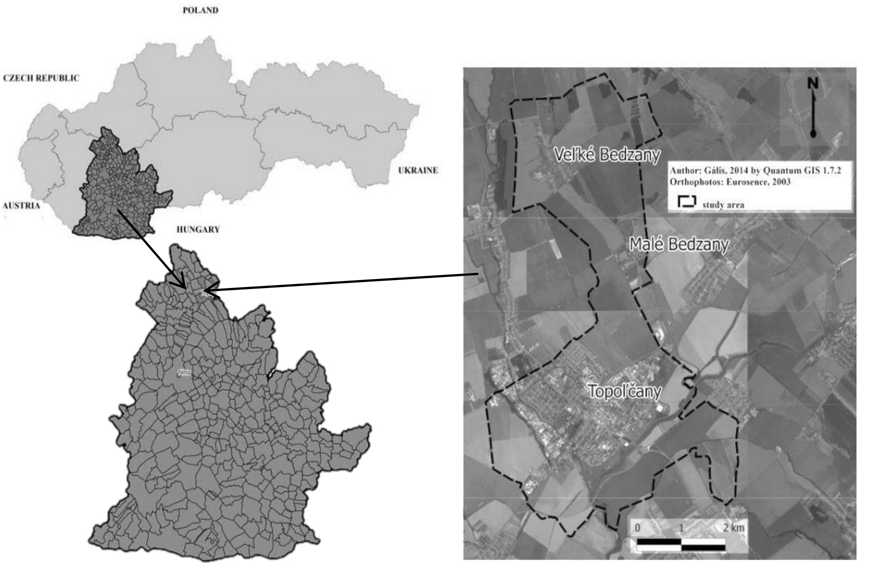

Fig. 1. Study area location.

The evaluation of dynamics changes of non-native plant species was carried out only for the corridor of the Nitra River because of the size of the study area and the quality of obtained data. The occurrence of non-native species in 2008 and 2010 was compared to the results found by the field research during 2011 and 2012. This comparison showed us changes in the number (increase or decrease) of individuals, in the size of invaded area, in the direction of the dispersion of individuals and the possible emergence of new sites around the corridor.

Results

Analysis of the current landscape structure

Totally, six groups of elements of current landscape structure were determined according to the work of Petrovič et al. (2009) on the basis of field research in 2008 and 2010–2012. The study area has heterogeneous landscape structure with the dominant agricultural use, high share of built-up areas and a low degree of forest and non-forest woody vegetation. A dominant percentage is represented by agricultural crops, less by built-up areas and the lowest percentage has raw lands (Fig. 2).

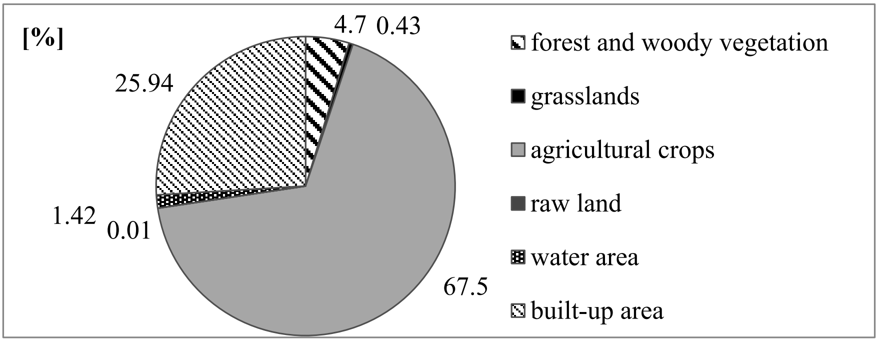

Fig. 2. Percentages of individual landscape structure categories in the study area.

Our analysis shows that the mean size of patches in the study area was 1.9 ha. The results of the coefficient of ecological stability indicate that the study area is slightly unstabilised. Elements with low ecological stability were formed by built-up areas in the central part and arable land in its surroundings. Medium and high degree of ecological stability was recorded in grasslands, water area (river, water body) and woody vegetation mainly in the banks of the river.

Individual elements of the current landscape structure were classified on the basis of orthophotos by GIS tools and corrected with field mapping, which was carried out in 2012 according to the classification key of elements that are mappable in the Slovak Republic (Petrovič et al., 2009). A total number of 45 elements were identified in the study area with the dominant percentage of elements from group of agricultural crops. The highest area was covered by the element of fields (1587.7 ha) that are located in surroundings of the town. The landscape elements from the group of built-up areas are technical objects (210 ha) and production-ornamental house gardens (127 ha).

