Lesn. Cas. For. J. 62 (2016) 56–66

ORIGINAL PAPER

Lesnícky časopis - Forestry Journal
http://www.nlcsk.sk/fj/

Species composition and diversity of non-forest woody vegetation along roads in the agricultural landscape

Attila Tóth*, Gabriel Kuczman, Ľubica Feriancová

Slovak University of Agriculture in Nitra, Faculty of Horticulture and Landscape Engineering, Tr. A. Hlinku 2, SK – 949 76 Nitra, Slovak Republic

Abstract

Non-forest woody vegetation represents an important component of green infrastructure in the agricultural landscape, where natural and semi-natural forest cover has only a low land use proportion. This paper focuses on linear woody vegetation structures along roads in the agricultural landscape and analyses them in three study areas in the Nitra Region, Slovakia. We evaluate species composition and diversity, species occurrence frequency or spatial distribution, their structure according to relatively achievable age and origin. For the evaluation of occurrence frequency, a Frequency Factor was proposed and applied. This factor allows a better comparison of different study areas and results in more representative findings. The study areas were divided into sectors based on visual landscape features, which are easily identifiable in the field, such as intersections and curves in roads, and intersections of roads with other features, such as cadastral or land boundaries, watercourses, etc. Based on the species abundance, woody plants present within the sectors were categorised into 1) predominant, 2) complementary and 3) mixed-in species; and with regard to their origin into 1) autochthonous and 2) allochthonous. Further, trees were categorised into 1) long-lived, 2) medium-lived and 3) short-lived tree species. The main finding is that among trees, mainly allochthonous species dominated. Robinia pseudoacacia L. was the predominant tree species in all three study areas. It was up to 4 times more frequent than other predominant tree species. Introduced tree species prevailed also among complementary and mixed-in species. Among shrubs, mainly native species dominated, while non-native species had a significantly lower proportion and spatial distribution. Based on these findings, several measures have been proposed to improve the overall ecological stability, the proportion and spatial distribution of native woody plant species. The recommendations and measures aim at enhancement of native species biodiversity, landscape identity and character, in order to meet the main landscape and biodiversity challenges identified in key biodiversity and landscape policies of Europe.

Key words: biodiversity; climate change; cultural landscape; green infrastructure; landscape architecture

Editor: Tomáš Hlásny

Introduction

Non-forest woody vegetation structures represent important compositional elements and green infrastructure components in current rural agricultural landscapes. They significantly form the visual and perceptual quality of current landscapes, their structure and character. They make landscapes more diverse and consequently more variable in spatial patterns and mosaics (Rózová 2004; Bell 2005; Demková & Lipský 2013). Current landscape structures can be considered contingent outcomes of past and present land uses, socio-economic and ecological processes and decisions that have shaped land use transitions (Supuka & Štěpánková 2006; Rounsevell et al. 2012). Creation of woodland structures is considered as an important landscape design tool for planning and creating agricultural areas. Planting of new woodlands on farmland changes land use patterns and enhances the appearance of the landscape (Insley et al. 1988; Salašová & Štěpán 2007). The woody component along field edges often provides the only permanent elements of structural and biological diversity in landscapes that have lost much of their naturalness in the process of urbanisation and intensification of agriculture (Sitzia et al. 2013). Non-forest woody vegetation formations are purposefully designed elements in cultural landscapes, which have been created in order to support optimal and efficient land use (Kurz et al. 2011; Supuka et al. 2013; Demková & Mida 2014), they have an indispensable position in our landscape, since they participate in the comprehensive formation of the landscape character, especially in scarcely forested flatlands with dominance of light and dry soils. Furthermore, they protect the landscape against erosion; function as bio-corridors and linkages between landscape sections; regulate the climate, including wind movement; prevent expansion of dust and noise and affect the radiation, temperature and moisture regimes of air and soil (Lampartová et al. 2015).

It is obvious that non-forest woody vegetation has many functions and provides a wide range of ecosystem services as mentioned above. It fulfils the main principle of sustainable and resilient landscapes, which according to Konôpka (2010) consists in their multifunctionality. According to Schaefer (1991) and Kuhn et al. (1991), trees are essential in sustainable agricultural systems to provide continuous and long-term crop and resource protection and a wide range of valuable benefits. Our landscapes are exposed to conti-

*Corresponding author. Attila Tóth, e-mail: attila.toth@uniag.sk, phone: +421 37 641 5420

nuously increasing effects of the changing climate (Brandle et al. 2004), including drought risk that threatens not only forests (Hlásny et al. 2014) but also agricultural landscapes (Supuka et al. 2013). Melo et al. (2013) state that climate has become warmer and more arid in the adjacent lowlands of Slovak Carpathians, e.g. in the Danube Lowland, where all the three study areas presented in this paper are situated. Hlásny et al. (2014) expect substantial drying of climate in southern Slovakia, which will require a change in species composition towards a higher proportion of drought tolerant species. The composition and diversity of woody plant species are also tackled by the EU Biodiversity Strategy to 2020 (European Commission 2011), which aims at conservation and protection of Europe´s biodiversity, including native woody plants, which are often displaced or out-competed by alien species. Native species represent according to the EU Biodiversity Strategy the core of the common European natural capital and heritage and their higher proportion in the landscape would significantly contribute to biodiversity enhancement. The literature review has shown that there are many studies on the function and importance of non-forest woody vegetation, however there is a lack of profound knowledge of their current species composition and diversity. The goal of this paper is therefore to assess species composition and diversity of woody plants accompanying roads in the agricultural landscape. The field research has been conducted in three study areas, which are represented by cadastral territories of three rural municipalities in the Nitra Region - Tvrdošovce, Dvory nad Žitavou and Kolíňany. The aims of this study are: 1) to evaluate species composition and diversity of woody plants; 2) to evaluate the ratio of autochthonous to allochthonous woody plant species; and 3) to evaluate the proportion of long-lived, medium-lived and short-lived woody plant species. Based on these findings, specific objectives will be defined, with the aim to increase the existing proportion of native and gradually lower the proportion of non-native woody plant species. This measure aims at improvement of the overall native biodiversity in woodland structures in the agricultural landscape, which at the same time helps to mitigate the impact of the changing climate and to overcome potential drought risks in the future.

2. Material and methods

The study has been conducted in three study areas (cadastral territories of three rural municipalities) – Tvrdošovce, Dvory nad Žitavou and Kolíňany, all located in the Nitra Region, in south-western Slovakia. The three study areas have been chosen based on comparable predominant land use (agriculture), geographical, geomorphological, climate, mean annual precipitation and potential natural vegetation characteristics. The study areas have an area of 55.56 km^2 (Tvrdošovce), 63.85 km^2 (Dvory nad Žitavou) and 12.50 km^2 (Kolíňany). Tvrdošovce is located approximately 30 km from Nitra to south-west, Dvory nad Žitavou approximately 45 km from Nitra to south-east and Kolíňany approximately 10 km from Nitra to north-east.

