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Land use changes and development of the non-forest woody vegetation in the Danubian Lowland in Slovakia

Ján Supuka*, Karol Šinka

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

Abstract

The aim of this paper is to assess the changes in the landscape structure of the Žitný Ostrov territory and in the woody species of the non-forest woody vegetation (NFWV) over the past 120 years. Within the assessed periods of 1892, 1949, 1969 and 2015, the shares of arable land increased by 17% while the ratio of the built-up areas with gardens increased by 3.7%. At the same time, natural habitats, grassland, waterlogged meadows and wetlands decreased by 26%. These changes, concerning small mosaic plots as well as large cultural blocks, were caused by the intensification of agriculture after 1948. Ecological stability and biodiversity of these areas has decreased. Thereafter 60 windbreaks were planted from 1951–1952 in an area of 30 ha. In total, 37 woody species were planted, of which 22 were alien species. After 25 years (in 1976), 19 of the same windbreaks were surveyed, observing 16 native and 12 alien woody species. During these periods, many rare alien and coniferous species died. In 2015, 13 windbreaks with 39 woody species were identified, both in the tree and the shrubby layer. The downside is that four of the long-time surviving species are invasive trees.

Key words: landscape structure changes; windbreaks; woody species; long-term monitoring

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1. Introduction

Geography and ecology potential, land-use forms and land ownership represent the basic criteria for the cultural landscape assessment and design (Kupka 2010; Verešová & Supuka 2012; Kuča et al. 2015). Land use changes are projected into historical and current landscape structure in composition, size and distribution of landscape elements in landscape image, as well as character in its cultural and perceived values (Hernik 2009; Agnoletti et al. 2010; Supuka et al. 2011). Pucherová (2004) published the results of landscape structure development and changes in five studied cadastral territories of Nitra suburbs in the time horizons of 1863, 1892, and 2002. By comparison of historical and current landscape structure, the author has identified a 10 – 30% decreasing share of landscape elements significant for ecological stability. This group includes forests, non-forest woody vegetation, permanent grassland, old traditional fruit orchards, and mosaic small size plots. However, there was an increase of large blocks of arable land, intensive fruit orchards, and new established water basins. The structural changes in the category of vineyard landscapes were assessed in studied territories of Slovakia in the cadastre Čajkov, Nitrianske Hrnčiarovce in Nitra vineyard region (Verešová & Supuka 2013), the traditional Small Carpathian vineyard region (Štefunková et al. 2011), as well as in the Bavaria vineyard region in Germany (Petit et al. 2012). Emphasis was given to landmark changes and their cultural and historical values for potential recreation use as well (Cieszewska et al. 2010).

Structural changes of the agriculture landscape in Slovakia with regard to the identification of historical structure elements and their changes were published by Špulerová et al. (2011). In the same way, landscape structure changes and development in the Podoubraví region in the Czech Republic were assessed (Lipský et al. 2011). Land use and land cover changes in China and the United States over the past 300 years were compared. A noticeable trend was the increase in croplands and decrease of the forest and grassland / shrub land areas in both USA and China, however, in different proportions. Larger areas of decrease were found in China, since the United States is a younger cultural country (Fanneng et al. 2015).

In the agricultural landscape structure, we shall work on the important assumption that the non-forest woody vegetation (NFWV) is an effective landscape ecological

*Corresponding author. Ján Supuka, e-mail: jan.supuka@uniag.sk

stability element. Its share in the countryside is closely related to the historical development, changes in land-use forms, intensification of agriculture technologies, and land ownership (Pucherová 2004; Kupka 2010; Kuczman 2014). In the whole Slovakia, the share of non-forest woody vegetation in agriculture landscapes was defined as 5 to 12% depending on geography and relief conditions, land-use form and land cover (Supuka et al. 2013). In France, conditions were identified as a 5 – 15% share of NFWV in agricultural landscape (Soltner 1991) per different phytogeographical conditions.

Important results were achieved in research of forest and windbreaks on biomass production and crop yields in agriculture landscape (Tutka 2010). The cumulative effectiveness of forest and windbreaks in distance by 100 and 150 m from forest margin caused yield increase of assessed crops by 7 – 15% depending on altitude, climate and soil characteristics. Stated value of agro-production forest function reaches 0.66 – 2.32 € year^{1} ha^{-1} according to the agro-climate regions of Slovakia (Tutka 2010).

The non-forest woody vegetation, as an important landscaping element with significant gene pool value, represents an old, oversized specimen of rare trees considered as elements of tree heritage (Morton 1998; Supuka & Pucherová 2013; Demková & Lipský 2017). In the lowland landscape of south-western Slovakia, woody species richness of *Prunus* genus in dispersed woody vegetation in the agriculture landscapes was surveyed (Baranec et al. 2011). In the protective forest belts on the territory of three forest units of the south-western Slovakia, 59 woody species were inventoried, including 19 native species (Varga et al. 1999). Great attention was payed to the identification and assessment of old fruit trees in the dispersed landscape vegetation. In Hriňová cadastre, 10 varieties were surveyed and in Hrušov cadastre, 13 varieties (Zrníková et al. 2014). The occurrences of Service Tree, *Sorbus domestica*, and Black mulbery, *Morus nigra*, as rare fruit trees were identified in 24 localities of agriculture landscape in NFWV elements (Paganová & Bakay 2010) and also in traditional mosaic structure vineyards of Western Slovakia (Verešová 2011). Service Tree is richly present in the geographical territory of White Carpathy in South Moravia, where its specific varieties were identified in 12 localities (Tetera et al. 2006).

In the Alpine pastoral landscape, participation of line form NFWV elements including hedges, as well as their effectiveness in landscape image and biodiversity was studied (Kurz et al. 2011). Planning, establishment, and management of NFWV in the rural agricultural landscapes of Slovakia have been published by Tóth et al. (2016), while the situation in the Czech Republic was described by Salašová (2001).

The aim of this paper is to assess the landscape structure development within the last almost 120 years, with emphasis on spatial changes in the non-forest woody vegetation and its woody plant biodiversity.

2. Material and methods

The chosen study area was the Žitný Ostrov territory, which is a part of geographical unit Danubian Lowland in the south-western Slovakia. In this territory, woody species composition and space structure of chosen protective forest belts (windbreaks) has been compared in three time horizons of 1951, 1976 and 2015. Thanks to one published contribution (Gemerský 1961), we have acquired an original document about space distribution of 60 windbreaks that were established in agriculture landscapes in the years 1951–1952. Spatial distribution of windbreaks on the Žitný Ostrov territory, as well as case planting plans of applied woody species is documented by the originally published maps and plans. The list of planted woody plant species is composed of plants representing wide species diversity. Later in 1976, we surveyed the woody species and spatial composition at 19 chosen windbreaks in six cadastral territories of the Žitný Ostrov territory, Dobrohošť, Horný Bar, Bodíky, Hubice, Malá and Veľká Paka. More particular investigation and assessment of the NFWV, their historical development, and the spatial distribution was provided in four time horizons (1892, 1949, 1969 and 2015). The assessment was accomplished on the landscape segments covering the cadastral territories of Dunajský Klátov (353.9 ha), Malé Dvorníky (747.6 ha), Veľké Dvorníky (139.2 ha), Jahodná (110.0 ha), Vydrany (118.9 ha); in total 1968.03 ha. Assessed landscape structure development and changes between established time horizons were accomplished by using historical maps: III. Military survey and cadastral maps (1892), aerial photo (1949, 1969) and ortho photo maps. (Used sources: © Geodetic and Cartographic Institute Bratislava – GKU Bratislava, © Topographic Institute – TOPU Banská Bystrica and © National Forest Centre – NLC Zvolen).

Non-forest woody vegetation (NFWV) was assessed through comprehensive field surveying (2015) according to the following criteria: origin (natural, cultural, mixed), spatial formation (line, group, area), and functional type (road and water body accompanying, windbreak, grove, etc.). Woody species composition in NFWV was assessed according to the growth categories (tree, shrub, climbing), as well as the share of occurrence and abundance of the tree and shrubby layers separately (Supuka et al. 2013).

Woody species proportion according to origin was assessed in NFWV elements by modified index of synantropisation (Jurko 1990; Supuka et al. 2013) in the equation form:

$$IS = \frac{N_a}{N_n} \quad [1]$$

Where: *Na* – number of alien woody species; *Nn* – number of native species.