Species analysis

Within the study area, we identified the presence of 55 species defined as non-native in the context of the work of Medvecká et al. (2012). Invasive species were represented by *Acer negundo*, *Ailanthus altissima*, *Amaranthus retroflexus*, *Ambrosia artemisiifolia*, *Apera spica-venti*, *Asclepias syriaca*, *Aster novi-belgii*, *Bidens frondosa*, *Conyza canadensis*, *Echinocystis lobata*, *Echinochloa crus-galli*, *Erigeron annuus*, *Galinsoga parviflora*, *Helianthus tuberosus*, *Impatiens parviflora*, *I. glandulifera*, *Lycium barbarum*, *Robinia pseudoacacia, Rumex patientia*, *Solidago canadensis* and *S. gigantea*.

From the category of casual species, we identified *Acer saccharinum*, *Amaranthus viridis*, *Atriplex hortensis*, *Berberis thunbergii*, *Fallopia aubertii*, *Helianthus annuus*, *Chamaecyparis lawsoniana*, *Kerria japonica*, *Liriodendron tulipifera*, *Pyracantha coccinea*, and *Rhus typhina*.

The identified naturalised species were *Abutilon theophrasti*, *Aesculus hippocastanum*, *Agrostemma githago*, *Amorpha fruticosa*, *Anthemis arvensis*, *Artemisia annua*, *Atriplex sagittata*, *Ballota nigra*, *Bromus tectorum*, *Bunias orientalis*, *Cichorium intybus*, *Datura stramo-*

nium, *Elaeagnus angustifolia*, *Fallopia × bohemica*, *Iva xanthiifolia*, *Lamium purpureum*, *Lupinus polyphyllus*, *Mahonia aquifolium*, *Parthenocissus quinquefolia*, *Phytolacca americana*, *Rudbeckia laciniata*, *Senecio vulgaris*, *Thlaspi arvense*.

From 55 identified non-native plant species, the biggest occurrence was achieved by invasive neophytes in the form of 19 species, followed by naturalized (14) and casual neophytes (10) (Fig. 3).

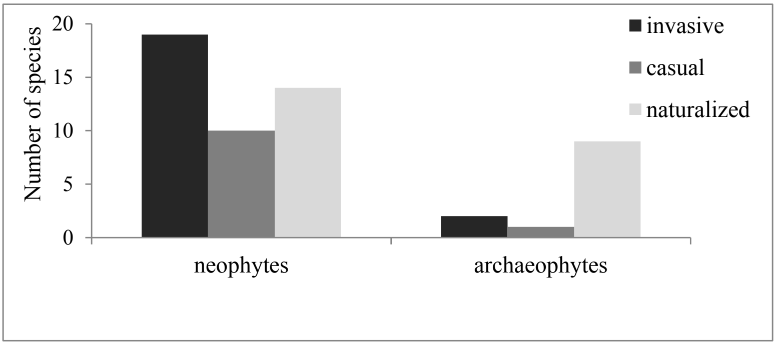

Fig. 3. Number of neophytes and archaeophytes in the study area.

This species spectrum belonged to 23 families: (16 species) *Astraceae*, (4) *Amaranthaceae*, (1) *Anacardiaceae*, (1) *Apocynaceae*, (2) *Balsaminaceae*, (2) *Brassicaceae*, (2) *Berberidaceae*, (1) Cucurbitaceae, (1) *Cupressaceae*, (1) *Elaeagnaceae*, (3) *Fabaceae*, (2) *Lamiaceae*, (1) *Magnoliaceae*, (1) *Malvaceae*, (1) *Papaveraceae*, (1) *Phytolaccaceae*, (3) *Poaceae*, (3) *Polygonaceae*, (2) *Rosaceae*, (3) *Sapindaceae*, (1) *Simaroubaceae*, (2) *Solanaceae*, (1) *Vitaceae*.

Shannon's diversity and evenness indices were used to determine the diversity of non-native species in elements (Table 1).

The landscape element with the highest value was ruderal vegetation without trees (H´= 2.228). Almost the same values were calculated for the elements: protection of aquatic dams (H´= 2.154) and industrial objects (H´= 2.117).

The highest number of non-native species was recorded within the landscape element of ruderal vegetation without trees (overall 22 species). The next largest occurrence was identified in the element of protection of aquatic dams (15 species). The lowest number of species was represented in the element of deciduous forests and alleys (2 species). Comparing the index of evenness of species community (Sheldon), the most even were communities located in the elements of deciduous forests and alleys (E = 0.965). The lowest value of community evenness was recorded in the element of ruderal vegetation without trees (E = 0.720) and vegetation of protection dams (E = 0.795).