Tvrdošovce and Dvory nad Žitavou are located in a typical agricultural landscape of the Danube Lowland, with an average altitude of 120 m a.s.l., while Kolíňany is located in a rather hilly upland landscape, with an average altitude of 199 m a.s.l. The woodland cover ranges from 0.04% (Dvory nad Žitavou), through 0.07% (Kolíňany), up to 1.00% (Tvrdošovce). In all three study areas, productive agricultural land (mainly arable land, with a low proportion of orchards and vineyards) has a high land use proportion ranging from 75.30% (Kolíňany), through 82.00% Tvrdošovce, up to 87.58% (Dvory nad Žitavou).

Within each study area, the mapping of non-forest woody vegetation was carried out. In Tvrdošovce, the mapping has been focused on accompanying woody vegetation of side roads in the open landscape connecting the municipality and the surrounding settlements. The mapping in Dvory nad Žitavou has been conducted in the south-eastern (S/E) and north-western (N/W) parts of the study area. The S/E part is mainly covered by agricultural land use, with scattered woodland spots. The N/W part is also covered mainly

Fig. 1. Location of the three study areas in the Nitra Region and Slovakia.

by arable land, orchards and vineyards. In Kolíňany, the emphasis was on linear non-forest woody vegetation elements within the entire study area. The same methodology of data collection has been applied in all three study areas. Non-forest woodlands have been studied along field roads, since these represent a very significant proportion of woodlands in areas where agriculture is the predominant land use.

Woody plant species have been studied along roads in the agricultural landscape in study areas of the three rural municipalities. Tree and shrub species have been analysed and evaluated separately. The linear non-forest woody vegetation structures have been divided into separately assessed sectors – Tvrdošovce (31 evaluated sectors), Dvory nad Žitavou (31 evaluated sectors). Kolíňany (21 evaluated sectors). The sectors have been established based on identifiable physical structures and features in the landscape, such as land, land use, built-up-area or administrative boundaries, intersections of roads or other patterns such as watercourses, railways, changes in direction of roads. The aim of this method was to have easily identifiable and observable physical structures to be mapped and documented in the field. The length of the sectors does not have a significant impact on the presence, distribution and density of non-forest woody vegetation and its species composition and diversity, since the distribution of vegetation is very variable – from sections without woody plants, through sections with individual woody plants or small groups of woody plants, up to semi-dense and dense linear woodland structures. Therefore, division into sectors of the same length would complicate an accurate identification of sectors in the field and lead to unrepresentative results, i.e. the sectors would not have been comparable in terms of vegetation cover. Therefore, the studied sectors could not be of same length. For each sector, the abundance of woody species was visually estimated using three categories: predominant, complementary and mixed-in, described in detail in Table 1.

Table 1. Categories used for the abundance estimation of woody plant species.

Role in species composition	Description
Predominant species	the most frequent species in the assessed sector of non-forest woody vegetation structure, total proportion ranging from 51 to 100%
Complementary species	frequent species, complementing the predominant species, total proportion ranging from 11 to 50%
Mixed-in species	minor or rare species, usually small groups or individual admixture, total proportion up to 10%

Based on the Decree No. 24 of the Ministry of Environment of the Slovak Republic from January 9 2003, which implements the national Act No. 543/2002 on Nature and Landscape Protection, the species were distinguished with respect to their origin and relatively achievable age. For species origin two categories were used, autochthonous and allochthonous. Relatively achievable age was classified within three categories (Table 2).

Table 2. Categories of relatively achievable age of woody plant species.

Relatively achievable age	Description
Long-lived species	high or significantly high relative age, i.e. 200 – 500 or more than 500 years
Medium-lived species	medium age, 100 – 200 years
Short-lived species	very low or low age, up to 50 years or between 50 and 100 years; includes all shrub species

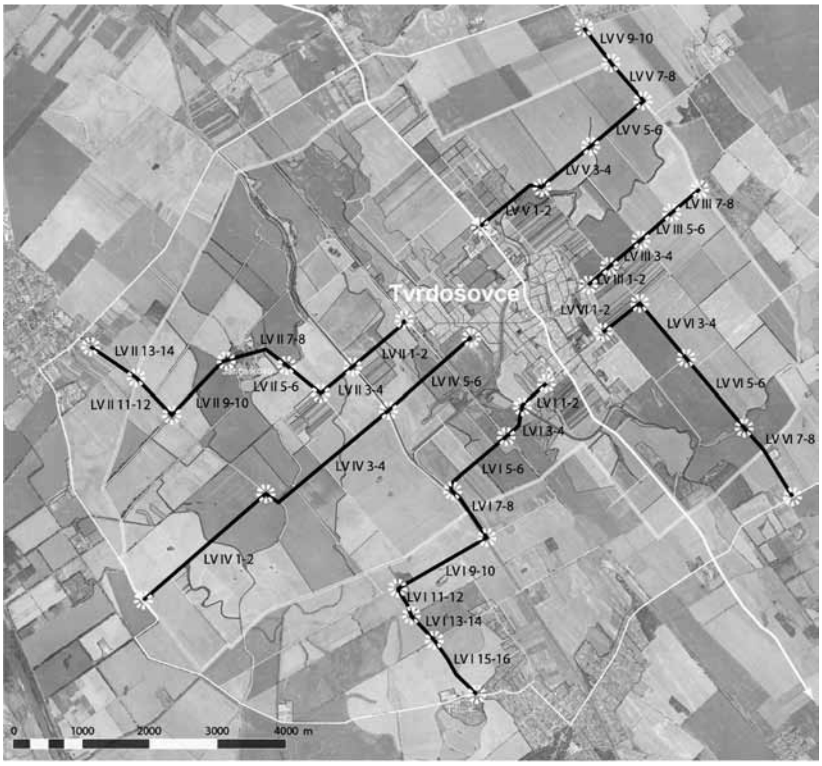

Fig. 2. Division of linear woody vegetation structures into sectors, example from the study area Tvrdošovce.

The frequency of occurrence of species has been evaluated within each study area, based on the following formula:

$$F_o = \frac{S_o}{S_t}$$

Where (F_o) is the Frequency Factor of occurrence of the species as predominant/complementary/mixed-in species; (S_o) is the number of sectors, where the species has been identified as predominant/complementary/mixed-in species and (S_t) is the total amount of assessed sectors in the study area.

The Frequency Factor has been developed by the authors to enable a better comparability of species composition and diversity between the different study areas. The proposed methodology aims to fill the methodological gap in assessing woody plant species composition and diversity in linear woodlands along roads, since currently there is no particular methodology tackling this issue.

The recommendations and measures on species composition enhancement proposed in the results are mainly based on Slovak and European legal political or strategic documents: the Slovak National Act No. 543/2002 on Nature and Landscape Protection, the EU Biodiversity Strategy to 2020 and the European Landscape Convention (Council of Europe 2000).

3. Results

The complete overview of documented tree and shrub species in the three study areas is elaborated in the Appendix 1–3.

3.1. Predominant tree species

Among the predominant tree species (in total 19 species), only *Robinia pseudoacacia* L., *Populus alba* L., *Salix alba* L. and *Populus nigra* L. are classified as predominant within each study area. The highest Frequency Factor in all three study areas has *Robinia pseudoacacia* L. (Tvrdošovce 0.52; Dvory nad Žitavou 0.45 and Kolíňany 0.24), while for other species it is much lower, ranging from 0.19 to 0.03. This clearly shows how widely distributed is this allochthonous medium-lived species.