Indexes were calculated for NFWV assessed in 1967 and 2015. The aim of this approach was to compare woody species changes and windbreak composition during a period of 60 years after they had been established.
From the terminology point of view, we should explain the differences in woody spatial formations. Windbreaks represent line form woody formations planted on lowlands with anti-wind erosion effect and climate mitigation. The term notion is used mainly in western literature sources, e.g. USA, UK, France (Insley 1988; Soltner 1991). Forest protection belts mean windbreaks and protective infiltration woody belts on slopes. Their main effect is wind and water anti-erosion. Notion is used mainly in forestry literature including Russian sources (Gemerský 1961; Varga et al. 1991; Tutka 2010). Non-forest woody vegetation (NFWV) includes all spatial woody formations in agriculture landscape, meaning linear forms (windbreaks, infiltration belts, accompanying belts along water streams and roads, tree alleys), area forms (small forests, groves, game refuges), and group and solitaire trees in rural landscape (Supuka et al. 2013; Demková & Lipský 2017).

3. Results

3.1. Assessment of the landscape structure development and changes at the Žitný Ostrov territory

The plantings of the first windbreaks on the Žitný Ostrov territory in the south-western Slovakia was closely connected to socio-economic changes after the World War II. Changes in the agricultural landscape can be seen in size, proportion, and distribution of landscape elements in the territorial space. They were influenced by the economic development, production and processing technologies, demography, and human settlement development. The expressive change seen in the agricultural landscape in Slovakia in the second half of the 20th century was also influenced by the process of technological intensification and land ownership. An interesting experiment in 1949 was the establishment of a rice field on 24.77 ha in the rated landscape segments (see Fig. 3 and Table 1). The establishment of large cooperative farms in the lowlands started prior to 1949–1950, mainly in the lowlands Podunajská, Východoslovenská and Záhorská. These changes can be observed in the lack of small size mosaic plot structure, in alternation by large cultural blocks, the removal of many natural valuable biotopes, drainage of some wetlands, and the removal of terraced balks, banks and line borders between plots. In many cases, permanent grasslands and spatial elements of non-forest woody vegetation have decreased as well. Moreover, new water canals and damps were built. These landmark changes are reflected as new features in the compositional aesthetic characteristics and dimensions of the study areas. The landscape ecological stability has decreased, as have culture-historical values and natural biodiversity. However, there was an increase in the cultural diversity of plant and animal varieties. The potential threat of water and wind erosion was increased. The landscape structure changes are generally seen in aerial photos of the country segment between 1949 and 1969 on the Žitný Ostrov territory (Fig. 1). Particular landscape structure changes and development within rated periods of 1892, 1949, 1969, and 2015 are presented on the attached maps (Fig. 2 – 5); the area share of landscape elements is given in Table 1.

The map and table show that in 1892, arable land was dominant, with more than 63% as the element of the cultural landscape and terra ferma. The second position belongs to natural elements of grasslands and waterlogged meadows used mostly as pastures. In total, these areas covered 29% of the assessed territory. These landscape elements should be considered as natural or near natural with high ecology and biodiversity benefits. The assessed lowlands were only 3.46% share of forest. This area had mostly alluvial character and involved predominating willow and poplar woody species. Colonization was quite low in the built-up areas at 1.42 ha, only because the landscape segment represented open rural country. The situation changed in 1949, when there was a rapid reduction in the share of grasslands and waterlogged meadows used as pastures, only 4.85%. There was an increase in the share of built-up areas and gardens. Water lines increased due to the wetland drainage and construction of the canals. An interesting experiment in 1949 was the establishment of a rice field on 24.77 ha in the rated landscape segments. When the countryside in 1949 and 1969 was compared, the landscape structure changed from small plot mosaics to larger cultural blocks of mainly arable land. The share of NFWV increased noticeably due to new plantings of windbreaks from 1951–1952 (Fig. 2, 3, 4; Table 1). The lands status between the period of 1969 and 2015 should be considered as relatively balanced in arable land, grassland and forest cover. The share of NFWV representing predominantly windbreaks has significantly increased and reached 6.56% in the rated landscape segment (Fig. 4, 5).

3.2. Assessment of the first windbreaks plantings at the Žitný Ostrov territory

As described in the previous chapter, in order to eliminate and mitigate negative features and processes in the landscape, new windbreaks or protective forest belts were established as a part of the non-forest woody vegetation (NFWV). According to the examples of the United States, Canada, Russia, Ukraine, China, France and other countries, the master plan for windbreaks establishment on the Žitný Ostrov territory in south-western part of Slovakia was elaborated. This area was

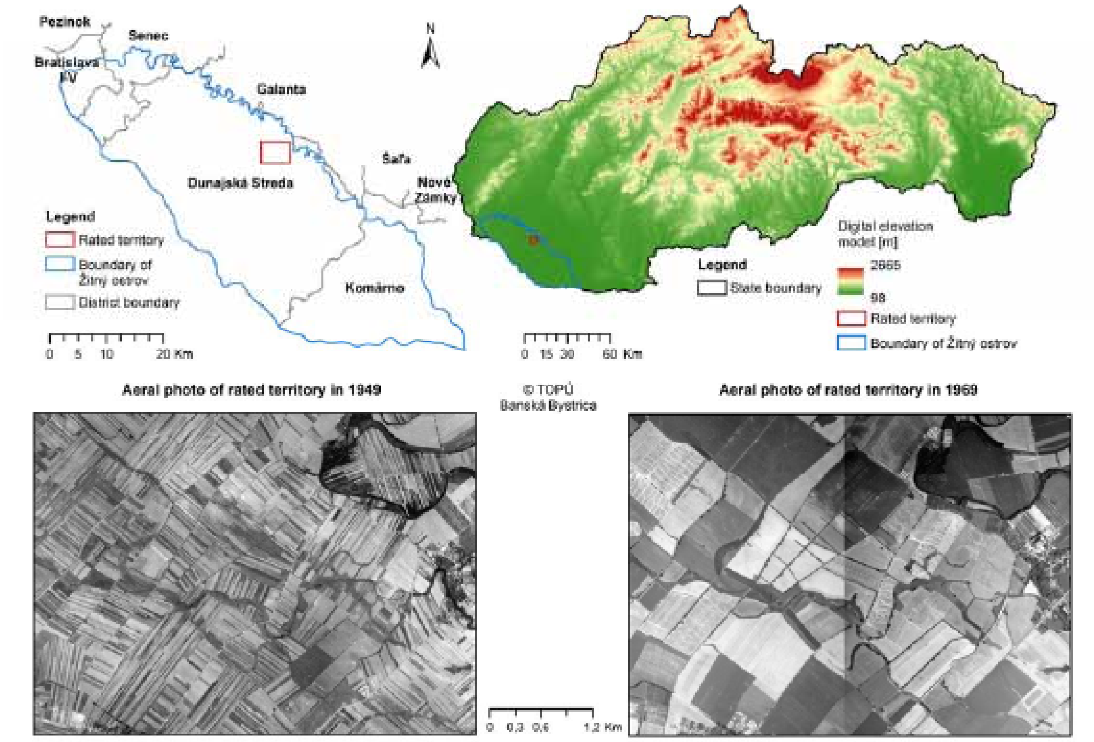

Fig. 1. Landscape structure changes at assessed landscape segment of the Žitný Ostrov territory between 1949 and 1969 time horizons. (Elaborated: Šinka 2017).

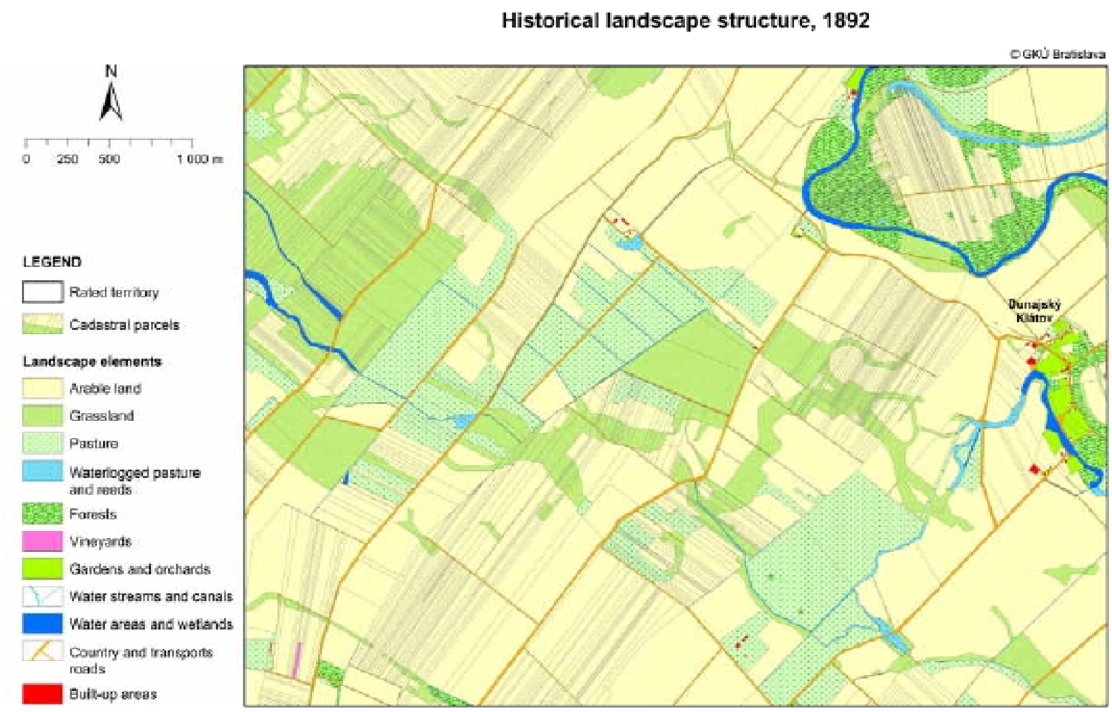

Fig. 2. Landscape structure of the assessed country segment and share of identified landscape elements in 1892. (Elaborated: Šinka 2017).

