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Alien and native woody plants in scattered vegetation in agricultural landscape

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Abstract

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The woody plant species composition has been evaluated in three cadastral territories of southwestern Slovakia, together in 77 habitats of non-forest woody vegetation (NFWV). A total of 43 tree species have been identified; 8 of them were alien and 5 species were cultural fruit trees. In total 20 shrub species were identified, out of which 3 were alien. Three woody species are classified as invasive according to the law in Slovakia: *Acer negundo* L., *Ailanthus altissima* (Mill.) Swingle, and *Lycium barbarum* L. They occurred only in 2, maximum in 4 of the evaluated habitats. The most occurring alien tree species *Robinia pseudoacacia* L. was generally identified in 58 habitats and in 48 habitats, with an incidence over 40% and dominance index of 70.6. The second most occurring alien tree *Populus* × *canadensis* had a dominance index of 8.3. The dominant native trees in NFWV were *Acer campestre* L.*, Fraxinus excelsior* L.*, Quercus robur* L.*, Salix fragilis* L. with the dominance index of 1–5 only.

Key words

agricultural landscape, southwestern Slovakia, species composition, woody plants

Introduction

In terms of biodiversity changes, the topic "biotic invasions" resonates in the scientific community from the beginning of the second half of the 20th century. It was presented in 1982 during the Scientific Committee on Environmental Problems (SCOPE) in the framework of the project "Ecology of Biological Invasions" (Drake et al., 1989). Biological invasion is characterised as the penetration, transfer, and introduction of species into areas and communities in which they did not naturally occur before and the subsequent expansion of these species (Colautti and Mac Isaac, 2004; Eliáš, 2009).

The introduction and transfer of woody plants to new areas have their historical background and reasons. The introduction advanced from phytogeographically and climatically comparable territories in mutual bilateral directions. Based on this principle, 9 gene centres have been defined with the assumption of plant introduction (Salaš and Lužný, 2010): 1) China (gene) centre, 2) Indian centre, 3) Central Asia, 4) Middle East, 5) Mediterranean centre, 6) Abyssinian centre, 7) South Mexico and Central America, 8) South America, 9) North America centre.

The reasons and objectives of plant introduction, including woody plants, are worldwide identical, as stated by several foreign authors (Henderson, 1998; Head,

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2017; Pyšek et al., 2002; Burda et al., 2015), or authors from Slovakia (Benčať, 1982; Medvecká et al., 2012). The general reasons for introduction of woody plants can be defined as follows (Benčať, 1982; Supuka, 1996, and others): a) enrichment of the species composition in food and forage sources; b) plants for the pharmaceutical and textile industry; c) woody plants for biomass production and for energy use; d) woody plants for forestry and wood industry; e) woody plants for changed environmental conditions and revitalisation of degraded land; f) range expansion of plants for social benefits; g) plants for research and breeding.

The process of plants introduction to and cultivation in new sites, can be specified into distinguished the following steps, which also represent the degree of success (Benčať, 1982): a) transfer, b) acclimatisation, c) adaptation, d) naturalisation, e) domestication.

Many introduced plants take invasive expression. They can eliminate former natural species and their biocoenoses (Eliáš, 1997). The author describes 4 phases of the transfer process: introduction, colonisation, naturalisation, and spreading. The above cited author argues that out of 100 introduced species, only 2 to 3 can reach the free spreading phase with the invasion potential. Many authors describe the sources and causes of invasive behaviour of trees (plants) as a form of their life strategy (e.g. Thébaud and Debussche, 1991; Eliáš, 1997, 2009; Richardson et al., 2000; Pyšek et al., 2002; Warren, 2007; Medvecká et al., 2012; and others). Biological invasive assumptions include: big amount of seeds and diaspora, broad ecological adaptability, high allelopathic behaviour in succession, no or rare occurrence of diseases and pests, the way of seed spreading (mainly anemochores and hydrochores), root shoots and polycormone sprouting ability, neglected or incorrect management of invasive woody plant species (Drake et al., 1989; Kelbel, 2012; Head, 2017).

The process of woody plant introduction is most often realised by botanical gardens and arboretums, where after a successful acclimatisation, these plants become a gene source for further research, reproduction and use in various social economy branches and in landscape creation (Benčať, 1982; Supuka, 1996; Kaločaiová, 2005; Hoťka and Barta, 2012; Krajčovičová and Šajbidorová, 2014; Uhrin et al., 2018).

Some of the introduced species in the naturalisation stage may form the theoretical potential for invasive growth or their invasive expansion has already been confirmed by research. In the Mlyňany Arboretum of the Slovak Academy of Sciences (SAS), 2,350 woody plant species have been identified, 40 species of them are considered as potentially invasive (based on ex situ seed self-production from an adult donor and self-regeneration) (Kuba and Tomaško, 2005. In the Botanical Garden of P. J. Šafárik University in Košice, 13 woody plant species with invasive and expansive reproduction and growth have been described (Kelbel, 2005). Some alien woody species e.g. *Acer negundo*, *Ailanthus altissima*, *Amorpha fruticosa*, and *Robinia pseudoacacia* are resistant to the complex of abiotic and biotic factors (Kelbel, 2012). These species are considered as invasive in Central European conditions by different authors and sources (Richardson et al., 2000; Pyšek et al., 2002; Modranský and Daniš, 2006; Medvecká et al., 2012; and others).