Correlation between species and elements of the current landscape structure

We analyzed the relation between identified non-native plant species and their localization in various elements of the current landscape structure. Using the ordination methods of DCA, T a b l e 1. Cenological characteristics of selected elements of landscape structure.

LE	deciduous forests	group forest deci	group of mixed forest	alley	riparian vegetation	shrub vegetation
S	2	5	3	2	13	4
H´	0,733	1,325	0,964	0,733	2,072	1,159
E	0,965	0,823	0,877	0,965	0,807	0,836
LE	big field area	small field area	house gardens	horticultural area	town center	park vegetation
S	10	12	12	10	7	10
H´	1,884	2,019	2,019	1,884	1,595	1,884
E	0,818	0,812	0,812	0,818	0,819	0,818
LE	city vegetation	ruderal vegetation	ruderal vegetation	vegetation traffic route	bank vegetation	sport area
S	13	22	10	8	15	5
H´	2,072	2,228	1,884	1,704	2,154	1,325
E	0,807	0,720	0,818	0,819	0,795	0,823
LE	industrial objects	bus station	railroad tracks	railway station		
S	14	5	13	13		
H´	2,117	1,325	2,072	2,072		
E	0,802	0,823	0,807	0,807		

Explanations: KP – landscape element, S – number of species, H´- diversity, E – evenness.

we tested the heterogeneity of species data. We found out that the value of length gradient was length of gradient = (SD) = 5.0180. Our model explains relatively small part of the total variability of data = 4.354. The first coordination axis explains 15% and the second axis 35.1% of cumulative variability of species data. The result of indirect ordination DCA is an ordination diagram (Fig. 4).

Biplot shows the ordination of species and landscape elements. The first axis explains species diversity, and the second axis explains the dominance of species within the landscape elements. All species are shown in the positive portion along the first ordination axis, except *Lamium purpureum*. In the first cluster, there are ordinated species such as *Aesculus hippocastanum*, *Liriodendron tulipifera* and *Mahonia aquifolium*, the occurrence of which is bound to park vegetation (6210 – number of landscape element). The second, more significant cluster (axis 1 +2 to +5), is formed by species such as *Acer negundo*, *Ailanthus altissima*, *Elaeagnus angustifolia*, *Parthenocissus quinquefolia* and *Rhus typhina*, which are connected to the vegetation of built-up area in the form of an urban center (6132) and other urban green (6220).

Other species in the direction of the gradient are *Amaranthus retroflexus*, *Ambrosia artemisiifolia*, *Amorpha fruticosa* and *Rumex patientia*. These types of vegetation are part of the built-up areas in the form of sports facilities (6242) and bus station (6622). Large clusters is a group of species such as *Erigeron annuus*, *Conyza canadensis*, *Fallopia* × *bohemica* and *Iva xanthiifolia*, which bind to ruderal vegetation – with trees (6241) and without trees (6242).