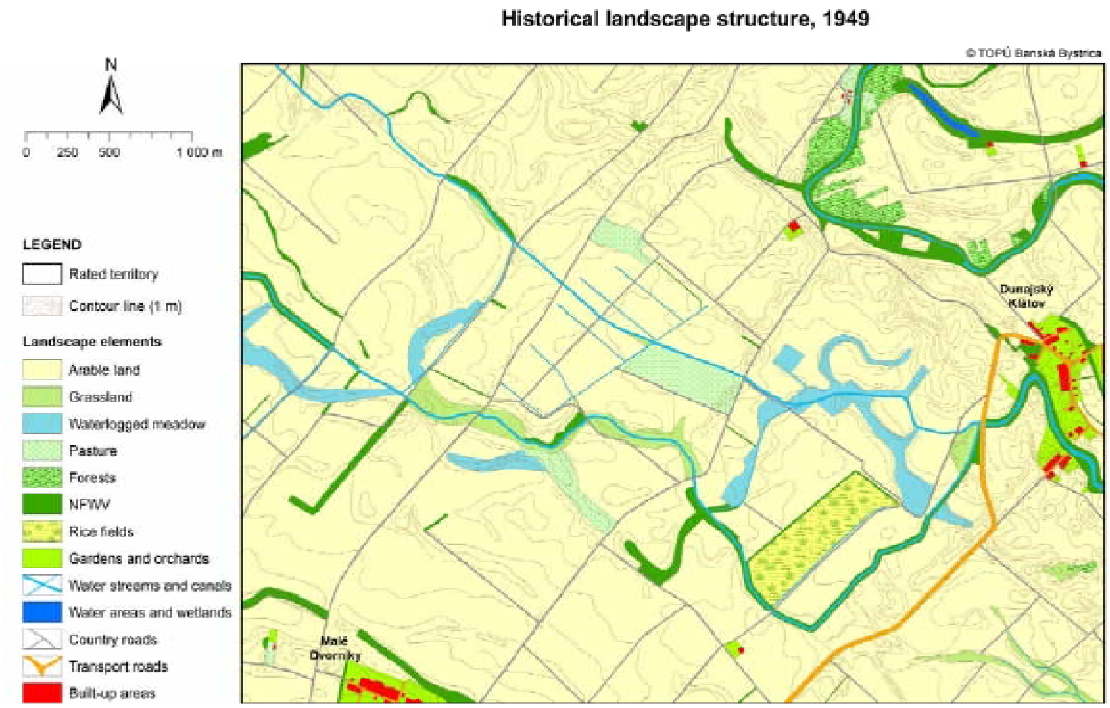

Fig. 3. Landscape structure of rated country segment and share of identified landscape elements in 1949. (Elaborated: Šinka 2017).

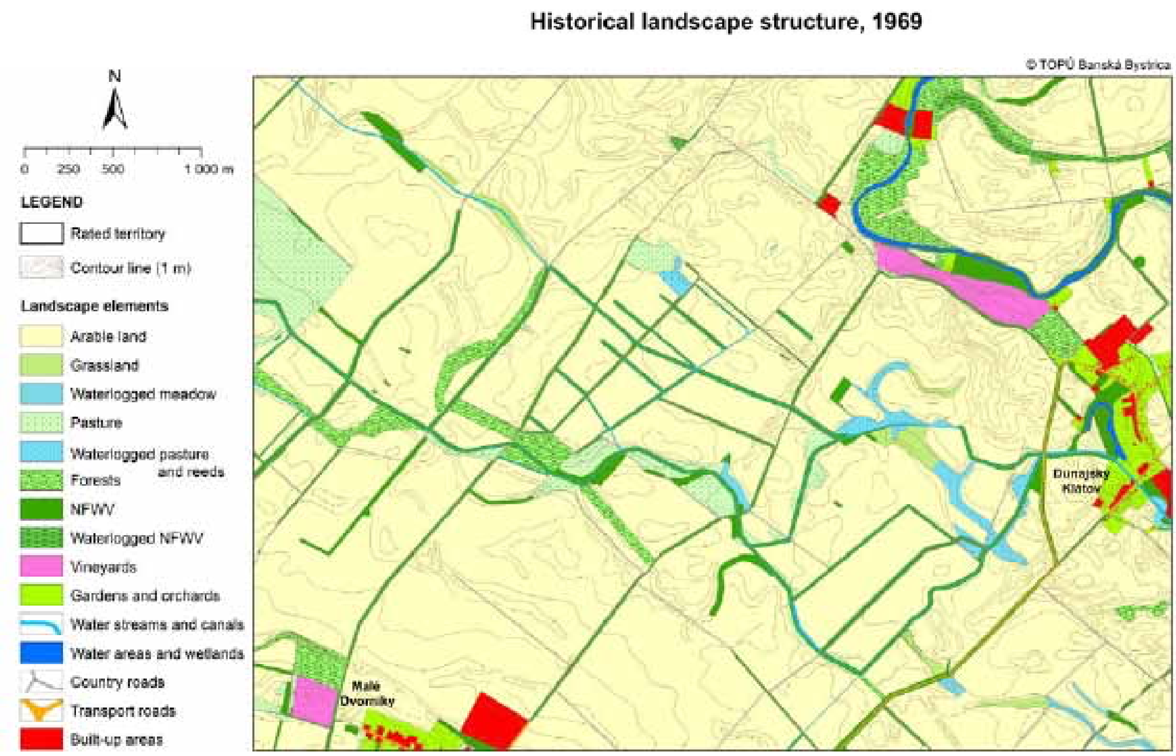

Fig. 4. Landscape structure of rated country segment and share of identified landscape elements in 1969. (Elaborated: Šinka 2017).

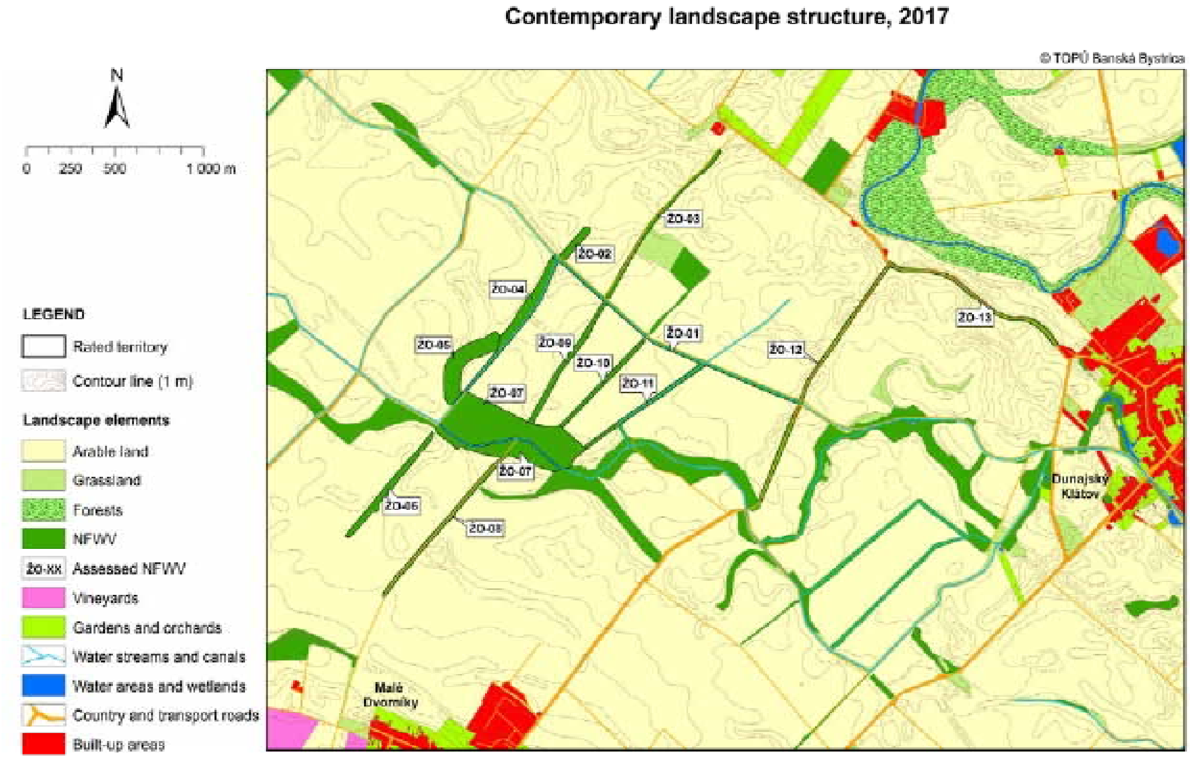

Fig. 5. Landscape structure of rated country segment and share of identified landscape elements in 2015. (Elaborated: Šinka 2017).