The introduction in woody plant species can have different invasive manifestations. Based on this theory, the following classification of invasive stages is presented (Supuka, 1997): a) invasive, b) protoexpansive, c) mesoexpansive, d) paraexpansive – often form mixtures with population of natural species, anthropogenically easy to control (e.g. *Aesculus hippocastanum*, *Catalpa bignonioides*, *Elaeagnus angustifolia*, *Fraxinus americana*). Another works (Modranský and Daniš, 2006; Daniš, 2008) present similar classification scheme where out of 104 assessed woody species, six species belonged to the group of invasive ones, 8 proexpansive, 20 mesoexpansive, 32 paraexpansive and 38 to the category of potentially expansive.

Within the 48 evaluated European countries, 5,789 alien plants have been mapped, 2,843 of them were introduced from outside of Europe. In terms of occurrence, 64.1% of alien plants occur in the urban-industrial landscape and 58.5% in the agricultural landscape, parks, and gardens. The category of ornamental and horticultural introduction includes 52.2% of introduced plants (Lambdon et al., 2008). The Czech alien flora consists of 1,454 species, 350 of them are archaeophytes and 1,104 are neophytes. According to the invasive status of the total number of species, 985 are classified as casuals, 408 as naturalised but not invasive, and 61 as invasive (Pyšek et al., 2012). The Slovak allochthonous flora consists of 916 introduced plants, 282 of them are plant species in the category of archaeophytes and 634 neophytes. According to their invasion status, most introduced species are casual – 507 species, followed by naturalised, but not invasive – 344 and invasive – only 29 species (Medvecká et al., 2012).

Under the Act No. 158/2014 Coll. and the Act No. 356/2019 Coll. on Nature and Landscape Protection in Slovakia, 7 herb species and 4 woody plant species were included in the category of invasive plants: *Acer negundo*, *Ailanthus altissima*, *Amorpha fruticosa*, *Lycium barbarum*, (https://www.enviro.gov.sk).

In the agricultural landscape, introduced woody plants were planted as fruit species, or into spatial compositions of scattered non-forest woody vegetation (NFWV) for the purpose of multiple benefits. They were disseminated from the originally planted sites to adjacent areas by humans or by other vectors (wind, water, birds, and animals etc.). According to many studies conducted in European countries (Richardson et al., 2000; Lambdon et al., 2008; Pyšek et al., 2012; Medvecká et al., 2012.; Špulerová et al., 2017; Burda, 2018), alien woody plant species were found in various habitats in agricultural landscape such as: fields, grasslands, forest-steppes, synanthropic wastelands, windbreaks and groves, small woodlands, shrublands, road sites, river banks, wetlands and marshes, traditional vineyards and orchards. In the agricultural landscape of Ukraine, beside native and alien herbal species, 11 woody species were mapped also, e.g. *Acer negundo*, *Ailanthus altissima, Amorpha fruticosa, Celtis occidentalis, Juglans cinerea,* (Burda, 2018). In scattered NFWV of the agri-

cultural landscape of Bohemia, in regions of Nové Dvory and Žehušice, a significant occurrence of alien woody species such as *Acer negundo, Robinia pseudoacacia*, *Syringa vulgaris*, and *Symphoricarpos albus* have been indicated (Demková and Lipský, 2012).

This paper aims to contribute to the existing knowledge of alien and invasive woody plants in scattered vegetation in agricultural landscape through 4 specific goals: (1) to evaluate the woody plant composition in spatial habitats of non-forest woody vegetation in three chosen cadastral areas in the agricultural landscape of Slovakia, (2) to classify tree species according to their origin and degree of invasive spreading, (3) to evaluate the habitats according to structural characteristics, such as frequency and dominance of woody plants with emphasis to alien and invasive species, (4) to describe the woody plant species presence in terms of biodiversity and the potential for invasion into surrounding landscape.

Materials and methods

Site characteristics

Research of woody plant species with emphasis on the differentiation of native and alien species was carried out in various spatial habitats of non-forest woody vegetation (NFWV) in agricultural landscape. For this purpose, three cadastral territories in southwestern Slovakia were chosen: Horné Lefantovce (HL, 40 NFWV were assessed), Čajkov (C, 24 NFWV were assessed) and Dunajský Klátov (DK, 13 NFWV were assessed). The studied areas had comparatively different phytogeographical characteristics, which are also reflected in the composition of the evaluated woody plant species.

Horné Lefantovce cadastral territory
The area belongs to the geographical unit of the Western Carpathians in the northwest part of the mountain range Tribeč, including the mountain complexes Zobor and Žibrica. The cadastral territory is situated at the foot of the Tribeč hills forming its eastern border and the floodplain valley of the Nitra river, forming the western border of the territory. The potential natural vegetation consists of oak-hornbeam Carpathian forests, and at higher altitudes also oak-beech forests (Maglocký, 2002). Hard floodplain forests were identified in the Nitra river valley on the western edge of the territory. The cadastral territory covers an area of 1,867.7 hectares and reaches a range of 194–458.5 m asl. In terms of land use, the following landscape elements are present: forests 54.4%, agricultural landscape 35.5%, built-up area 2.7% (Supuka et al., 2013).