Predominant tree species occurring in two of the three study areas are: *Fraxinus excelsior* L. ($F_o \leq 0.19$); *Prunus domestica* L. ($F_o \leq 0.19$); *Negundo aceroides* Moench ($F_o \leq 0.07$); *Juglans regia* L. ($F_o = 0.03$).

Predominant tree species occurring in one of the three study areas are: *Prunus cerasifera* Ehrh. ($F_o = 0.13$); *Acer platanoides* L. ($F_o = 0.07$); *Fraxinus angustifolia* Vahl ($F_o = 0.07$); *Gleditsia triacanthos* L. ($F_o = 0.07$) and other tree species with a Frequency Factor of 0.03 (*Acer saccharinum* L.; *Ailanthus altissima* (Mill.) Swingle; *Fraxinus ornus* L.; *Morus alba* L.; *Morus nigra* L.; *Populus x canadensis* Moench; *Tilia platyphyllos* Scop.).

Concerning tree species origin, 58% of species are allochthonous and 42% autochthonous. The most frequent predominant tree species, *Robinia pseudoacacia* L. is allochthonous. The most frequent autochthonous tree species are *Populus alba* L. and *Salix alba* L., followed by *Populus nigra* L. and *Fraxinus excelsior* L. ($0.13 \leq F_o \leq 0.19$). The most frequent allochthonous tree species (excluding *Robinia pseudoacacia* L.) are *Prunus domestica* L.; *Negundo aceroides* Moench; *Juglans regia* L.; *Prunus cerasifera* Ehrh. and *Gleditsia triacanthos* L., descending respectively ($0.03 \leq F_o \leq 0.19$).

Concerning the relatively achievable age, most of the predominant tree species are medium-lived, representing 58% ($F_o \leq 0.52$), followed by short-lived tree species (31.5%; $F_o \leq 0.19$) and long-lived tree species (10.5%; $F_o \leq 0.07$).

Abbreviations used in the figure 3: *Robinia pseudoacacia* (RP), *Populus nigra* (PN), *Salix alba* (SA), *Prunus cerasifera* (PC), *Fraxinus angustifolia* (FA), *Gleditsia triacanthos* (GT), *Fraxinus excelsior* (FE), *Prunus domestica* (PD), *Negundo aceroides* (NA), *Juglans regia* (JR).

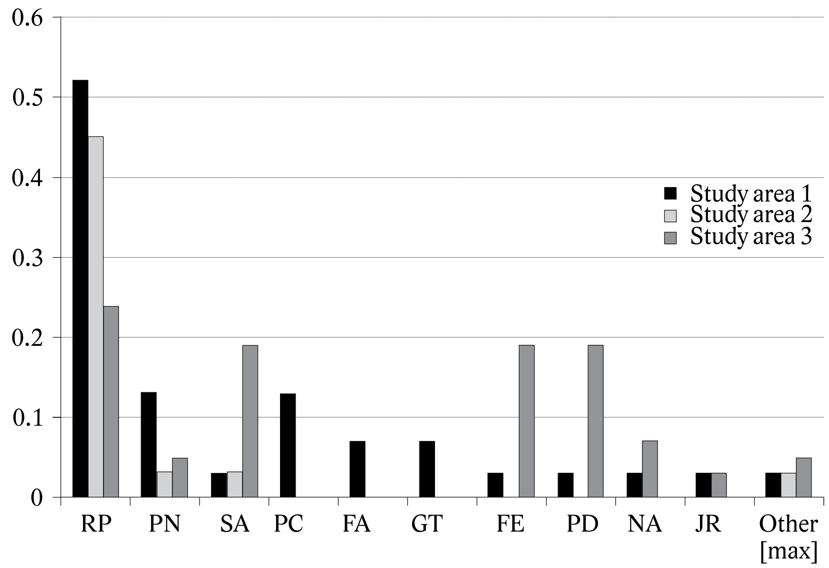

Fig. 3. Overview of the most important predominant tree species in the three study areas based on their Frequency Factor (F_o).

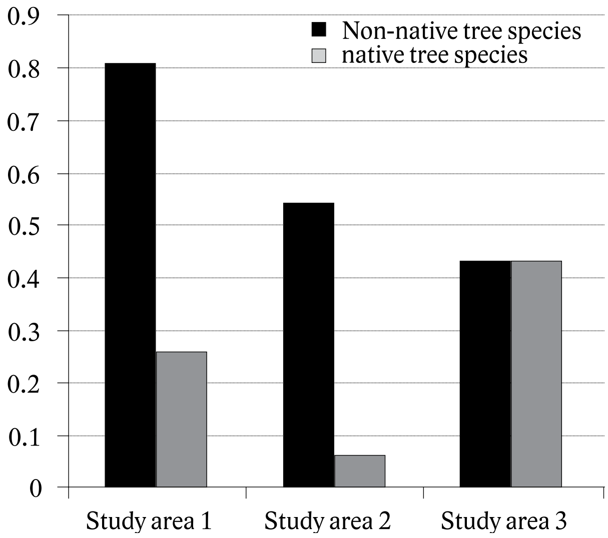

Fig. 4. Overview of the most important predominant tree species in the three study areas based on their origin weighted by their Frequency Factor (F_o).

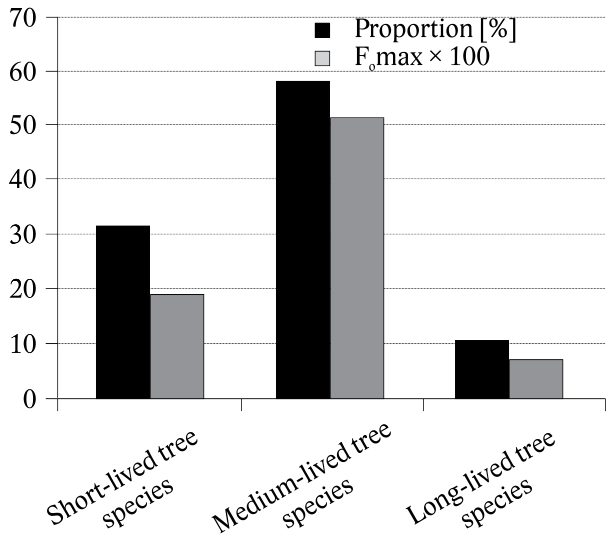

Fig. 5. Overview of the most important predominant tree species based on their relatively achievable age weighted by their Frequency Factor (F_o)

3.2. Complementary tree species

The most frequent complementary tree species (from 22 species in total) are *Prunus cerasifera* Ehrh. (F_o **=** 0.32) and *Juglans regia* L. (F_o **≤** 0.26), both allochthonous fruit tree species.

Complementary tree species occurring in two of the three study areas are: *Juglans regia L.* ($0.07 \leq F_o \leq 0.26$); *Robinia pseudoacacia* L. ($0.07 \leq F_o \leq 0.16$); *Malus domestica* Borkh. ($0.07 \leq F_o \leq 0.14$); *Prunus domestica* L. ($0.03 \leq F_o \leq 0.10$); *Fraxinus excelsior* L. ($0.05 \leq F_o \leq 0.07$); *Populus alba* L. ($F_o = 0.07$).