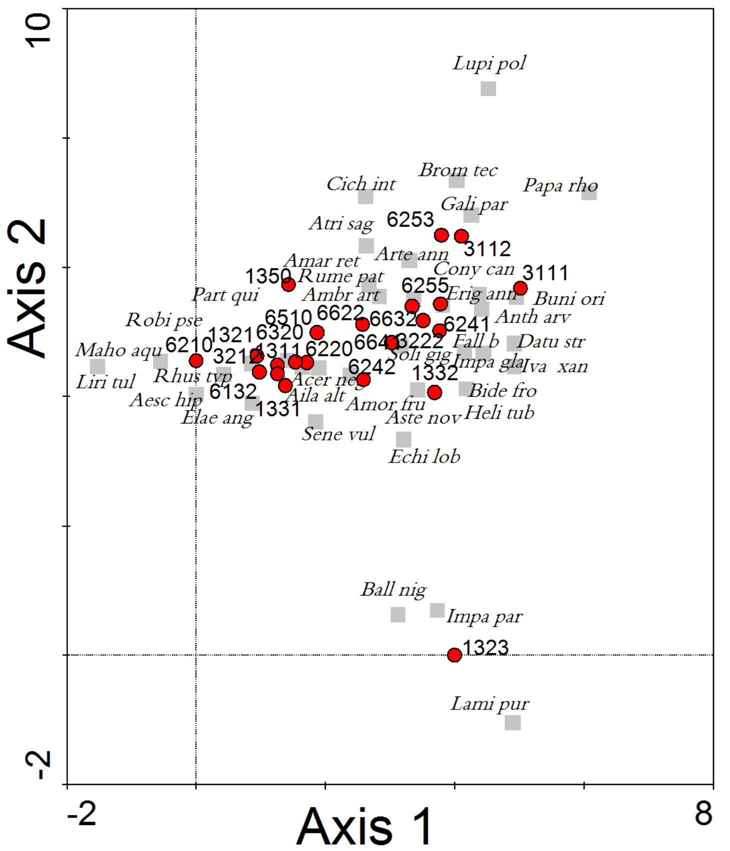

Fig. 4. Correlation of non-native species to landscape elements (DCA).

The third cluster (axis 1 + 5 to 7) can be divided into smaller ones. The first cluster represents large-scale fields (3111) and small-scale fields (3112). Around these elements, species such as *Artemisia annua*, *Bromus tectorum*, *Bunias orientalis*, *Galinsoga parviflora* and *Papaver rhoeas* were recorded. The next cluster includes the vegetation around terrestrial communications (6253) to which are attached species such as *Amaranthus retroflexus*, *Artemisia annua* and *Atriplex sagitata*. Strong cluster of species are tied to water corridor and its immediate surroundings: *Aster novi-belgii*, *Bidens frondosa*, *Echinocystis lobata*, *Fallopia × bohemica*, *Helianthus tuberosus*, *Impatiens glandulifera* and *Solidago gigantea* were present within the element of riparian vegetation (1332).

Partial distortion brings into the ordination graph called 'outliers', which is a distance landscape element 1323 represented by species such as *Ballota nigra*, *Impatiens parviflora* and *Lamium purpureum* occurring as herbal floor within the group elements of mixed trees. Relatively independent position in the diagram has *Lupinus polyphyllus*, which is the species that prefers forest edges and dry grasslands.

We also tested the use of linear direct gradient analysis (RDA), although the value of SD is 5.0180, which is above the recommended limit for its use. The result is the ordination graph (Fig. 5). We ordinated species and environmental variables (area of landscape element, degree of hemeroby, light, heat, nutrients, moisture). The result is surprisingly logical when comparing the correlation of environmental factors with one another and also the correlation of species according to their ecological characteristics and the correlation to the factors.

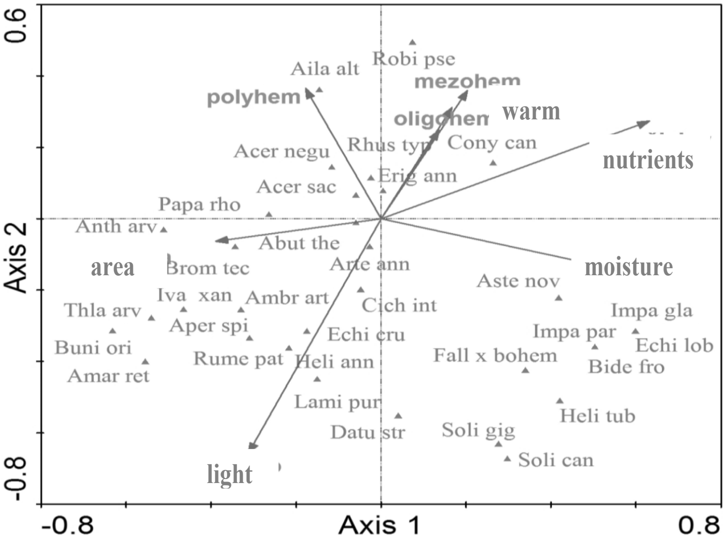

Fig. 5. Correlation of non-native plant species to environmental values (RDA).

Using RDA, we found out that species such as *Acer negundo*, *Ailanthus altissima*, *Rhus typhina* and *Robinia pseudoacacia* correlated with the degree of anthropogenic impact (hemoroby) on the ecosystem. The results of field survey indicates that species prefer particular habitats in contact with the built-up areas altered by human. The largest area within landscape elements is achieved by large-scale fields. Using RDA, we found out that the species such as *Abutilon theophrasti*, *Anthemis arvensis*, *Bromus tectorum* and *Thlaspi arvense* preferentially occur within large-scale fields (edges of the fields). The larger the element, the higher is the probability it is colonised by one of the target non-native species. Significant environmental variable was moisture. Direct RDA confirmed that species such as *Aster novi-belgii*, *Impatiens glandulifera*, *I. parviflora, Echinocystis lobata* and other prefer habitats with higher humidity. Species were recorded mainly as a part of the riparian vegetation and accompanying vegetation of the Nitra River.