Čajkov cadastral territory
The area is located on the southern slopes of the western part of the Štiavnické Mountains. The northern boundary is formed by the ridge of this mountain range, the southern boundary of the cadastre is formed by the edge of the Danube Upland. From phytogeographical point of view, forest-steppe communities and oak-hornbeam Carpathian forests dominate (Maglocký, 2002). The cadastral territory has an area of 2,394.5 hectares with an altitude ranging from 190 to 747 m asl. In terms of land use, the following landscape elements are represented: forests 55.5%, agricultural landscape 38.8%, built-up area 2.4%. The territory has a rich wine-growing tradition, where the present area is 138 hectares. Up to 70% of the area belongs to historical mosaic structures, where there is also a rich occurrence of exotic trees with a predominance of rare fruit species (Verešová and Supuka, 2012).

Dunajský Klátov cadastral territory
The assessed area belongs to the geographical unit of the Danubian Lowland, part of the Danubian Plain with fluvial to oeolian-fluvial natural landscape. The altitude ranges from 110.5 to 118.9 m asl. The potential natural vegetation is represented by willow-poplar and ash-elm-oak forests (Maglocký, 2002). The assessed area with a unit name forms a landscape segment with a total area of 1,968.1 hectares, and 7 cadastral areas: Malé Blahovo, Malé Dvorníky and Veľké Dvorníky, Dunajský Klátov, Jahodná, Ohrady, Vydrany, This segment was chosen owing to the occurrence of non-forest woody vegetation, where native and alien species were evaluated. From the land-use point of view, the dominant part is agricultural landscape 83.6% (90% of agricultural landscape is arable land), 6.6% is covered by forests, and 2.8% by built-up areas (Supuka and Šinka, 2018).

Research methods and woody plant assessment

The woody plant species were mapped and evaluated in terms of their origin and potential of invasive spreading, respectively; according to a modified original methodology of expansion assessment (Supuka, 1997). The following categorisation was used in this paper:

Aa) Invasive woody plant species: produce large amounts of diaspores (seeds), spread by wind, water and animals over 50 to 100 m from donor, high seed survival, strong generative and vegetative self-reproduction, including bud shoots. They have a high allelopathic and competitive ability, inhibit the growth and displace populations of other native but also many introduced species. They often create monocultures. Mechanical and chemical control is difficult and ineffective. Coexistence with ecologically related species is possible, rarely in the population core, more frequent at the margins. The following species have been included in this group: *Acer negundo*, *Ailanthus altissima*, *Lycium barbarum, Robinia pseudoacacia*; or, alien herbs *Impatiens sp., Reynoutria sp.*

Ab) Protoexpansive woody plant species: produce a lot of diaspores, show a relatively strong self-reproducing ability from seeds or root polycormones. They have moderate competitive abilities against other species, often forming compact group populations within close reach of the parent (up to 20 to 40 m). This group includes for example: *Amorpha fruticosa*, *Catalpa bignonioides*, *Celtis occidentalis*, *Paulownia tomentosa*, *Pyracantha coccinea*, *Rhus typhina*, *Syringa vulgaris.*

Ac) Mesoexpansive woody plant species: create sev-

eral seeds of various types. They show good self-reproducing ability from seeds and root rejuvenates. They create autonomous, often dense group populations. They have a weaker competitive ability, often growing in coexistence with other species. This group includes: *Berberis aquifolium*, *Campsis radicans*, *Elaeagnus angustifolia*, *Hippophae rhamnoides*, *Fraxinus americana*, *Laurocerasus officinalis*, *Parthenocissus quinquefolia*, *Populus × canadensis*, *Rosa rugosa*.

Ad) Paraexpansive woody plant species produce many and often large fruits that are barochorous or zoochorous. They are naturalised and domesticated, many of them have a good fruitiness and good self-reproducing ability. Coexistence with other species is common and realistic. This group includes: *Aesculus hippocastanum*, *Juglans nigra*, *J. regia*, *Morus alba*, *Prunus amygdalus, P. cerasifera*, *Quercus rubra*.

The field survey of woody plants in spatial categories of NFWV was performed in three cadastral territories: Čajkov (C) – in 2012, Horné Lefantovce (HL) – in 2013, Dunajský Klátov (DK) – in 2015. In each category of NFWV, woody plant species were evaluated separately in the tree layer and in the shrub layer. Here, we separately evaluated the coverage of the tree and shrub layer and the abundance of individual tree and shrub species in layers, with an accuracy of 5%. (Supuka et al., 2013).

Frequency of woody plant occurrence in NFWV was specified to four groups:
* – dominant and very often occurrence, over 40%
X – occurrence in 10 to 40%
+ – occurrence less than 10%
0 – no occurrence.

Woody species were evaluated according to their origin (A – alien, N – native) and according two spatial categories of habitats (A, B) and their composition types (1, 2, 3) (Supuka et al., 2013):
A) Area or group habitat of woody plants, or NFWV
1 – Solitary tree
2 – Small forests, groves, extensive and abandoned orchards
3 – Forests and groups in contact areas of water bodies
B) Linear habitat of woody plants, or NFWV
1– Windbreaks and forest protection belts with anti-erosion function, woody lines at the border of plots
2 – Roadside vegetation and vegetation along railways
3 – Riverside vegetation, vegetation along water streams and canals.