Complementary tree species occurring in one of the three study areas are: *Prunus cerasifera* Ehrh. ($F_o = 0.32$); *Fraxinus angustifolia* Vahl ($F_o = 0.16$); *Fraxinus ornus* L. ($F_o = 0.13$); *Populus x canadensis* Moench ($F_o = 0.13$); *Ailanthus altissima* (Mill.) Swingle ($F_o = 0.10$); *Salix fragilis* L. ($F_o = 0.10$) and other tree species with a Frequency Factor ranging from 0.07 to 0.03 (*Acer campestre* L.; *Cerasus avium* (L.) Moench; *Negundo aceroides* Moench; *Populus nigra* L.; *Salix alba* L.; *Acer platanoides* L.; *Acer pseudoplatanus* L.; *Pyrus communis* L. emend. Burgsd.; *Sorbus aucuparia* L. and *Ulmus minor* Mill.).

Concerning origin, 41% of the documented tree species are allochthonous and 59% autochthonous. The most frequent autochthonous tree species are *Fraxinus excelsior* L.; *Populus alba* L.; *Fraxinus angustifolia* Vahl; *Fraxinus ornus* L. and *Salix fragilis* L., descending respectively ($0.07 \leq F_o \leq 0.16$). The most frequent allochthonous tree species are *Prunus cerasifera* Ehrh.; *Juglans regia* L.; *Robinia pseudoacacia* L.; *Malus domestica* Borkh. and *Populus x canadensis* Moench, descending respectively ($0.07 \leq F_o \leq 0.32$).

Concerning the relatively achievable age, most of the complementary tree species are short-lived, representing

50% ($F_o \leq 0.32$), followed by medium-lived tree species (36%; $F_o \leq 0.26$) and long-lived tree species (14%; $F_o \leq 0.07$).

3.3. Mixed-in tree species

The most frequent mixed-in tree species (from 37 species in total) are *Prunus cerasifera* Ehrh. ($F_o = 0.42$); *Juglans regia* L. ($0.10 \leq F_o \leq 0.29$) and *Ailanthus altissima* (Mill.) Swingle ($F_o = 0.29$), all three of them allochthonous species.

Mixed-in tree species occurring in all three study areas are: *Juglans regia* L. ($0.10 \leq F_o \leq 0.29$) and *Populus nigra* L. ($0.03 \leq F_o \leq 0.19$).

Mixed-in tree species occurring in two of the three study areas are: *Cerasus avium* (L.) Moench ($0.14 \leq F_o \leq 0.19$); *Salix alba* L. ($0.03 \leq F_o \leq 0.16$); *Populus alba* L. ($0.13 \leq F_o \leq 0.16$); *Prunus domestica* L. ($0.07 \leq F_o \leq 0.10$) and other tree species with a Frequency Factor ranging from 0.07 to 0.03 (*Acer platanoides* L.; *Robinia pseudoacacia* L.; *Acer saccharinum* L. and *Populus tremula* L.).

Mixed-in tree species occurring in one of the three study areas are: *Prunus cerasifera* Ehrh. ($F_o = 0.42$); *Ailanthus altissima* (Mill.) Swingle ($F_o = 0.29$); *Malus domestica* Borkh. ($F_o = 0.16$); *Morus alba* L. ($F_o = 0.13$); *Negundo aceroides* Moench ($F_o = 0.13$); *Aesculus hippocastanum* L. ($F_o = 0.10$); *Fraxinus excelsior* L. ($F_o = 0.10$); *Morus nigra* L. ($F_o = 0.10$); *Pyrus communis* L. emend. Burgsd. ($F_o = 0.10$) and other tree species with a Frequency Factor ranging from 0.07 to 0.03 (*Catalpa bignonioides* Walt.; *Fraxinus ornus* L.; *Populus x canadensis* Moench; *Pyrus pyraster* (L.) Burgsd.; *Quercus robur* L.; *Ulmus minor* Mill.; *Acer pseudoplatanus* L.; *Carpinus betulus* L.; *Celtis occidentalis* L.; *Gleditsia triacanthos* L.; *Platycladus orientalis* (L.) Franco; *Populus simonii* Carriére; *Tilia platyphyllos* Scop.; *Ulmus glabra* Huds.; *Ulmus laevis* Pall.; *Pinus sylvestris* L.; *Betula pendula* L.; *Picea abies* L.

Concerning origin, 49% of the documented mixed-in tree species are allochthonous and 51% autochthonous. The most frequent autochthonous tree species are *Populus nigra* L.; *Cerasus avium* (L.) Moench; *Salix alba* L.; *Populus alba* L. and *Fraxinus excelsior* L., descending respectively ($0.03 \leq F_o \leq 0.19$). The most frequent allochthonous tree species are *Prunus cerasifera* Ehrh.; *Juglans regia* L.; *Ailanthus altissima* (Mill.) Swingle; *Malus domestica* Borkh.; *Morus alba* L. and *Negundo aceroides* Moench, descending respectively ($0.10 \leq F_o \leq 0.42$).

Concerning the relatively achievable age, most of the mixed-in tree species are medium-lived, representing 43% ($F_o \leq 0.29$), followed by short-lived tree species (38%; $F_o \leq 0.42$) and long-lived tree species (19%; $F_o \leq 0.07$).

3.4. Predominant shrub species

Among the predominant shrub species (in total 8 species), *Sambucus nigra* L. is the only one occurring in all three study areas ($0.14 \leq F_o \leq 0.65$). The other predominant shrub species reach a Frequency Factor of maximum 0.29, which illustrates very well the wide distribution of this autochthonous species.

Predominant shrub species occurring in two of the three study areas are: *Rosa canina* L. ($0.24 \leq F_o \leq 0.29$); *Salix caprea* L. ($0.07 \leq F_o \leq 0.19$).

Predominant shrub species occurring in one of the three study areas are: *Prunus spinosa* L. ($F_o = 0.23$); *Rhus typhina* L. ($F_o = 0.14$) and other species, such as *Euonymus europaeus* L.; *Lycium barbarum* L. and *Syringa vulgaris* L. ($0.03 \leq F_o \leq 0.07$).

Concerning origin, 37.5 % of the documented shrub species are allochthonous and 62.5 % autochthonous. The most frequent predominant shrub species, *Sambucus nigra* L. ($F_o \leq 0.65$), is autochthonous. The most frequent shrub species are autochthonous ($0.07 \leq F_o \leq 0.65$), while allochthonous species have only a low frequency and special distribution ($0.03 \leq F_o \leq 0.14$).

Abbreviations used in the figure : *Sambucus nigra* (SN), *Rosa canina* (RC), *Salix caprea* (SC), *Prunus spinosa* (PS), *Rhus typhina* (RT), *Euonymus europaeus* (EE), *Lycium barbarum* (LB), *Syringa vulgaris* (SV).