Table 1. Historical and contemporary landscape structure in assessed cadastral territories of the Žitný Ostrov territory at south western Slovakia.

Landscape elements	Area [ha] by years				Contribution [%] by years			
	1892	1949	1969	2015	1892	1949	1969	2015
Arable land	1244.72	1622.39	1583.35	1586.40	63.25	82.44	80.45	80.61
Grassland	306.25	29.14	11.43	58.34	15.56	1.48	0.58	2.96
Waterlogged meadow	—	46.55	3.21	—	—	2.37	0.16	—
Pasture	254.41	30.73	60.25	—	12.93	1.56	3.06	—
Waterlogged pasture and reeds	13.59	—	17.77	—	0.69	—	0.90	—
Forests	68.05	22.71	63.26	50.86	3.46	1.15	3.21	2.58
NFWV	—	79.61	99.72	129.06	—	4.05	5.07	6.56
Waterlogged NFWV	—	—	6.90	—	—	—	0.35	—
Vineyards	0.39	24.77 RF	18.79	6.34	0.02	1.26	0.95	0.32
Gardens and orchards	11.32	24.25	33.32	31.40	0.58	1.23	1.69	1.60
Water streams and canals	7.15	28.63	14.51	7.52	0.36	1.45	0.74	0.38
Water areas and wetlands	4.38	2.10	9.11	10.23	0.88	0.11	0.46	0.52
Country roads	43.41	38.09	17.86	32.81	2.21	1.94	0.91	1.67
Transport roads		11.89	5.29			0.60	0.27	
Built- up areas	1.42	7.15	23.26	55.08	0.07	0.36	1.18	2.80
Sum	1968.03	1968.03	1968.03	1968.03	100.00	100.00	100.00	100.00

Explanation: — landscape element has not been identified, RF – rice field (see Fig. 3).

planted between 1951 and 1952 as the first territory. We have acquired the original results and conclusions that were later published in 1961 (Gemerský 1961). These results provided basic documentation for the succeeding research of chosen windbreaks from the viewpoint of woody species and spatial composition. The spacing of 60 established windbreaks on the Žitný Ostrov territory are shown on a copy of the original map (Fig. 6) and the planting scheme (Fig. 7) of the applied woody species (origin elaborated by Gemerský 1961). For windbreaks establishment 13,155 pieces of forest plant stocks were used, obtained from three arboriculture nurseries. From the nursery in Banská Štiavnica, 4,185 pieces of woody plants were acquired, in the following species composition: *Acer platanoides* L., *A. pseudoplatanus* L., *A. rubrum* L., *A. tataricum* L., *Fraxinus americana* L., *F. excelsior* L., *F. pubescens* Lam. (*F. pennsylvanica* Marsh.), *Ailanthus glandulosa* Desf., *Malus eleyi* Hesse (*M. domestica* Borkh. ´Eleyi´), *Carya ovata* K. Koch, *Chaenomeles lagenaria* Koidz., *Gleditsia triacanthos* L., *Chamaecyparis lawsoniana* Parl., *Picea pungens* Engelm., *Pinus nigra* Arnold., *Maackia amurensis* Rupr., *Phellodendron amurense* Rupr. From the nursery in Gabčíkovo, 3,390 pieces in the following woody species were imported: *Popolus x euroa-*

mericana (Dode) Guinier (*P. x canadensis* Moench), cv. *Robusta, Marilandica, Serotina, P. deltoides* Marsch, *P. alba* L., *Tilia platyphyllos* Scop. From Dobor (Baka) nursery, 5,580 pieces of the following woody species were acquired: *Acer negundo* L., *Quercus robur* L., *Juglans nigra* L., *Aesculus hippocastanum* L., *Alnus incana* (L.) Moench, *Ulmus campestris* L., *Prunus mahaleb* L., *P. spinosa* L., *Salix alba* L., *S. fragilis* L., *S. viminalis* L., *S. caprea* L., *Myricaria germanica* Desv. (*Tamarix germanica* L.), *Morus alba* L., *M. nigra* L. Together from the three arboriculture nurseries, 13,155 pieces in 37 woody plant species were acquired and planted, from which 22 were alien species.

According to the original master plan, the plantings of woody species were applied in different compositions (Fig. 7), the windbreaks consisted of 5 – 7 rows with a width span of 5 – 12 m and from 100 to 1 000 m in length. Row spacing was 1.3 m on average and between woody plants in each row, there was a 1 and 2 m space. Considering the average exposure dates under author coordination that were planted in the assessed territory, there were almost 30 ha of windbreaks in total length of 30 km during 1951 and 1952. It was a small but very useful contribution for the windbreaks establishment in Slovakia, compared to the total area of planted windbreaks during the period of 1950–1964 in Bratislava region, which achieved a total of 342.22 ha, as stated by Gemerský (1961).

As presented in the published contribution, the plantations were experimental investigations of practice character. Therefore, different combinations of woody species were chosen in the composition and planted in the rows of windbreaks (Fig. 7). Middle rows consisted of poplars (*Populus sp.*) as pioneer trees, following by the objective skeleton tree species, such as native trees of the genus *Acer, Quercus, Tilia*. The marginal rows were planted by using coniferous and alien deciduous trees. Later, ecotone shrubby woody species were also planted. Very high number of alien woody plants was identified, representing 22 species from the total 37 species used for the windbreaks.

The most attractive and rare specimen planted was *Maackia amurensis,* cultivated in arboriculture nursery Banská Štiavnica, while seeds were collected from maternal trees of the Arboretum Kysihýbel. That was how this specimen was probably introduced to the open agriculture landscape in Slovakia for the first time.

3.3. Assessment of the woody species composition on chosen windbreaks in 1976

In 1976, the research of woody species composition and distribution on the Žitný Ostrov territory was conducted prior to the construction of the Danube water dump. A list of investigated woody species in the windbreaks of defined territory is shown in the Table 2 (surveyed and documented by Supuka; in Benčať et al. 1984). From the

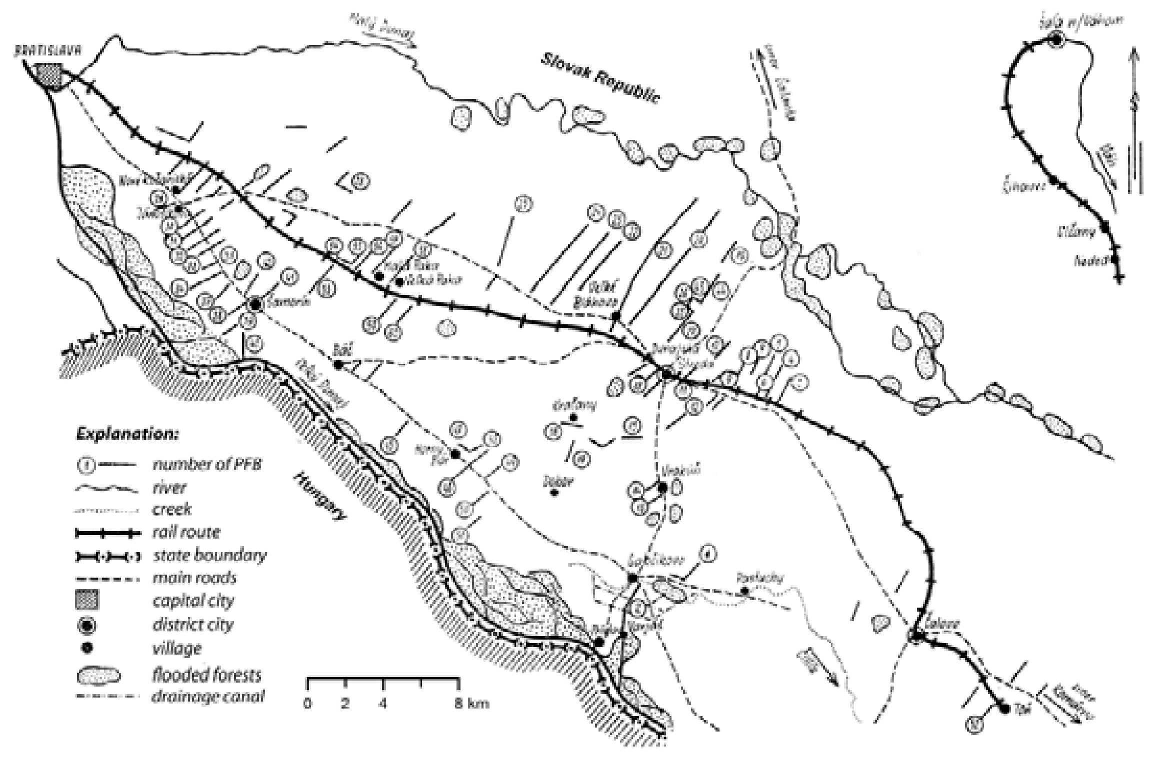

Fig. 6. Distribution of 60 planned protective forest belts (PFB) at the Žitný Ostrov territory, South- Western part of Slovakia. Original scheme has drawn by Gemerský (1961). (Adjusted by Šinka & Supuka 2016).