Methods of structural traits assessment of the habitats and their statistical evaluation

Based on field records and evaluation of individual woody plant species frequency, structural traits of evaluated habitats (respectively elements of NFWV) were assessed (Jurko, 1990; Moravec et al., 1994; Supuka et al., 2013):
a) Dominance index of alien woody species for each cadastral territory. Alien species are considered dominant if they occur in the evaluated NFWV (habitats) to an extent higher than 40%. The dominance index and frequency index were calculated for native and alien tree species with an incidence above 10%, also with an incidence above 40% coverage. The dominance and frequency of shrubs existence was considered according to incidence above 5% of coverage.

$$Di(x) = \sum_{i=1}^{n} \frac{Nd}{N} \times 100, \quad (1)$$

where *Di* is dominance index of woody plant species, *Nd* is significance value of the i-the alien tree species, and *N* is sum of significance values of all species with defined occurrence.

$$Nd = PA \times F, \quad (2)$$

where *Nd* is species significance coefficient, *PA* is the average area cover of the species in assessed NFWV habitats where the species occurred, *F* is number of NFWV habitats in which the species occurred within a defined cover (species stability).
b) Frequency index of woody species occurrence

$$F = \frac{Pd}{Pc} \times 100, \quad (3)$$

where *Pd* is number of habitats in which the woody species occurred, and *Pc* is total number of habitats in the evaluated territory.

For the purpose of statistical evaluation of the habitat traits, we used the non-metric multidimensional scaling (NMDS) and Bray-Curtis index for analyses of similarities between studied cadastral territories and the frequency of occurrence of individual tree species in assessed habitats. Bray-Curtis index expresses a quantification of woody species on different studied cadastral territories. The statistical analysis was done using the statistical software PAST (Hammer, 2015).

Results

The paper is focused on the analysis of woody species composition in spatial habitats of non-forest woody vegetation (NFWV) in the agricultural landscape in three different cadastral territories: Horné Lefantovce (HL), Čajkov (C), and Dunajský Klátov (DK). As presented in the methodology, the studied areas have different phytogeographical features, different natural and fertility potential, but almost identical history development and changes in landscape structure. Changes in agricultural land use are caused due to land ownership, intensification of agriculture technologies and management processes. A turning point in this matter was the collectivisation and industrialisation of agriculture in the 1950s in Slovakia. The dominant impacts were from the land consolidation, with progressive arable land formation into large blocks (often exceeding 100 hectares or more, mainly in lowlands), chemical substances supplemented for plant nutrition and plant protection purposes. As a result, the landscape structure has changed, the ecological stability of the landscape and the

environmental quality of soil, water and air decreased. This process took place in almost all developed countries, but in the form of the natural market consolidation and intensification. Based on the results of international scientific research, to mitigate the negative phenomenon of intensified agricultural management, there were elaborated the theoretical base and practical advices for applying (implementation) of forest fragments into the agricultural landscape. These fragments have the character of groups or lines. The terminology may be different, but the substance is identical, e.g. protective forest belts, windbreaks, non-forest woody vegetation, fragmented forest habitats (Supuka and Šinka, 2018). The integration of these components into the agricultural landscape took place in former Czechoslovakia (Zachar and Tešliar, 1989; Demková and Lipský, 2012; Supuka et al., 2013). Planting mainly NFWV line habitats in Slovakia was carried out in 1950s and 1960s, including the agricultural landscape of the evaluated cadastral territories. In this process, there were used also alien woody plants, some of them recently classified as 'invasive'. During the years 2012–2015, 77 habitat formations of NFWV were evaluated in three cadastral territories, and their woody species composition were assessed. The base elements in the NFWV habitats are tree species, shrub species are at the margins or in the undergrowth. We have identified 43 tree species, 8 of them were alien and 5 were cultural fruit species (e.g. cherries, plums, pears). This group is represented by both allochthonous and autochthonous species. Many introduced woody plants are already domesticated as important fruit species belonging to the group of archaeophytes (e.g. *Juglans regia*, *Prunus amygdalus*). It has been shown that the proportion of alien species is not so high compared to the native species. *Acer campestre*, *Fraxinus angustifolia*, *F. excelsior*, *Populus alba*, *P. nigra*, *Prunus padus*, *Quercus robur*, *Salix alba*, *S. fragilis* and *Ulmus laevis* are the most common native tree species found in the studied habitats. These species are typical representatives of softwood and hardwood floodplains and they were found in habitats along water streams, canals, the watersides of ponds, fragments of wetlands in the cadastral territory of Dunajský Klátov. On drier localities and slopes in the other two cadastral territories (Horné Lefantovce, Čajkov), the most abundant native species were represented by the genus *Acer*, *Quercus* (mainly *Q. cerris*, *Q. petraea)*, *Fraxinus excelsior*, species of the genus *Malus*, *Prunus*, *Pyrus*, and *Tilia*. The introduced alien tree species were represented by *Acer negundo*, *Acer saccharinum*, *Aesculus hippocastanum*, *Ailanthus altissima*, *Celtis occidentalis*, *Populus* × *canadensis*, *Prunus cerasifera*, *Robinia pseudoacacia* (Table 1). These are predominantly found in planted windbreaks, protective belts, and tree alleys along roads or as planted monocultures (*Populus* × *canadensis*, *Robinia pseudoacacia*). The core tree in windbreaks in all three cadastral territories was clearly *Robinia pseudoacacia*, occurring in 58 of all 77 examined habitats (Table 1). This species is dominant in windbreaks and protective belts in the cadastral area of Horné Lefantovce, the lowest presence was found in the cadastral area of Dunajský Klátov, with a higher representation and dominance of the cultivated hybrid species *Populus* × *canadensis*. According to the methodology, we processed the occurrence of tree species occurring in the proportion above 10% in the assessed habitats, by cadastral territories. At the same time, we calculated the structural features of habitats in terms of the dominance and frequency of tree species (Table 2). The diversity of woody species was almost the same, 14–16 species in each evaluated cadastral territory. The differences were only in the representation of species, which also reflected the ecological conditions of the evaluated areas. There were 4 to 5 alien species in each territory. The sporadic occurrence includes *Acer saccharinum* (roadside alley in Čajkov cadaster), *Aesculus hippocastanum* (often in tree alleys along roads), *Ailanthus altissima* (only in windbreaks in Dunajský Klátov cadaster), *Acer negundo* (Čajkov and Dunajský Klátov only). The structural character of habitats was also evaluated with the occurrence of tree species above 40% in all studied areas together, with an emphasis on significant dominance (Table 3). Dominant in windbreaks was *Robinia pseudoacacia* in the order from the highest to lowest frequency, but also in relation to the cadastral territory (Horné Lefantovce – most frequent, Čajkov – less frequent, Dunajský Klátov – least frequent). Black locust in up to 48 habitats had an incidence of over 40% with a dominance index of 70.6 and most often formed monocultures in the assessed windbreaks. *Populus* × *canadensis*, which had the highest frequency in the cadastral area of Dunajský Klátov and the lowest in Horné Lefantovce, was second in dominance. Wind, water, and animals are the basic vectors of alien species diaspore spread. The most pronounced manifestation of expansion was found in *Acer negundo*, *Ailanthus altissima*, *Robinia pseudoacacia.* Lower manifestation of self-reproduction and survival of new individuals was found in *Celtis occidentalis*, *Fraxinus americana*, *Prunus cerasifera*, but also in the domesticated fruit species *Juglans regia*. In summary, the process of self-reproduction and dissemination has been identified in all alien tree species except for *Aesculus hippocastanum* and *Populus* × *canadensis.*