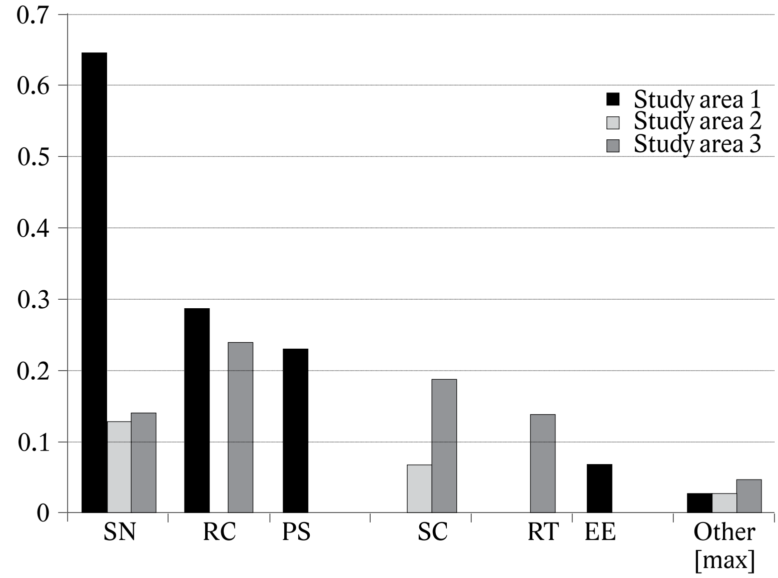

Fig. 6. Overview of the most important predominant shrub species in the three study areas based on their Frequency Factor (F_o).

3.5. Complementary shrub species

Among the complementary shrub species (in total 10 species), *Prunus spinosa* L. is the only one occurring in all three study areas ($0.07 \leq F_o \leq 0.13$).

Complementary shrub species occurring in two of the three study areas are: *Rosa canina* L. ($0.10 \leq F_o \leq 0.39$) and *Sambucus nigra* L. ($F_o = 0.19$).

Complementary shrub species occurring in one of the three study areas are: *Hippophae rhamnoides* L. ($F_o = 0.14$); *Euonymus europaeus* L. ($F_o = 0.13$); *Swida sanguinea* (L.) Opiz ($F_o = 0.13$); *Lycium barbarum* L. ($F_o = 0.10$) and other species, such as *Ligustrum vulgare* L.; *Rubus fruticosus* L. agg. and *Tamarix tetrandra* Pall. ($0.03 \leq F_o \leq 0.05$).

Concerning origin, 30% of the documented shrub species are allochthonous and 70% autochthonous. The most frequent complementary shrub species are all native. Allochthonous species have only a low frequency of occurrence and spatial distribution ($0.03 \leq F_o \leq 0.14$).

3.6. Mixed-in shrub species

Among the mixed-in shrub species (in total 12 species), *Rosa canina* L. ($0.13 \leq F_o \leq 0.26$) and *Prunus spinosa* L. ($0.10 \leq F_o \leq 0.16$) are the only species occurring in all three study areas.

Mixed-in shrub species occurring in two of the three study areas are: *Sambucus nigra* L. ($0.13 \leq F_o \leq 0.26$) and *Ligustrum vulgare* L. ($0.03 \leq F_o \leq 0.07$).

Mixed-in shrub species occurring in one of the three study areas are: *Swida sanguinea* (L.) Opiz ($F_o = 0.19$); *Euonymus europaeus* L. ($F_o = 0.13$); *Crataegus monogyna* Jacq. ($F_o = 0.10$); *Elaeagnus angustifolia* L. ($F_o = 0.10$) and other species, such as *Syringa vulgaris* L.; *Lycium barbarum* L.; *Rhamnus catharticus* L. and *Mahonia aquifolium* (Purch) Nutt. ($0.03 \leq F_o \leq 0.07$).

Concerning origin, 33% of the documented shrub species are allochthonous and 67% autochthonous. The most frequent mixed-in shrub species are all native. Allochthonous species have only a low frequency of occurrence and spatial distribution ($0.03 \leq F_o \leq 0.10$).

3.7. Species composition and diversity – proposed measures and changes

Considering the relatively achievable age, the proportion of long-lived tree species is significantly lower compared to medium-lived and short-lived species and the species diversity is also very low – only two long-lived autochthonous tree species occur, with a very low distribution or frequency. In complementary tree species, the diversity of native species is higher than the diversity of allochthonous species; however native tree species have a much lower spatial distribution and quantitative proportion. Considering the relatively achievable age, the proportion of long-lived trees is very low compared to medium-lived and short-lived species, while the species diversity is also very low – only three long-lived autochthonous tree species occur among complementary species, with a very low distribution.

Based on the findings of the field research and according to several national and international policy documents - the Slovak National Act No. 543/2002 on Nature and Landscape Protection, the EU Biodiversity Strategy to 2020, the European Landscape Convention and authors Kurz et al. (2011), Sitzia et al. (2013), Supuka et al. (2013), it is necessary, that native plant species are enhanced in the landscape, since they significantly impact the regional and local landscape identity, character and visual design. It is therefore highly recommended that regionally suitable native woody plant species are preferred to non-native woody plant species, as required by the Slovak National Act No. 543/2002. However, in our literature review, we have not found any recommendations on exact numbers, percentage or proportion of native and non-native woody plant species. We recommend therefore 50% as the minimum proportion of native woody plant species in the landscape, in order to avoid dominance of alien woody plant species. This results in the following measures and recommendations:

1) To continuously increase the current proportion of native tree species, suitable for the specific area based on the potential natural vegetation (this means an increase by at least 8% for predominant species from 42% to at least 50%). Complementary (59%) and mixed-in native species (51%) have a higher proportion than non-native species; it is therefore recommended to sustain and ideally increase this proportion by future plantings. The aim of this proposal is to have as high proportion of regionally suitable native species as possible, but at least more than the half of the species - this measure would enhance not only the native biodiversity as proclaimed in the EU Biodiversity Strategy to 2020, but also the identity of the local landscapes as proclaimed by the European Landscape Convention.

Native shrub species prevail in all study areas and in all abundance categories (for categories see Table 1) – as in terms of species diversity, as well as in terms of spatial distribution and frequency of occurrence. It is therefore proposed to sustain and ideally increase the proportion of native shrub species, suitable for the specific area based on the potential natural vegetation. This would mean a preference of regionally suitable native species to alien species as required by the Slovak National Act No. 543/2002 on Nature and Landscape Protection.

2) It is recommended to have a proportion of at least 30 % of long-lived regionally suitable native tree species in non-forest woodland structures in the agricultural landscape (Supuka 1992; Supuka et al. 2013). It is therefore recommended to continuously increase the proportion of long-lived regionally suitable native tree species to at least 30% (from the current 10.5% in predominant species; 14% in complementary species and 19% in mixed-in species). The aim of this measure is to enhance long lasting natural features in the landscape, which is important for landscape perception proclaimed in the European Landscape Convention.

3) To continuously increase the spatial distribution (F_o) of long-lived native tree species to at least 0.30 (from the current 0.07 in predominant, complementary and mixed-in species), in order to achieve a balanced vegetation structure in the landscape as suggested by Supuka (1992) and Supuka et al. (2013).

4) To continuously increase the spatial distribution (F_o) of native tree species to at least 0.50 (from the current maximum of 0.16 in complementary species and 0.19 in mixed-in species)

5) To continuously increase the proportion and spatial distribution (F_o) of traditional native fruit tree species to at least 0.30 (from the current maximum of 0.07 in complementary species and 0.19 in mixed-in species). The legal tool to change species composition of non-forest woody vegetation in Slovakia is the Slovak National Act No. 543/2002 on Nature and Landscape Protection, which requires plantations of regionally suitable native woody plant species based on the potential natural vegetation. The practical implementation consists mainly in local actions by the municipal authorities, more precisely their environmental commissions, which have the legal power to implement the proposed measures, i.e. mainly to plant regionally specific native species and where necessary to reduce the spreading of invasive non-native species. The local municipal authority defines the species composition of new or compensatory plantings, thus it has the legal power and the practical implementation tools.