Changes in non-native plant species were evaluated only for the Nitra River corridor. We compared the changes in the occurrence of target species to each other between years 2008, 2010, 2011 and 2012. Frequency of habitats of non-native species was transformed in the context of the work of Pyšek et al. (2002): 1 = 1–4 sites, 2 = 5–14 sites, 3 = 15–49 sites, 4 = 50–499 sites (Fig. 6).

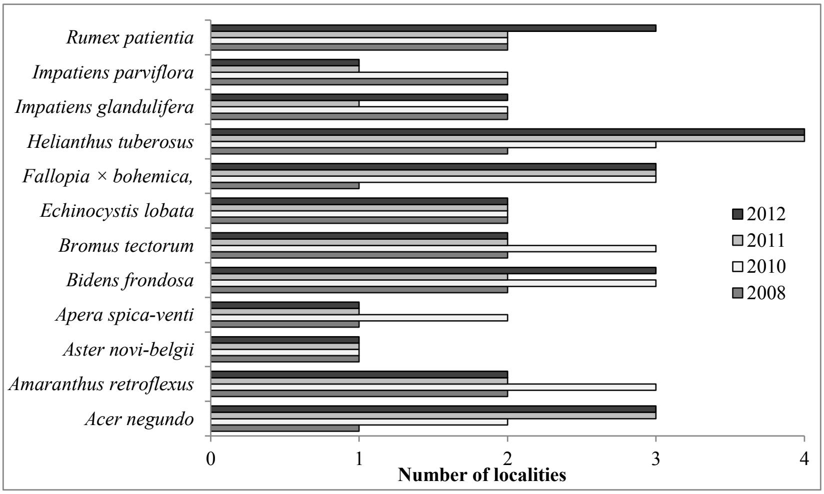

Fig. 6. Changes in the number of invaded habitats within the river corridor.

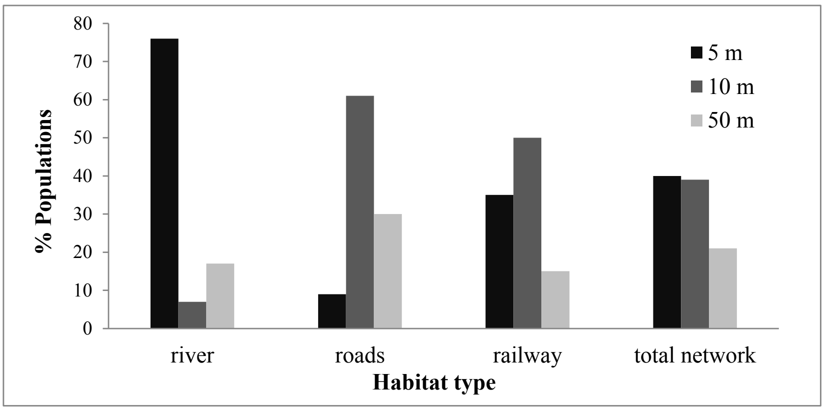

Fig. 7. Populations occurrence (%) in 5, 10 and 50 m buffers around linear in the study area.

We found an increase in the frequency of changes (2008 and 2010–2012) in all species except *Aster novi-belgii* and *Impatiens glandulifera*. The largest number of habitats was found for species *Helianthus tuberosus* (value 4). This species created more numerous clusters in more than 50 locations within the river corridor. It often formed monocultures and filled the space between the river bank and flood protection dike. Interms of non-native species plant communities, the occurrence of species in the form of small groups is predominant. Extensive plantations were created by *H. tuberosus*, *Impatiens glandulifera* and *Echinocystis lobata*. The relative increase in population number between the compared years rates with a maximum 1 number increase for species such as *Acer negundo*, *Helianthus tuberosus* and *Rumex patientia*. In 2012, the number of invaded localities of target species populations increased by 35% as compared to year 2008. Almost the same number of invaded localities present in 2008 and the number of new populations found in 2012 was found amongst species such as *Aster novi-belgii, Apera spica-venti*, *Bromus tectorum*, *Echinocystis lobata* and *Impatiens glandulifera*. The decrease in number of target species was recorded only for *I. parviflora* as the result of cutting wood species and thus changing the appropriate abiotic conditions. The influence of roads, rivers and railways on the distribution of populations was also examined. Roads, rivers and railways represented, respectively, 7% of the landscape unit area (Fig. 7).