In the field work, we have paid attention also to the occurrence of shrub species in habitats of NFWV according to the surveyed cadastral territories (Table 4). A total of 20 shrub species have been identified, 3 of them were alien. Every habitat in the evaluated cadastral territory had 11 to 14 species of shrubs, most of them were in Dunajský Klátov. Shrubs were identified at the edges of NFWV habitats (as a category of ecotones) or as undergrowth of trees. A very common undergrowth of *Robinia pseudoacacia* was formed by *Sambucus nigra*. Mainly in the sloping areas of the Horné Lefantovce and Čajkov cadastral territories, line habitats (hedges) of shrubs or with sporadic occurrence of trees were identified. They are the remains of former boundaries, terrain balks and terraces or land boundaries. Shrubs provide very important ecosystem services in NFWV habitats in the agricultural landscape. Their presence enhances the biodiversity, they are a part of the food chain or they provide shelters for different wildlife species (e.g. animals, birds, insects), they increase protective effect of line form habitats, ecological stability, as well as visual and aesthetic landscape values.

Table 1. Occurrence of tree species in NFWV according to the spatial habitat category and cadastral territory

Spatial category habitat		A1			A2			A3			B1			B2			B3			Species Frequency
Origin/Cadastral territory	Origin	HL	C	DK	HL	C	DK	HL	C	DK	HL	C	DK	HL	C	DK	HL	C	DK	
Tree species layer																				
Acer campestre L.	N	0	0	+	+	X	0	0	0	0	X	*	0	*	X	0	X	X	0	38
Acer negundo L.	Aa	0	0	+	+	0	0	0	0	0	+	0	*	0	X	0	0	0	0	4
Acer platanoides L.	N	0	0	+	+	0	0	0	0	+	+	0	0	+	0	0	+	0	0	8
Acer pseudoplatanus L.	N	0	0	0	0	0	0	0	0	+	0	0	+	0	0	0	0	0	X	3
Acer saccharinum L.	Ab	0	0	0	0	0	0	0	0	0	0	0	0	0	*	0	0	0	0	1
Acer tataricum L.	N	0	0	0	0	X	0	0	0	0	0	+	0	0	0	0	0	+	0	3
Aesculus hippocastanum L.	Ad	0	+	+	0	0	0	0	0	0	*	0	0	+	+	0	0	0	0	4
Ailanthus altissima (Mill.) Swingle	Aa	0	0	+	0	0	0	0	0	0	0	0	0	0	0	X	0	0	0	1
Alnus glutinosa L. Gaertn.	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	X	0	0	1
Carpinus betulus L.	N	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	+	0	2
Celtis occidentalis L.	Ab	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	1
Fraxinus americana L.	Ab	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	1
Fraxinus angustifolia Vahl.	N	0	0	0	0	0	0	0	0	*	0	0	+	0	0	0	0	0	0	2
Fraxinus excelsior L.	N	0	0	+	0	0	0	0	0	+	X	0	+	+	X	+	X	+	0	35
Juglans regia L.	Ad	0	0	X	0	0	0	0	0	0	+	0	+	*	*	X	+	0	0	25
Malus domestica Borkh.	N	0	0	X	0	0	0	0	0	0	0	0	0	X	X	0	+	+	+	6
Populus alba L.	N	0	0	+	0	0	0	0	0	+	0	0	+	0	+	X	+	+	+	10
Populus × *canadensis* Moench	Ac	0	0	+	0	0	0	0	0	*	*	0	*	0	0	0	+	*	*	15
Populus × *canescens* (Aiton) Smith	N	0	0	+	0	0	0	0	0	X	0	0	+	0	0	0	0	0	X	4
Populus nigra L.	N	0	0	+	0	+	0	0	0	+	+	0	X	0	X	+	+	X	+	14
Populus tremula L.	N	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	1
Prunus amygdalus Batsch	Ad	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	2