4. Discussion

We found out that *Robinia pseudoacacia* L. dominates in all three study areas. This non-native species has been identified as the main tree species in bio-corridors in south-western Slovakia by Baranec et al. (2015), as well as by Supuka (1992) and Supuka et al. (2013). There is thus a clear evidence of a significantly wide distribution of this species in agricultural landscapes of Slovakia. This is partly the result of inappropriate tree plantings mainly in the previous century and partly also due to vital or in some cases even invasive distribution of this species (Gojdičová et al. 2002).

Baranec et al. (2015) have evaluated also *Populus x canadensis*, which is not of such significance in areas assessed in this paper. This is likely the reason of different management interventions in past decades, where the planting of fast growing tree species in the agricultural landscape was common. They also documented populations of *Prunetalia spinosae*, mainly hybrids of *Prunus spinosa* (*Prunus x fruticans* and *Prunus x fetchneri*), which was found to occur as one of the most frequent complementary shrub species. This justifies a wide distribution of *Prunus spinosa* in agricultural landscapes of south-western Slovakia. Baranec et al. (2015) also identified the problem of superseding native *Prunus spinosa* by hybrids of *Prunus x fruticans*. Similarly to our results, the latter authors found a frequent occurrence of *Populus alba*, *Populus tremula* and *Salix fragilis* in Veľké Úľany and Čechynce. This can be explained by comparable potential natural vegetation. Similarly to Supuka et al. (2013), we found valuable old tree species along roads in the study areas of rural agricultural landscape, such as *Quercus robur* (stem diameter in breast height $d_{1.3}$ = 1.61 m; stem circumference in breast height $c_{1.3}$ = 5.05 m), *Pyrus pyraster* ($d_{1.3}$ = 0.86 m; $c_{1.3}$ = 2.70 m) or *Morus nigra* ($d_{1.3}$ = 0.65 m; $c_{1.3}$ = 2.03 m) in the study area of Tvrdošovce. These trees are very significant in terms of natural and cultural heritage as well as gene pool and biodiversity. Similarly to Kurz et al. (2011) and Supuka et al. (2013), we have documented the occurrence of traditional fruit tree species such as *Prunus sp., Cerasus avium, Juglans regia, Malus domestica, Pyrus sp.* and *Sorbus aucuparia*, but in contrast to Kurz et al. (2011), we have not documented a significant proportion of *Acer sp.* and other long-lived native tree species, which is a result of different management approaches in past decades and can indicate pathways for improvements and biodiversity enhancement in the study areas. In line with Supuka (1992) and Supuka et al. (2013), we have also documented a high proportion and spatial distribution of shrub species *Rosa canina*, *Sambucus nigra, Prunus spinosa, Lycium barbarum* and tree species *Cerasus avium, Fraxinus excelsior, Juglans regia, Malus domestica, Populus nigra, Prunus cerasifera, Prunus domestica, Salix alba, Salix caprea* and *Salix fragilis*. Contrary to Supuka (1992), there is a less significant proportion and spatial distribution of *Populus x canadensis, Acer campestre, Carpinus betulus, Crataegus laevigata, Quercus robur, Tilia cordata* and a much higher proportion and distribution of *Populus alba* and *Salix alba*.

The proposed measures aiming to increase the proportion of native woody plants agree with the approach of Insley et al. (1988), who state that when planning new farm woodlands, the first thing to consider is the existing landscape character and identity of the area, which is partly formed by native woodland species. The main features to consider are the landform, existing vegetation patterns (especially semi-natural vegetation), land use patterns (in particular the prominence of hedgerows and hedgerow tree patterns), and the character of the landscape. Based on this statement, an increase of endemic woody plant species has been proposed, since these enhance the identity and character of current landscapes as proclaimed by the European Landscape Convention. Besides landscape character and identity aspects, also the biodiversity plays a key role in the proposed measures, which is in line with Rey Benayas & Bullock (2015), who propose a widespread strategic re-vegetation to enhance wildlife in European agricultural landscapes by planting woodland islets and hedgerows for ecological restoration in extensive agricultural landscapes. This approach allows wildlife enhancement, provision of a range of ecosystem services, maintenance of farmland production, and conservation of values linked to cultural landscapes. Our approach not only maintains the farmland production, but also supports a multifunctional and efficient land use, since we propose mainly linear woodland structures. Strategic re-vegetation in actively farmed fields can include planting woodland islets, hedgerows and isolated trees. These woodland structures have the potential to enhance wildlife, agricultural production, and other services at the field and landscape scales since they hardly compete for farmland use. In this study and particularly in the proposed measures, a preference has been given to native species, since woodland structures in the agricultural landscape should be only planted by a variety of native shrub and tree species (Thompson et al. 2009; Rey Benayas & Bullock 2015). This agrees with the approach of Cramer et al. (2015), who state that when restoring woodlands in extensive agricultural landscapes, the emphasis should be placed on the development of self-sustaining ecosystems, protecting native biodiversity and according to Cunningham et al. (2015), planting a mixture of native trees and shrubs is best for biodiversity. Thus a significant enhancement of native woody plant species and an active restoration of agricultural landscapes is needed in the study areas, which according to Rey Benayas et al. (2008) should involve large-scale plantings of native trees and tree growth management. The technical implementation of the proposed measures means mainly planting a mixture of native trees and shrubs, which according to Barrett et al. (2008), has become a cornerstone strategy for natural resource management in agricultural landscapes. For the technical implementation of this measure, active planting seems to be the most efficient tool, since many native plant species need to be actively planted, due to a lack of local seed sources (Flinn & Vellend 2005). Planting of native woody plant species in open landscape (non-built-up or non-urbanised areas) is also required by the Slovak National Act No. 543/2002 on Nature and Landscape Protection as well as by the EU Biodiversity Strategy to 2020.

Planting native woody plant species in the agricultural landscape not only enhances biodiversity as argued above, but also provides landscape planning and landscape management with a strategic tool for climate change mitigation and drought risk management. According to Cunningham et al. (2015), in low-rainfall areas (<800 mm year^{-1}), native species are likely to be less vulnerable to drought and climate change and provide higher biodiversity benefits to native wildlife species (Lindenmayer et al. 2003).

The results can be generalised for rural agricultural landscapes in lowlands and slightly hilly upland areas of Slovakia and other Central European countries. A comparison of different case studies from Central European countries would be valuable to compare the current situation and work on collaborative measures at the European or bilateral level.

5. Conclusion

The presented results extend the existing knowledge on species composition, diversity and spatial distribution of non-forest woody vegetation in the agricultural landscape, with a particular focus on trees and shrubs growing along roads in the open landscape. It has been found that among trees, allochthonous (introduced) species dominate, while among shrubs autochthonous (native) species prevail. Moreover a low proportion and distribution of long-lived tree species has been documented. Based on these findings, several measures have been proposed, in order to improve the existing situation of native species diversity, spatial distribution and ecological resilience of rural landscapes. The results can be applied mainly at the local level, in municipal decision making and governance, but it can be a useful tool also in policy making at the regional, national or EU level, since the assessment methodology is in line with the national nature and landscape protection policy. Further research and verification of the applied methodology could help in creating and transferring knowledge on woody plant species in rural agricultural landscapes, their composition, diversity, relatively achievable age and origin.