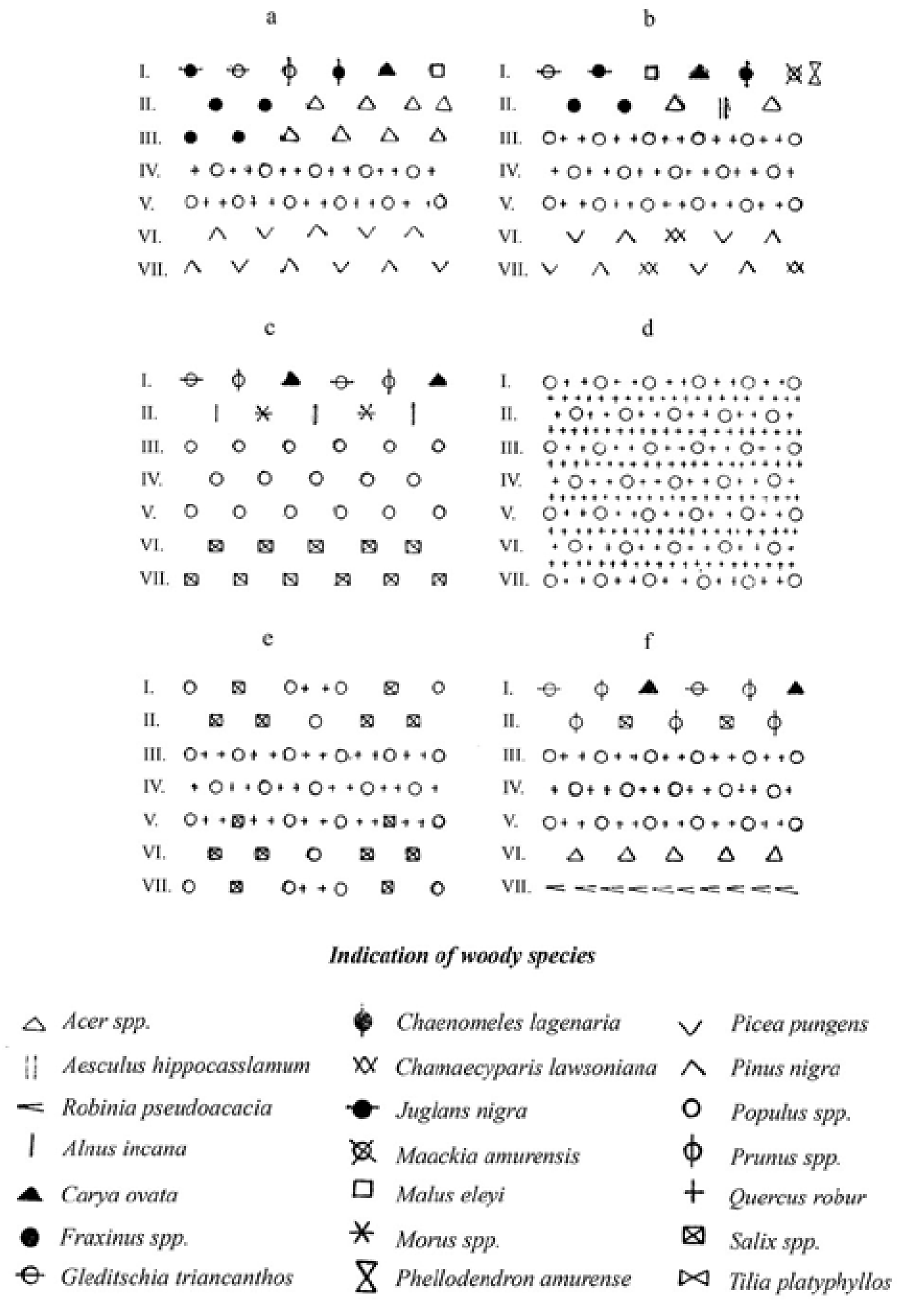

Fig. 7. Distribution of woody plant species in planting model plots (a–b) and rows (I.–VII.) in the protective forest belts (PFB). Original scheme has been drawn by Gemerský (1961) (Adjusted by Šinka and Supuka 2016).

total number of 19 assessed windbreaks, 12 of them were identified as identical to windbreaks founded in 1951-1952 (No. 23, 25, 26, 28, 29, 30, 31, 32, 33, 34; in Fig. 6). Concerning spatial characteristics, the windbreaks have reached 5, 10, 15 and 20 m in width and an average of 7 to 15 m in height during the past 25 years. Among the 28 inventoried woody species, 12 of them were alien. Windbreaks have achieved different density depending on the applied woody species and the number of planted rows or width of forest belt. They had 70 – 90% tree crown canopy or stand density. In wider windbreaks (15 – 20 m in width), auto-regeneration processes were identified when a new woody species generation appeared because of natural successive processes, disseminated by wind or animal vectors.

There were certain differences between the woody species composition in the assessed periods. In 1976, neither coniferous nor deciduous woody species such as *Carya ovata, Chaenomeles lagenaria, Maackia amurensis, Phellodendron amurense, Myricaria germanica* were found. The reason might lie in the allocation of the above mentioned woody species to other than inspected and inventoried windbreaks. The plants died due to drought, water flooding, game nibbling or mechanical damages. There was a high probability that when surveying the windbreaks in 1976, there were incorrect woody species identified, e.g. poplar hybrids, North American ashes, and rare *Maackia amurensis* and *Phelodendron amurense*. In the case of *Maackia amurensis,* there was probably an identification mistake and the trees were inventoried as *Caragana arborescens* in 1976 (see Table 2). When a direct comparison of the woody species composition between the time horizons of 1952 and 1976 was made, the investigated windbreaks were very problematic. Original planting projects from 1951–1952 were inaccessible or could not be found. The projects were probably not elaborated for each windbreak separately and planting was provided per a published variable model scheme (Fig. 7).

The state of woody species composition on the Žitný Ostrov territory windbreaks looked very rich in 1976. On the one hand, it creates a variable and rare woody species gene pool; on the other hand, it is an important food source and spatial habitat for supporting animal biodiversity. However, many alien woody species are currently considered as very invasive.

Table 2. Woody species composition in chosen windbreaks at Žitný Ostrov territory in 1976.

Tree species layer	Register number of assessed windbreak																			
	23	25	26	27	28	29	30	31	32	33	34	35	91	92	93	94	95	95a	96	
Acer campestre L.		+	+																	2
Acer platanoides L			+		+	+	+				+								+	6
Ailanthus altissima (Mill.) Swingle		+											+	+	+					4
Caragana arborescens Lam.				+												+				2
Crataegus laevigata (Poir) DC			+				+	+	+	+		+			+		+			8
Euonymus europapeus L.		+	+		+	+		+							+				+	7
Fraxinus excelsior L.		+	+			+					+	+	+			+				7
Gleditsia triacanthos L.			+																	1
Juglans nigra L.												+				+				2
Juglans regia L.													+	+						2
Lonicera tatarica L.																+			+	2
Ligustrum vulgare L.			+			+					+					+			+	5
Morus alba L.							+	+												2
Negundo aceroides Moench.	+	+	+		+		+	+			+	+	+	+	+	+			+	13
Populus alba L																		+		1
Populus x *canadensis* Moench.	+			+			+	+	+	+	+	+		+	+		+			11
Quercus robur L.					+											+			+	3
Rhamnus catharticus L.															+	+				2
Robinia pseudoacacia L.	+	+	+		+	+	+	+	+	+						+		+	+	12
Rosa canina L.	+	+	+	+	+		+	+		+	+		+		+	+	+	+	+	15
Rubus fruiticosus L.			+						+				+							3
Salix alba L.																		+		1
Sambucus nigra L.	+	+		+	+	+		+	+	+	+		+	+	+		+			13
Sophora japonica					+															1
Swida sanguinea (L.) Opiz.	+	+	+													+		+	+	6
Syringa vulgaris L.		+	+													+			+	4
Ulmus carpinifolia Gled. Non Borkh.	+	+	+		+	+	+						+			+				8
Viburnum opulus L.		+																	+	2
Species biodiversity in windbreaks	7	12	14	4	9	7	8	8	5	5	6	6	8	5	8	13	4	5	12	

Explanation: + occured woody species in relevant windbreak.