Origin: N, Native; Aa–Ad, Alien species according to the category of invasive manifestation. Habitat category: A1–A3, Area form; B1–B3, Linear form. Cadastral territory: HL, Horné Lefantovce; C, Čajkov; DK, Dunajský Klátov. Occurrence in habitats: 0 – no, + – ≤ 10%, X – 10–40%, * – ≥ 40%.

Table 1. Continued

Spatial category habitat		A1			A2			A3			B1			B2			B3			Species Frequency
Origin/Cadastral territory	Origin	HL	C	DK	HL	C	DK	HL	C	DK	HL	C	DK	HL	C	DK	HL	C	DK	
Tree species layer																				
Prunus avium (L.) L.	N	0	0	+	+	+	0	0	0	0	+	0	0	+	+	0	+	+	+	26
Prunus cersifera Ehrh.	Ad	0	0	X	0	0	0	0	0	+	+	0	X	+	0	+	X	0	0	17
Prunus cerasus L.	N	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0
Prunus domestica L.	N	0	0	x	0	+	0	0	0	0	*	0	0	+	+	0	0	+	0	8
Prunus insititia L.	N	0	0	0	0	0	0	0	0	0	0	+	+	0	0	0	0	0	0	2
Prunus padus L.	N	0	0	0	0	0	0	0	0	+	+	0	0	+	0	+	X	0	0	14
Pyrus communis L. Emend Burgsd.	N	+	+	+	0	0	0	0	0	0	+	+	0	+	0	+	0	+	0	9
Quercus cerris L.	N	0	0	+	0	0	0	0	0	0	+	0	0	+	+	0	X	+	0	14
Quercus daleschampii Ten.	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	1
Quercus pedunculiflora (K.Koch)	N	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	+	0	2
Quercus petraea (Mattusch.) Liebl.	N	0	0	+	0	X	0	0	0	0	+	0	0	X	0	0	0	+	0	6
Quercus robur L.	N	0	0	+	X	0	0	0	0	0	+	0	+	0	0	0	+	+	0	7
Robinia pseudoacacia	Aa	0	0	+	*	*	0	0	0	+	*	X	*	*	*	*	*	*	+	58
Salix alba L.	N	0	0	+	0	0	0	0	0	0	0	0	0	0	+	0	+	+	0	8
Salix caprea L.	N	0	0	0	0	0	0	0	0	+	0	0	0	0	+	0	0	0	0	2
Salix cinerea L.	N	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	+	0	0	2
Salix fragilis L.	N	0	0	+	+	0	0	0	0	X	+	0	X	0	X	+	X	*	+	28
Tilia cordata Mill.	N	0	0	X	+	+	0	0	0	0	+	0	0	0	+	0	0	0	0	5
Tilia platyphyllos Scop.	N	0	0	+	0	0	0	0	0	0	+	0	0	0	0	0	+	0	0	2
Ulmus laevis Pall.	N	0	0	0	X	0	0	0	0	0	+	0	0	0	0	0	+	+	0	6
Ulmus minor Mill.	N	0	0	0	+	0	0	0	0	0	+	0	0	+	0	0	+	0	0	5

Origin: N, Native; Aa– Ad, Alien species according to the category of invasive manifestation. Habitat category: A1–A3, Area form; B1–B3, Linear form. Cadastral territory: HL, Horné Lefantovce; C, Čajkov; DK, Dunajský Klátov. Occurrence in habitats: 0 – no, + – ≤ 10%, X – 10–40%, * – ≥ 40%.

Table 2. List of tree species manifesting beyond 10% occurrence in the studied cadastral territories, with their dominance and frequency