Acknowledgement

The presented research has been financially supported by the Cultural and Educational Grant Agency (KEGA) of the Ministry of Education, Science, Research and Sport of the Slovak Republic within the Grants KEGA No. 001SPU-4/2014 Green Infrastructure and Urban Agriculture and KEGA No. 003SPU-4/2014 Non-forest Woody Vegetation in the Landscape, its Biodiversity, Gene Pool and Landscape Architectural Significance.

References

Baranec, T., Ikrényi, I., Galuščáková Ľ., 2015: Vegetácia biokoridorov na JZ Slovensku. Dendroflóra strednej Európy. Zvolen, TU Zvolen, Arborétum Borová hora, p. 111–119.

Barett, G. W., Freudenberger, D., Drew, A., Stol, J., Nicholls, A. O., Cawsey, E. M., 2008: Colonisation of native tree and shrub plantings by woodland birds in an agricultural landscape. Wildlife Research, 35:19–32.

Bell, S., 2005: Elements of Visual Design in the Landscape. London and New York, Spon Press, Taylor & Francis Group, 220 p.

Brandle, J. R., Hodges, L., Zhou, X. H., 2004: Windbreaks in North American agricultural systems. Agroforestry Systems, 61:65–78.

Council of Europe, 2000: European Landscape Convention. European Treaty Series – No. 176. Florence.

Cramer, V. A., Hobbs, R. J., Standish, R. J., 2008: What´s new about old fields? Land abandonment and ecosystem assembly. Trends in Ecology & Evolution, 21:104–112.

Cunningham, S. C., Mac Nally, R., Baker, P. J., Cavagnaro, T. R., Beringer, J., Thomson, J. R. et al., 2015: Balancing the environmental benefits of reforestation in agricultural regions. Perspectives in Plant Ecology, Evolution and Systematics, 17:301–317.

Demková, K., Lipský, Z., 2013: Changes in the extent of non-forest woody vegetation in the Novodvorsko and Žehušicko region (Central Bohemia, Czech Republic). Acta Universitatis Carolinae, Geographica, 48:5–13.

Demková, K., Mida, P., 2014: Classification of the non-forest woody vegetation and its relation to habitat conditions: Case study from White Carpathians (Western Slovakia). Polish Journal of Ecology, 62:401–412.

European Commission, 2011: The EU Biodiversity Strategy to 2020. Luxembourg: Publications Office of the European Union, 28 p, ISBN 978-92-79-20762-4.

Flinn, K. M., Vellend, M., 2005: Recovery of forest plant communities in post-agricultural landscapes. Frontiers in Ecology Environment, 3:243–250.

Gojdičová, E., Cvachová, A., Karasová, E., 2002: Zoznam nepôvodných, inváznych a expanzívnych cievnatých rastlín Slovenska 2. Banská Bystrica, Ochrana prírody, 21:59–79.

Hlásny, T., Mátyás, Cs., Seidl, R., Kulla, L., Merganičová, K., Trombik, J., 2014: Climate change increases the drought risk in Central European forests: What are the options for adaptation? Lesnícky časopis - Forestry Journal, 60:5–18.

Insley, H., Davies, H. L., Craven, D. R. J., MacKenzie, R. F., Jones, G.B., Marshall, B. A. et al., 1988: Farm Woodland Planning. London, Her Majesty's Stationery Office, 142 p.

Konôpka, J., 2010. From production to multifunctional utilization of forest ecosystems. Lesnícky časopis - Forestry Journal, 56:81–92.

Kuhn, G., Brandle, J. R., Rietveld, W. J., 1991: Forestry's Role in Sustainable Agriculture. The Third International Windbreaks & Agroforestry Symposium Proceedings. Ridgetown College, Canada, p. 76–78.

Kurz, P., Machatschek, M., Iglhauser, B., 2011: Hecken: Geschichte und Ökologie, Anlage, Erhaltung und Nutzung. Graz, Stuttgart, Leopold Stocker Verlag, 440 p.
Lampartová, I., Schneider, J., Vyskot, I., Rajnoch, M., Litschmann, T., 2015: Impact of Protective Shelterbelt on Microclimate Characteristics. Ekológia (Bratislava), 34:101–110.
Lindenmayer, D.B., Hobbs, R.J., Salt, D., 2003: Plantation forests and biodiversity conservation. Aust. Forest., 66:62–66.
Melo, M., Lapin, M., Kapolková, H., Pecho, J., 2013: Climate trends in the Slovak part of the Carpathians. In: Kozak, J., Ostapowicz, K., Bytnerowicz, A., Wyżga, B. (eds.): The Carpathians: Integrating Nature and Society Towards Sustainability. Springer Berlin Heidelberg, p. 131–150.
Rey Benayas, J. M., Bullock, J. M., Newton, A. C., 2008: Creating woodland islets to reconcile ecological restoration, conservation, and agricultural land use. Frontiers in Ecology and the Environment, 6:329–336.
Rey Benayas, J. M., Bullock, J. M., 2015: Vegetation restoration and other actions to enhance wildlife in European agricultural landscapes. Rewilding European Landscapes. Springer International Publishing, p. 127–142.
Rounsevell, M. D. A., Pedroli, B., Erb, K.-H., Gramberger, M., Busck, A. G., Haberl, H. et al., 2012: Challenges for land system science. Land Use Policy, 29:899–910.
Rózová, Z., 2004: A Picture of the courtyard in settlements of rural type. Acta horticulturae et regiotecturae, 7:23–26.
Salašová, A., Štěpán, M., 2007: Landscape Planning in the Czech Republic – Opportunities, Visions, and Limits. Journal of Landscape Ecology, 1:125–134.
Schaefer, P., 1991: The Vital Roles of Trees in Sustainable Agricultural Systems. The Third International Windbreaks & Agroforestry Symposium Proceedings. Ridgetown College, Canada, p. 67-69.
Sitzia, T., Trentanovi, G., Marini, L., Cattaneo, D., Semenzato, P., 2013: Assessment of hedge stand types as determinants of woody species richness in rural field margins. IForest, 6: 201–208.
Supuka, J., 1992: Dendrologické otázky tvorby poľnohospodárskej krajiny južného Slovenska. Introdukované dreviny v prírodnom prostredí južného Slovenska. Zvolen, LVÚ, p. 30–43.
Supuka, J., Štěpánková, R., 2006: Súčasná krajinná štruktúra Nitry a okolia ako predpoklad optimalizácie poľnohospodárskej krajiny. Acta horticulturae et regiotecturae, 9:1–4.
Supuka, J., Šinka, K., Pucherová, Z., Verešová, M., Feriancová, Ľ., Bihuňová, M. et al., 2013: Landscape Structure and Biodiversity of Woody Plants in the Agricultural Landscape. Brno, Mendel University in Brno, 187 p.
Thompson, J. R., Moilanen, A., Vesk, P. A., Bennett, A. F., Mac Nally, R., 2009: Where and when to revegetate?: A quantitative method for scheduling landscape reconstruction. Ecological Applications, 19:817–827.