3.4. Assessment of woody species composition on chosen windbreaks in 2015

In 2015 we focused our research on the development of the landscape structure changes through four time horizons with regards to the share of NFWV on chosen landscape segments. Those results are described in the previous chapter. The distribution of surveyed woody vegetation formations is shown in Fig. 5. There is a real correspondence between surveyed windbreaks in 1967 and 2015, specifically in the windbreaks No. 26, 27, 35 (in 1976) and ŽO-3, ŽO-9 (in 2015). The frequency of appearance of woody species in surveyed windbreaks from ŽO-1 till ŽO-13 is given in Table 3. Overall, there were 27 deciduous woody species identified in the tree layer and 12 species in the shrubby layer. Nine of them (9) were alien tree species. Four alochtonous species should be considered with high potential in invasive growth manifestation, as are *Ailanthus altissima* (Mill.) Swingle, *Fraxinus americana* L., *Negundo aceroides* Moench., *Robinia pseudoacacia* L. The above noted species are remnants from the first plantings, since they were found in the list of species planted in 1951–1952 and were also surveyed in 1976. All the mentioned trees have high auto-regeneration abilities at stands because of their invasive manifestation. A high percentage of the trees were identified as other alien trees, *Populus x canadensis* (Aiton) Smith and *Populus nigra* L.´Italica´. Both species belong to traditional tree species applied in windbreaks on rated landscape segment of south-western Slovakia and have survived up to the present. Unfortunately, these alien tree species are dominant in the windbreaks. From native trees, *Populus nigra* L., *Fraxinus excelsior* L. and *Salix fragilis* L are dominant. Concerning shrubby layer, all the inventoried species are of native origin. The characteristics of the woody species in surveyed windbreaks are presented in Table 3 per tree and shrubby layers and percentage of abundance. In some windbreaks, a minimum of 9 woody species and a maximum of 18 species were identified (found in ŽO-4). As a part of the field research, we focused our attention on the inventory of oversized and old trees rather than native trees as gene pool resources. The species surveyed were e.g. *Populus alba* L. ($d_{1.3}$=73 cm, tree height=30 m, crown width=25 m), *Salix fragilis* L. (140 cm/32 m/28 m), *Populus nigra* L. (91 cm/35 m/30 m), *Quercus robur* L. (92 cm/33 m/16 m). The estimated age of trees is about 150 years old.

3.5. Assessment of the woody species synantropisation in NFWV surveyed in 1976 and 2015

According to the method stated in chapter 2, the index synantropisation was calculated for each windbreak surveyed in 1976 and 2015. Calculated values theoretically reached within span of 0.0 – 1.0. Afterwards, three score groups in synantropisation level were stated: a) low level ≤ 0.25; moderate level – 0.26-0.49; high level ≥ 0.50. On assessed of 19 NFWV in 1976 (Table 2) the distribution according to achieved synantropisation indexes is follow: low level – 4 NFWV (windbreaks No. 95, 95a), moderate – 12 NFWV (No. 23, 25, 26, 28, 29, 32, 33, 34, 91, 93, 94, 96), high level – 5 NFWV (No.27, 30, 31, 35, 92). In 2015 the synantropisation indexes on assessed 13 NFWV (Table 3) were as follow: low level – 8 NFWV (windbreaks and other line forms, No. 1, 2, 4, 5, 6, 10, 11, 12), moderate level – 5 NFWV (No. 3, 7, 8, 9, 13), high level – 0 NFWV. While surveying the NFWV in 2015 more specific mapping method was used, taking into account cover abundance in reléves. In spite of lower indexes, the results show high cover and dominance of many alien trees in NFWV, such as *Populus x canadensis, Robinia pseudoacacia, Prunus cerasifera, Negundo aceroides*. Less share has *Ailanthus altissima*, but in high invasive growth manifestation. These alien trees determinate landscape character in many cases. In many cases, we could observe occurrence of the fruit trees, e.g. *Juglans regia, Malus domestica, Pyrus communis, Morus alba,* which also support biodiversity.

Table 3. Woody species composition in chosen windbreaks at Žitný Ostrov territory in 2015.

Tree species layer	Occurrence of woody species in % according to set number of NFWV												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Acer campestre L.				15									
Acer platanoides L				5									
Acer pseudoplatanus L	5			5		20							
Acer pseudoplatanus L. ´Atropurpureum´	10												
Ailanthus altissima (Mill.) Swingle													30
Celtis occidentalis L.							+						
Cerasus avium (L.) Moench	5												
Fraxinus americana L.								5					
Fraxinus angustifolia Vahl.				55							15		
Fraxinus excelsior L.				+	5		10	10			10	10	10
Juglans regia L.							5	10	5		5	30	20
Malus domestica Borkh.	+												
Negundo aceroides Moench.						40							
Populus alba L.	5			+			5		10	35	10		
Populus x canadensis Moench.	55		30	10	85	10	60	10	20				
Populus x canescens (Aiton) Smith.	10								5		10		
Populus nigra L.	+		10	+		10		35	20	25	15		
Populus nigra L. ´Italica´									+		5		
Prunus cerasifera Ehrh.	+	5	20		5				10	+	15	10	
Prunus padus L.							10			20	5		
Pyrus communis L.												+	
Quercus robur L.						+					+		
Robinia pseudoacacia L.	5	90	10	5	+	10		10	10			40	40
Salix alba L.									10				
Salix caprea L.	5			5									
Salix cinerea L.	5			+									
Salix fragilis L.	5		30		5	10	10	20	10	20	10	10	
Shrubby species layer	1	2	3	4	5	6	7	8	9	10	11	12	13
Crataegus laevigata (Poir.) DC	55	5	20	20	20	15		15	10			40	30
Euonymus europaeus L.		5			5	10		5	10			5	
Frangula alnus Mill.	5		10	20	15	10	15	10			5		
Ligustrum vulgare L.	5							5			+		
Prunus insititia Juls.	+	5		+					+	10	+		
Prunus spinosa L.	5		20	10	10		30					10	30
Rhamnus catharticus L.	5	5	20	10	10	10		10		10	10		
Rosa canina L.	5	5	20			15			10	5	5	+	10
Salix viminalis L.	+												
Sambucus nigra L.	+	70	10	20	20	40	35	15	20	10	5	10	30
Swida sanguinea (L.) Qpiz.	10	10		20	20		20	30	50	65	70	35	
Viburnum opulus L.	5							10			5		

Explanation: 20-percentage of the occurrence, + less than 5% occurrence.

4. Discussion

Agricultural and forest landscapes show distinct footprints of development and alternative structural changes, as was assessed in ten countries of the Carpathian region in the Eastern and Central Europe, including Slovakia, over the past 250 years (Munteanu et al. 2014). There are several published sources in the Eastern Europe countries, such as Slovakia and Czech Republic that have documented expressive landscape changes caused by consolidation and intensification of agriculture (Salašová 2001; Supuka et al. 2008; Lipský et al. 2011; Štefunková et al. 2011 and others). Although this socio-economic process does not apply for example to western European countries, their landscape structure changes are distinct due to mainly industrialization and intensification of agriculture technologies at the advanced farms, e.g. in France, Germany, England, but also in the United States and Canada (Insley 1988; Soltner 1991). In these countries, arable land share has increased and permanent grasslands decreased, which is similar to our region. In order to obtain new agriculture land, deforestation reached its maximum in the 19th century. In many localities, this trend has been continuing until the present day, e.g. in the Amazonian rain forest. Removal of natural ecosystems and valuable habitats, adjustment of natural water streams, and arrangement of new water irrigation nets were already known in Egypt, China and Middle East historical territories. The level of scientific knowledge in natural sciences was reflected in the establishment of windbreaks at the beginning of 20th century, firstly in the Western and later in Eastern countries (the United States, Canada, France, Russia, China, and former Czechoslovakia). Those were expressive and positive contributions for strengthening the land protection, ecological stability and landscape architectural values; in new scientific terms defined as ecosystem services (Reyers et al. 2009; Lampartová et al. 2015).