Cadastral territory	Horné Lefantovce (HL)		Čajkov (C)		Dunajský Klátov (DK)	
Tree species	Dominance	Frequency	Dominance	Frequency	Dominance	Frequency
Acer campestre	10.0	60.0	12.20	58.3	-	-
Acer negundo	0.0	0.0	0.90	4.1	3.60	15.4
Acer pseudoplatanus	–	–	–	–	1.80	23.1
Acer saccharinum	–	–	4.60	4.2	–	–
Acer tataricum	–	–	0.60	12.5	–	–
Aesculus hippocastanum	1.1	5.0	–	–	–	–
Ailanthus altissima	–	–	–	–	2.80	7.7
Alnus glutnosa	0.8	2.5	–	–	–	–
Fraxinus angustifolia	–	–	–	–	6.40	15.4
Fraxinus excelsior	6.4	50.0	0.60	33.3	4.60	53.8
Juglans regia	3.3	30.0	8.50	29.2	5.50	46.1
Malus domestica	1.3	5.0	4.90	12.5	–	–
Populus alba	–	–	0.60	12.5	5.00	46.1
Populus × canadensis	2.8	7.5	8.80	16.6	21.90	61.5
Populus × canescens	–	–	–	–	4.60	23.1
Populus nigra	–	–	2.50	16.6	8.70	69.2
Prunus cerasifera	2.5	22.5	–	–	5.00	61.5
Prunus domestica	1.4	10.0	1.20	16.7	–	–
Prunus padus	2.7	27.5	–	–	1.80	23.1
Quercus cerris	1.1	25.0	–	–	–	–
Quercus petraea	0.3	7.5	1.20	12.5	–	–
Quercus robur	0.9	10.0	–	–	–	–
Robinia pseudoacacia	61.2	85.0	41.20	58.3	17.40	76.9
Salix fragilis	2.5	17.5	12.20	45.8	10.90	76.9
Tilia cordata	–	–	–	–	–	–
Ulmus laevis	1.7	10.0	–	–	–	–
Total	100.00		100.00		100.00	
N – Summary occurrence	3,195		1,565		1,095	

The spring blossom of native *Prunus spinosa* and *Rosa canina* show the largest dominance and frequency occurrence in habitats. Other important evaluated native plants are species of genera *Cornus*, *Crataegus*, *Euonymus*, *Ligustrum*, *Rhamnus*, *Rubus*, and *Sambucus* (Table 4). There were identified only 3 alien shrub species, mainly in habitats of contact zones between the human settlements and open landscapes. *Syringa vulgaris* is considered to have been planted intentionally, then, it consequently expanded by root polycormones. The other two species are disseminated by birds (*Lycium barbarum*, *Parthenocissus tricuspidata*) or polycormones (*Lycium barbarum*). The frequency and dominance of alien shrubs in the studied NFWV habitats are very low and we do not expect any significant invasive pressure on natural woody communities. The self-reproductive process and succession of new young individuals have been identified in habitats, but they were not spontaneous and with no high frequency.

Windbreaks planted on arable land in linear forms are maintained and controlled indirectly – by ploughing to the edge of the windbreaks, eliminating new seedlings and root shoots. On enclaves and gaps, on unkempt grasslands at the edges, or inside habitats, the process of self-reproduction of alien trees and shrubs and filling these gaps was evident, especially with the most expansive woody species mentioned above.

The differences in the frequency of occurrence of individual tree species between the assessed cadastral territories are shown with the results of non-metric multidimensional scaling (NMDS) analysis and based on Bray-Curtis similarity measures (Fig. 1). The stress value is 0.1024, which indicates a medium quality of the model. Some of

Table 3. Dominance and frequency of tree species with more than 40% occurrence in the studied habitats at all cadastral territories

Tree species	All cadastral territories (HL, C, DK)	
	Dominance	Frequency
Acer campestre	5.0	3.9
Acer negundo	1.1	1.3
Acer saccharinum	2.1	1.3
Aesculus hippocastanum	1.1	1.3
Fraxinus angustifolia	1.6	1.3
Juglans regia	7.6	5.2
Populus × canadensis	8.3	5.2
Prunus domestica	1.3	1.3
Robinia pseudoacacia	70.6	48.1
Salix fragilis	1.3	1.3
Total	100.00	

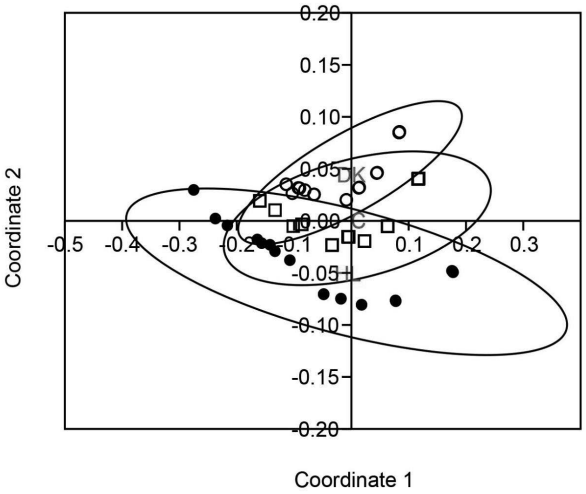

Fig. 1. Non-metric multidimensional scaling ordination of sites based on Bray-Curtis similarity measures representing the tree species occurrence in the studied cadastral territories. Horné Lefantovce (full dots), Čajkov (open squares) and Dunajský Klátov (open dots). Stress = 0.1024.