Landscape networks played an important role as dispersal corridors for target species in the study area. They were habitat for overall 34 non-native species. About 14 species occurred within selected buffers around the Nitra River corridor. Almost 20 non-native species were situated around railway corridor and 17 species around roads. Forty percent and 39% of the target species occurred within a 5 and 10 m buffer around selected corridors. Despite habitat differences, the number of target species was very similar between the three studied corridors in area.

Discussion

The communities of non-native plant species in the study area

The study area in terms of land use is an anthropogenically altered area with a predominance of elements with low degree of ecological stability. In landscape, *Acer negundo* was proportionally the most widespread species followed by *Ailanthus altissima* and *Robinia pseudoacacia*. Species were especially part of urban vegetation and were identified predominantly in abandoned areas at the periphery as well as in the town center. Similar conclusion are presented by Kowarik (2008), who observed almost the same changes in the number of occurrence of species from the town center towards its edge.

Many species recorded in our study are part of the surrounding vegetation for several decades: *Acer negundo*, *Ailanthus altissima*, *Ambrosia artemisiifolia*, *Bidens frondosa*, *Bunias orientalis*, *Conyza canadensis*, *Galinsoga parviflora*, *Impatiens glandulifera*, *I. parviflora*, *Iva xanthiifolia*, *Lycium barbarum*, *Robinia pseudoacacia*, *Rudbeckia laciniata*, *Stenactis annua*. This is evidenced by the works of Řehořek, Svobodová (1985), Eliáš (1992), Feráková et al. (2002), Pauková, Eliáš (2010), who identified almost the same species composition in the neighboring districts of Nitra, Zlaté Moravce and Nové Zámky.

The elements of current landscape structure

Fifty-five non-native plant species were identified during the research in the cadastral area of the Topoľčany town. These species were recorded within 22 (of 45 total) landscape elements that belong to three groups: forest and shrubs vegetation, agricultural crops and built-up areas. Twenty-one non-native plant species were detected within the group of tree and shrub vegetation represented by six landscape elements. Mainly non-native tree species were bound to the elements: *Acer negundo*, *Elaeagnus angustifolia* and *Robinia pseudoacacia*. The group of agricultural crops was represented by four landscape elements in which we identified 30 non-native plant species.

Species, defined also like weeds on arable land, were recorded in the edge parts of fields: *Abutilon theophrasti*, *Anthemis arvensis*, *Datura stramonium*, *Iva xanthiifolia*, *Papaver rhoeas* and *Thlaspi arvense*. These results indicate that their occurrence can be mostly localised only in the edge parts of fields and outside possible agricultural interventions. The last group are built-up areas. It was represented by six elements of the current landscape structure with the highest number of non-native species (47). Most of non-native plant species was recorded within the element of ruderal vegetation without trees (22 species). It was followed by elements such as protection of aquatic dams (15 species) and industrial and technical objects (13).

Strong correlations were found between the composition of non-native species and elements of landscape structure and their values in the area of environment. Results of ordination analyses DCA and RDA suggest that non-native species prefers certain types of landscape elements and correlates with some environmental variables (degree of hemoroby, light and humidity). Similar conclusions of species composition and relation to the elements of landscape structure are provided in the works published by Mahy et al. (2006) and Thiele et al. (2008). They also suggest that some landscape elements (habitats) are preferred by invasive species especially those that are linked to human activity. Our opinion corresponds with results of other case studies (Anderson et al., 2013) and suggests the fact that introduction of non-native species depends not only on the type of landscape elements but also on biotic, abiotic conditions and the degree of anthropogenic changes (hemoroby).

Conclusion

The study area with dominated urban and agricultural habitats is exposed to higher fragmentation of elements. Biotope selection differed according to the non-native species. Anthropic habitats with a high probability of disruption occurrence (ruderals, urban and industrial) were selected almost by all species mainly invasive neophytes. Natural and semi-natural biotopes included especially species from naturalised and casual categories. We found strong relations amongst elements of landscape structure and the occurrence of population disruption. Results of ordination analysis suggest that non-native species prefer certain types of landscape elements and correlate with some environmental variables. We proved that microhabitats, such as corridors, play an important role in species introduction and their future dispersion.

Dynamics within human-driven landscapes may also lead to the creation of new habitat for non-native taxa. Therefore, it is important to understand the impacts of landscape structure on the dynamics of spatial-temporal models in the landscape and habitat scale.

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