At the time of spontaneous establishment of new anthropogenic woody line vegetation, a number of alien species were planted. Many of those showed high adaptability level, auto-reproduction and domestication manifestation currently called invasive with negative destruction effects to natural biodiversity. To this category belong e.g. *Robinia pseudoacacia* L., *Ailanthus altissima* (Mill.) Swingle and *Negundo aceroides* Moench, very often surveyed in studied windbreaks of Slovakia and in other European countries (Soltner 1991; Supuka et al. 2013 and others). Elimination of the alien invasive plants is currently very problematic both technically and biologically. On the one hand, old and oversized native trees and cultural fruit species create a considerable cultural gene pool (Paganová & Bakay 2010; Supuka & Pucherová 2013; Verešová & Supuka 2013). On the other hand, in scattered woody vegetation a number of plant taxonomy issues or identification of species has occurred. Varieties of the genus *Prunus* are very often part of NFWV elements in agriculture landscape (Baranec et al. 2011). In historical agriculture landscape structure on upland of Slovakia, mostly shrubby species between plots on the borders and terraces were surveyed (Špulerová et al. 2017).

In many cases, the line form of NFWV is pruned and shaped as hedges especially in Western countries, e.g. in Austria (Kurz et al. 2011), France or England (Soltner 1991). These formations create uniform landscape networks with low visual value and a low potential for use as a wild life habitat. Low shares of line form NFWV and natural habitats in agriculture landscape are considered as a negative factor (Salašová 2001; Supuka et al. 2013; Demková & Lipský 2017). Contemporary share of NFWV is generally low, reaching 3 – 10% on average (Insley 1988; Pucherová 2004; Supuka et al. 2013; Kuczman 2014). There are attempts to establish an EU Foundation for new elements within the framework of European Agriculture Policy (EAP) in order to increase the share to 8 – 12%.

5. Conclusions

The land cover changes on Žitný Ostrov territory were assessed within the rated periods of 1892, 1949, 1969, and 2015. The landscape elements, pasture, grassland, waterlogged meadows and wetlands were found at a rapid decrease in area share from 29% land cover in 1892 to 2.96% in 2015. This caused a decrease in ecological stability and biodiversity. In the same period, arable land has increased by 17% and built-up areas by 2.7%. Amelioration of natural water areas and wetlands was also caused by the construction of water drainage canals used for irrigation system. Small mosaic plots were altered as large cultural plots increased between 1949 and 1969.

The investigation of NFWV started by examining the original planting schemes and the list of applied woody species in the new established windbreaks from period of 1951–1952. Unfortunately, planting projects for protective forest belts were not found. More than 13 thousand pieces in 37 woody species, including 22 alien species, were received and planted from three arboriculture nurseries. In the assessed territory, almost 30 ha of windbreaks in total length 30 km were established. Many applied alien woody species were attractive in that time, e.g. *Maackia amurensis, Phellodendron amurence, Morus alba Gleditsia triacanthos,* or from the group of coniferous, e.g. *Chamaecyparis lawsoniana*, *Picea pungens*, *Pinus nigra*. In 1967, from total number of 19 assessed windbreaks, 12 were identified as identical to windbreaks planted in 1951-1952. Currently, 28 woody species were identified, including 12 alien ones. Therefore, there are less woody species today than in 1952. In 2015 the research focused on the development of landscape structure changes through four time horizons with regards to the share of NFWV in the chosen landscape segment. Thirteen windbreaks were surveyed, while real coincidences between 1967 and 2015 were at three windbreaks No. 26, 27, 35 (in 1976) and ŽO-3, ŽO-9 (in 2015). At all windbreaks, 27 deciduous woody species in tree layers were identified, including 9 alien species. Four alochtonous species should be considered with high potential in invasive growth manifestation as are *Ailanthus altissima*, *Fraxinus americana*, *Negundo aceroides*, and *Robinia pseudoacacia*. These woody species are mostly remnants from the first plantings, because they were found in the list planted in 1951–1952 and were surveyed in 1976 and again in 2015. There were many oversized and old native trees surveyed, representing rare gene pool resources.

The assessed windbreaks at Žitný Ostrov territory need woody species and spatial reconstruction. Due to their density, thinning of the trees is necessary in order to enable crown size growth and stability. It is recommended to remove dead and strongly damaged trees and leave some native trees with cavities for supporting bird and insect diversity. Gradually, the above mentioned invasive tree species should be removed and replaced by native species of the genus *Acer, Carpinus, Cerasus, Fraxinus, Padus, Populus, Pyrus, Quercus, Salix, Tilia* and *Ulmus*. Large gaps in windbreaks should be planted by a new tree species, in ecotones by native shrubs.

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ORIGINAL PAPER

Weight parameters of body parts in sika deer (*Cervus nippon nippon*) from the Konstantinolázeňsko microregion, the Czech Republic

Vladimír Hanzal[1, 2], Klára Košinová[1*], Radek Pokorný[2], Pawel Janiszewski[3], Vlastimil Hart[1]

[1]*Czech University of Life Sciences, Faculty of Forestry and Wood Sciences, CZ–165 21 Praha 6, Czech Republic*
[2]*University of South Bohemia in České Budějovice, Faculty of Agriculture, Studentská 1668, CZ–370 05 České Budějovice, Czech Republic*
[3]*University of Warmia and Mazury in Olsztyn, Faculty of Animal Bioengineering, ul. M. Oczapowskiego 5/366, 10-719 Olsztyn, Poland*

Abstract

Sika deer is widely spread species, in Czech Republic mostly occurred in West Bohemia. This species is defined as one of the most harmful ungulate game in the forests. For the wildlife population of sika deer in the microregion Konstantinolázeňsko in West Bohemia, total weight after the hunt, weight after expelling organs, weight of the head and distal parts of the limbs, and weight of the internal organs (heart, lung, liver, spleen, kidney) were determined. Correlations between the weights of specific body parts (organs) were evaluated. Ratio between the weight after expelling organs (after gralloch) and the weight after hunt (total weight) was determined. The weight after expelling organs was 74% of the total weight. Moreover, a positive correlation was found between the age and weight of individuals, and between the male age and the weight of the head. Without taking into account age differences, we show that males have a higher body weight than females, a form of sexual dimorphism.

Key words: sika deer; venision; dressed body weight; organs weight; gralloch, trophy

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1. Introduction

In recent years, game damage in the Pilsen and Karlovy Vary regions has reached the highest values in the whole Czech Republic. In 2004 the Karlovy Vary region with more than CZK 9 million of damage, the Pilsen region was the third among the regions 2002 with CZK 7.4 million. The highest damage was found in dominant tree species, i.e. in spruce and pine, damage to other trees is negligible in absolute numbers. In the sum of all the trees, the most frequent damage was the reduction of the growth by bark peeling and browseing. High damage to very young spruce stands is probably due to their relatively high surface area, very low yields of honeysuckles and high deer stays. Deers are simply forced to implement their food needs virtually wherever possible (Dvořák & Čermák 2008).

Game hunting is used as a management technique, for example to control population size and improve population health and quality. It may represent an effective tool for prevention to game damage to forest stands and helps to harmonize interests of both hunting and forestry communities (Konôpka et al. 2015). At the same time, game meat is gaining popularity for human consumption. Game has historically made a certain share of consumed meat for human being. In recent years, some recovery in game meat consumption has been observed. All edible parts of wild game, not only muscle, but also edible intestines, fat, bones and meat products, are considered to be venison. If we process commonly used parts such as intestines, stomachs, pre-jaws, etc. for further consumption, they will also be considered as game (Adámková & Štochová 2011; Saláková 2014; Winkelmayer 2005).

Sika deer is directly associated with increasing population and can be linked to damaged forest habitat. Sika deer are also a highly adaptable species, which are often hunted for their meat and taken as trophies. The population is increasing, that means also increasing hunting of this species. Sika deer have been documented in the Czech Republic since 1891, when it was brought into Kluk deer-park by Poděbrady (Kokeš 1970; Rakušan 1988).

Introduction of this species into a non-native habitat may change its weight parameters as a part of adaptation to novel environments, such as the type of home range

Corresponding author. Klára Košinová, e-mail: kosinovak@fld.czu.cz

resource availability (e.g. food). Dressed-whole body weight relationships should be site- and season-specific to obtain unbiased estimates of whole body weight because of season, geographic variation in morphology, and nutritional state (Jones et al. 2008). For example, roe deer (*Capreolus capreolus*) in Western Poland shows higher carcass weight in the areas dominated by ploughland compared to areas dominated by forest (Janiszewski et al. 2011).