Appendix 1: Woody plant species composition in non-forest woody vegetation structures along roads in the agricultural landscape, locality: study area Tvrdošovce.

Growth characteristic	Predominant species	Complementary species	Mixed-in species
Tree species	***Robinia pseudoacacia*** L. (16); *Populus nigra* L. (4); *Prunus cerasifera* Ehrh. (4); *Fraxinus angustifolia* Vahl (2); *Gleditsia triacanthos* L. (2); *Acer saccharinum* L.; *Ailanthus altissima* (Mill.) Swingle; *Fraxinus excelsior* L.; *Fraxinus ornus* L.; *Juglans regia* L.; *Morus alba* L.; *Morus nigra* L.; *Negundo aceroides* Moench; *Populus alba* L.; *Populus* x canadensis Moench; *Prunus domestica* L.; *Salix alba* L.	***Prunus cerasifera*** Ehrh. (10); ***Juglans regia*** L. (8); ***Fraxinus angustifolia*** Vahl (5); ***Robinia pseudoacacia*** L. (5); *Fraxinus ornus* L. (4); *Populus x canadensis* Moench (4); *Ailanthus altissima* (Mill.) Swingle (3); *Acer campestre* L. (2); *Cerasus avium* (L.) Moench (2); *Fraxinus excelsior* L. (2); *Malus domestica* Borkh. (2); *Negundo aceroides* Moench (2); *Populus alba* L. (2); *Salix alba* L. (2); *Acer pseudoplatanus* L.; *Prunus domestica* L.; *Pyrus communis* L. emend. Burgsd.; *Sorbus aucuparia* L.; *Ulmus minor* Mill.	***Prunus cerasifera*** Ehrh. (13); ***Ailanthus altissima*** (Mill.) Swingle (9); ***Juglans regia*** L. (7); ***Cerasus avium*** (L.) Moench (6); ***Populus nigra*** L. (6); ***Malus domestica*** Borkh. (5); ***Salix alba*** L. (5); *Morus alba* L. (4); *Negundo aceroides* Moench (4); *Populus alba* L. (4); *Aesculus hippocastanum* L. (3); *Fraxinus excelsior* L. (3); *Morus nigra* L. (3); *Pyrus communis* L. emend. Burgsd. (3); *Acer platanoides* L. (2); *Catalpa bignonioides* Walt. (2); *Fraxinus ornus* L. (2); *Populus* x *canadensis* Moench (2); *Prunus domestica* L. (2); *Pyrus pyraster* (L.) Burgsd. (2); *Quercus robur* L. (2); *Robinia pseudoacacia* L. (2); *Ulmus minor* Mill. (2); *Acer pseudoplatanus* L.; *Acer saccharinum* L.; *Carpinus betulus* L.; *Celtis occidentalis* L.; *Gleditsia triacanthos* L.; *Platycladus orientalis* (L.) Franco; *Populus simonii* Carriére; *Populus tremula* L.; *Tilia platyphyllos* Scop.; *Ulmus glabra* Huds.; *Ulmus laevis* Pall.
Shrub species	***Sambucus nigra*** L. (20); ***Rosa canina*** L. (9); ***Prunus spinosa*** L. (7); *Euonymus europaeus* L. (2); *Lycium barbarum* L.	***Rosa canina*** L. (12); ***Sambucus nigra*** L. (6); *Euonymus europaeus* L. (4); *Swida sanguinea* (L.) Opiz (4); *Prunus spinosa* L. (4); *Lycium barbarum* L. (3); *Rubus fruticosus* L. agg.; *Tamarix tetrandra* Pall.;	***Swida sanguinea*** (L.) Opiz (6); ***Prunus spinosa*** L. (5); *Euonymus europaeus* L. (4); *Rosa canina* L. (4); *Sambucus nigra* L. (4); *Crataegus monogyna* Jacq. (3); *Elaeagnus angustifolia* L. (3); *Syringa vulgaris* L. (2); *Ligustrum vulgare* L.; *Lycium barbarum* L.; *Rhamnus catharticus* L.

Explanatory note: If the amount of sectors of occurrence (S_o) is higher than 1, it is stated in brackets following the species name. The total amount of assessed sectors is 31. If the (S_o) is 5 or more, the species is bolded.

Appendix 2: Woody plant species composition in non-forest woody vegetation structures along roads in the agricultural landscape, locality: study area Dvory nad Žitavou.

Growth characteristic	Predominant species	Complementary species	Mixed-in species
Tree species	***Robinia pseudoacacia*** L. (14); *Populus alba* (4); *Acer platanoides* L. (2); *Negundo aceroides* Moench. (2); *Juglans regia* L.; *Populus nigra* ´Italica´ L.; *Tilia platyphyllos* Scop.; *Salix alba* ´Tristis´ L.	*Juglans regia* L. (2); *Populus alba* L. (2); *Robinia pseudoacacia* L. (2); *Acer platanoides* L.; *Populus nigra* L.	***Populus alba*** L. (5); *Juglans regia* L. (3); *Pinus sylvestris* L. (2); *Acer platanoides* L.; *Acer saccharinum* L.; *Betula pendula* L.; *Picea abies* L.; *Populus nigra* L.; *Populus tremula* L.; *Robinia pseudoacacia* L.; *Salix alba* ´Tristis´ L.
Shrub species	*Sambucus nigra* L. (4); *Salix caprea* L. (2); *Syringa vulgaris* L.	***Sambucus nigra*** L. (6); *Rosa canina* L. (3); *Prunus spinosa* L. (2)	***Rosa canina*** L. (8); ***Sambucus nigra*** L. (8); *Prunus spinosa* L. (4); *Ligustrum vulgare* L. (2); *Mahonia aquifolium* (Purch) Nutt.

Explanatory note: If the amount of sectors of occurrence (So) is higher than 1, it is stated in brackets following the species name. The total amount of assessed sectors is 31. If the (So) is 5 or more, the species is bolded.

Appendix 3: Woody plant species composition in non-forest woody vegetation structures along roads in the agricultural landscape, locality: study area Kolíňany.

Growth characteristic	Predominant species	Complementary species	Mixed-in species
Tree species	***Robinia pseudoacacia*** L. (5); *Prunus domestica* L. (4); *Salix alba* L. (4); *Fraxinus excelsior* L. (4); *Populus nigra* L.; *Populus alba* L.	*Malus domestica* Borkh. (3); *Prunus domestica* L. (2); *Salix fragilis* L. (2); *Fraxinus excelsior* L.	***Juglans regia*** L. (6); *Cerasus avium* (L.) Moench (3); *Prunus domestica* L. (2); *Populus nigra* L. (2)
Shrub species	***Rosa canina*** L. (5); *Salix caprea* L. (4); *Rhus typhina* L. (3); *Sambucus nigra* L. (3)	*Hippophae rhamnoides* L. (3); *Ligustrum vulgare* L.; *Prunus spinosa* L.	*Rosa canina* L. (3), *Prunus spinosa* L. (2)

Explanatory note: If the amount of sectors of occurrence (So) is higher than 1, it is stated in brackets following the species name. The total amount of assessed sectors is 21. If the (So) is 5 or more, the species is bolded.