Table 4. Dominance and frequency of shrub species with more than 5% occurrence in the studied habitats according to the cadastral territories and total cadastral territories (Total)

Cadastral territory	Horné Lefantovce		Čajkov		Dunajský Klátov		Total	
Shrub species	Domin.	Freq.	Domin.	Freq.	Domin.	Freq.	Domin.	Freq.
Clematis vitalba L.	2.7	30.0	0.2	4.1	–	–	1.0	16.9
Cornus mas L.	0.3	5.0	0.2	4.1	–	–	0.2	3.9
Cornus sanguinea L.	0.3	5.0	4.4	41.7	20.1	76.9	0.1	28.6
Corylus avellana L.	–	–	0.2	–	–	–	0.1	2.6
Crataegus laevigata (Poir.) DC	9.0	42.5	8.8	41.6	12.1	69.2	10.0	46.7
Crataegus monogyna Jacq.	9.8	40.0	7.9	50.0	7.6	61.5	8.4	46.7
Euonymus europaeus L.	5.3	47.5	1.8	25.0	2.8	46.1	3.3	40.3
Frangula alnus Mill.	–		–		5.5	61.5	1.8	10.4
Ligustrum vulgare L.	2.8	37.5	0.2	4.2	1.0	23.0	1.3	24.7
Lycium barbarum L.	0.2	2.5	–	–	–	–	0.1	1.3
Parthenocissus quinquefolia (L.) Planch.	0.2	2.5	–	–	–	–	0.1	1.3
Prunus insititia L.	–	–	–	–	2.4	46.1	0.8	7.8
Prunus spinosa L.	25.1	90.0	37.3	95.8	7.9	53.8	23.4	85.7
Rhamnus cathartica L.	1.0	12.5	–	–	6.2	69.2	2.4	18.2
Rosa canina L.	21.4	92.5	24.1	83.3	5.5	69.2	17.0	85.7
Rubus fruticosus L.	5.8	47.5	9.4	37.5	5.9	76.9	7.0	49.3
Salix viminalis	–		–		0.3	7.6	0.1	1.3
Sambucus nigra L.	15.4	67.5	5.5	54.1	22.1	92.3	22.5	67.5
Syringa vulgaris L.	0.5	5.0	–	–	–	–	0.2	2.6
Viburnum opulus L.	–	–	–	–	0.7	15.3	0.2	2.6
Total	100.0		100.0		100.0		100.0	
N – Summary occurrence	3,010		2,265		1,450			

the counting points within the three assessed cadastral areas are overlapping, which indicates the similarity of tree species occurrence mainly in Dunajský Klátov and Čajkov cadastral territories. The cadastral territory area of Horné Lefantovce shows higher difference in tree species occurrence compared to the other two cadastral areas assessed.

Discussion

The planting of alien trees in small woodlands and scattered NFWV in agricultural landscape is historically linked to the intensification and industrialisation of agriculture and the rapid increase in the shares of arable land in large-scale plots. One of the most comprehensive documents on the subject is the proceedings of scientific papers from the 3rd International conference in Canada 'Windbreaks and agroforestry' (Finch and Baldwin, 1991). Altogether 87 scientific papers present problems and ways of solution in more than 15 countries of the world, e.g. Canada, Australia, Russia, China, France, UK, India, Egypt, Argentina, and Czechoslovakia. All mentioned published articles and other sources (Soltner, 1991) deal with planting of native and alien woody plants in composed elements of NFWV. Windbreaks with a total length of 30 km were planted in the Danube Lowland of Slovakia between 1951 and 1955 (Zachar and Tešliar, 1989), where in 19 currently assessed windbreaks there were identified 27 tree species, including 10 alien with 3 invasive species (Supuka and Šinka, 2018). From the published sources, we have found that Europe was particularly attractive to American tree species, with *Robinia pseudoacacia* significantly dominating the habitats of NFWV in agricultural landscapes. For instance, Tóth et al. (2016) have mapped and assessed three selected cadastral territories in the Nitra Region and derived a conclusion that *Robinia pseudoacacia* has the highest frequency factor among all identified predominant tree species in NFWV structures. In the European List of Invasive Plants, up to 7 woody plant species are in the category of invasive (Brundu and Richardson, 2016). We have identified 3 invasive tree species in our studied areas. Black locust is almost accepted in Europe as far as a domesticated alien tree, due to its historical services and benefits, e.g. timber biomass, melliferous effect and better adaptability to changed environment in comparison to the native species (Benčať, 1982). When assessing woody plant species in suburban and rural landscape in individual NFWVs (Hodge, 1995), there were also used the structural features of habitats such as species frequency, mean density of plots, woody plant high stratum and importance value (White et al., 2014). We applied similar structural features of habitats, such as frequency and dominance of woody plant species and their percentage coverage in evaluated NFWV elements. In our study, we identified an indirect control of invasive tree species in windbreaks by annual ploughing along the windbreak boundaries. In Hungary, there are applied more methods for controlling and eliminating black locust *(Robinia pseudoacacia*) and tree of heaven (*Ailanthus altisima*), e.g. chemicals, sprout cutting, or removing bark from tree trunks (Korda, 2015). It is necessary to give emphasis on woody plants that in many European and Slovak documents (EU Regulation No. 2019/1262, Regulation of the Government of the Slovak Republic No. 449/2019 Coll. and, the Act on Nature and Landscape Protection No. 543/2002 Coll. as amended by 356/2019 and others) are listed an invasive plant species that raise concerns about possible disturbances in natural ecosystems (https://www.enviro.gov.sk). In the above-mentioned regulation of the Government of SR, the category of invasive woody plants includes *Acer negundo*, *Ailanthus altissima*, *Amorpha fruticosa*, and *Lycium barbarum*. Black locust (*Robinia pseudoacacia*) was removed from the list of invasive plants. On the other hand, Medvecká et al. (2012) assessed *Robinia pseudoacacia* as an invasive woody species.

Research and permanent monitoring in each country needs to be focused towards reducing, controlling or possibly stopping the main invasive woody plant species in the landscape.

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