There are few different studies about sika deer weight in regions across the Czech Republic. In the Bouzovsko region, in the former breeding area of sika deer, the average weight of fawns is 15.3 kg, the average weight of the doe is 26.4 kg, the deer under 4 years weighs on average 39.1 kg, and the average weight of adult deer is 42.7 kg (Babička et al. 1977). Other sources show, that the male fawns weighed 15.1 kg and the female fawns were 13.6 kg. Doe aged 1.5 years weigh 20.9 kg, at the age of 2 – 4 years weighed 23.8 kg, and deer >4 years weighed 26.4 kg. The average weight of spikes was 28.1 kg, deer older than two years weighed 35.2 kg, three years 39.7 kg, four years 42.3 kg, deer under 8 years 45.1 kg, and deer older than 8 years weighed 50.7 kg (Husák 1986). The weight of the newly born fawn was in the range of 4.7 – 7 kg and after half a year they ranged from 25 – 35 kg. The weight of the gralloched deer is about 40 – 60 kg (Jiřík et al. 1980). The population of sika deer in the district of Pilsen North (weighed after expelling organs, deer without head and doe and fawns with head) shows the average weight of the fawns was 15.7 kg, the average weight of the hind was 23 kg, the four-year-old hinds were 24 kg, and deer older than four-year-olds hind weighed 28 kg. The weight of deer older than eight years is 42.7 kg (Husák et al. 1986). In the area of Litovel after World War II two sizes and colour differences in sika deer were described. Larger and darker fawns weighed 16 – 20 kg, hinds 25 – 30 kg and adult headless deer more than 50 kg. The smaller, lighter character is represented by fawns 13 kg, 25 kg hinds weight, deer weighing 40 kg (Wolf 1999).

In addition, because trophy hunting it is also very important to know the weight of male sika deer head with antlers. Body weight and size, in turn, influenced mineral composition of the antlers of Iberian red deer in Spain (Landete-Castillejos et al. 2007). The weight of the head with antlers is 3.4 kg that is 6.6% of the total weight (Husák 1986). Antler weight of pampas deer (*Ozotoceros bezoarticus*) is increasing with increasing body weight, which is body weight greater in adult males than in males younger than 3 years old (Ungerfeld et al. 2011).

It is also important to understand the difference between the weight of live individual and the weight of individual after expelling organs, i.e. gralloch (Rajský et al. 2013) for the meat production and processing industry. The average weight of the ungralloched fawns from LZ Manětín is 26.4 kg, gralloching weighed 17.5 kg, which is 66.2% of the original weight. The weight after expelling organs was 66.4% of total weight. The weight of the deer was 66.1% versus the ungralloched weight (Husák 1986). Zima (1986) shows a weight loss of 28% in the fawns, the gralloched body has 72% of the original weight, the gralloched hind has a 74% of the weight. The weight of the gralloched body without the head was 65% of the live weight of the fawns regardless of sex, the hind and the deer had 69% of the original weight after being gralloch and without the head. Gralloched hinds

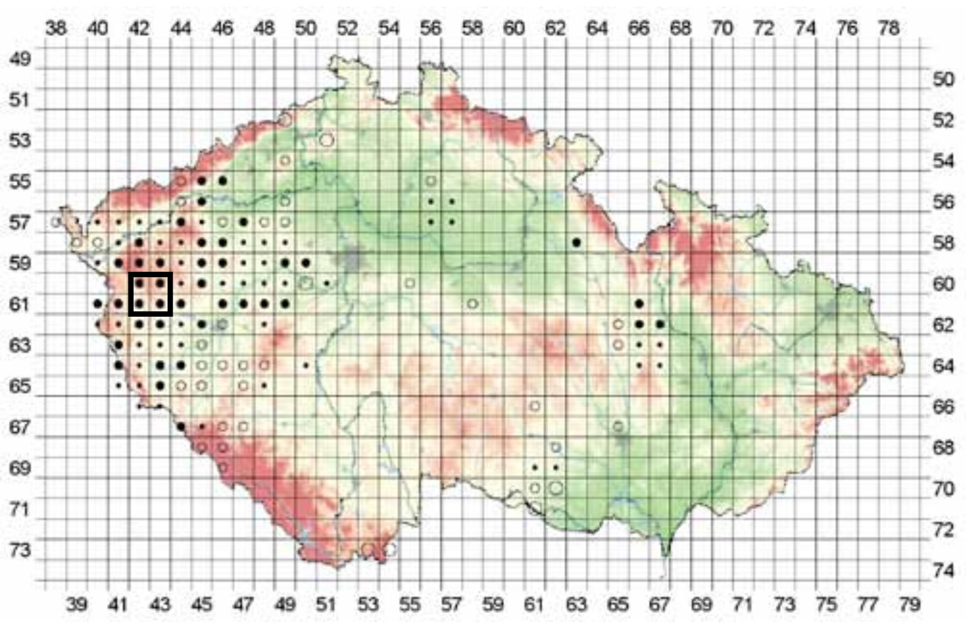

Fig. 1. The extension of the sika deer (*Cervus nippon nippon*) in the Czech Republic – full colored circle means higher density of occurrence, outlined circle lower density of occurrence (Anděra & Gaisler 2012). The bold frame indicates the Konstantinolázeňsko microregion.

in the winter season had 70.2% of weight before being gralloched, in the summer season was 64.5% of the total weight of the body. Gralloched deer was found to have a 71.9% share compared to ungralloched in the winter season, with summer hunting being 71.6%. The difference between the summer and winter seasons of the deer is not statistically conclusive and after rounding the two seasons can be averaged to 72% (Feldhamer et al. 1984; Husák 1986; Zima 1989).

Most studies deal with comparing the weight and age (Babička et al. 1977; Husák et al. 1986; Hanák 2015; Heroldová & Zejda 2002; Janiszewski et al. 2009; Jiřík et al. 1980; Mařík 1995; Wolf 1999), sex (e.g. Ježek et al. 2016; Lochman 1993; Hanák 2009) and other parameters but there are no studies about particular weights of the organs. Information about the weight of the organs and each part of sika deer body are still missing and are very important for the game processing.

The body weight of the individual is directly dependent on the food offer. Therefore information about the weight of the individual indicates amount of food needed by the individual animal or the entire population in the given area.

The aim of this study was to document the weight of the game (in particular *Cervus nippon nippon*) before the shooting, after gralloch and after the game has cooled. Moreover we intended to find the basic differences between these variables, the percentage ratio of the weights, the relationship of these weights and the influence of some aspects on the weight of the individual or the weight of the individual´s body parts. Weight dependence on the individual's age as well as weight dependence on the sex were expected.

2. Material and methods

In order to obtain the data, 63 individuals of sika deer hunted were weighed. All game was hunted in the northwest edge of the West Bohemia, in the Konstantinoláňsko microregion, Czech Republic, at the border of the Plzeň and Karlovy Vary regions (Fig. 1). Sika deer game were hunted on individual hunts and one common hunt in the 2016/17 hunting season.

Two digital scales were used to obtain weight data, both used simultaneously. The first is the KERN HCN 200K500IP suspension weight with a maximum weighing capacity of 200 kg and an accuracy of 50 g, this weight was used to weigh the whole pieces hunted before and after the gralloch, and for weighing game after it has cooled down. Second, the Dahongying ACS-40 stationary weight with a maximum weighing of 40 kg and an accuracy of 5 grams, it was used for the weight of the internal organs, the head, and the distal parts of the limbs. The simultaneous use of both scales was necessary especially for the low accuracy of the weighing instrument, which would not be able to obtain the exact weight of the individual organs while being blocked by the gralloching game. The used stationary weight was also accurate enough to gain the weight of the smaller organs weight (the kidneys, spleen and hearts often did not weigh more than 0.5 kg), however, the weighing of whole pieces under 40 kg was not able (weighing capacity) due to its small loading area.

Internal organs were weighed even if they were damaged by shooting unless they were almost destroyed. Most commonly weighed damaged lungs and liver, the least damaged were the kidneys. Heart weight was recorded without a crust (a blood clot in the heart cavities) and a pericardium. The lungs were weighted without trachea and esophagus. The renal weight is given simultaneously in both kidneys without a protective fat capsule. The spleen was weighed without fat, and no part of the atrophy was visible. Live weight or total weight is the weight of the game after the hunt, including the head and distal parts of the limbs with only loss of part of the blood caused by the shot. The weight after expelling organs (gralloched) is reported after the gralloch, including the head and distal parts of the limbs. Chilled mass is the weight of the gralloched piece without the head and distal parts of the limbs, weighed 12 – 24 hours after expelling organs. The weight of legs is the weight of all four legs simultaneously. The weight of the head is also reported for the individuals affected of shoot in it, including the antlers, tongue and the last bite (small brunch). The percentage is calculated from live weight, excluding weight loss by cooling, which is calculated from the weight gralloched after deduction of head mass and legs.

The wild game was gralloch as soon as it was hunted and taken to the place of weighing, except for one deer (found the next day), the game was weighed within 2 hours of its hunt.

After arriving at the weighing area, the hunted game were cut across both Achilles' tendons to place a spacer shall. First, the weight was placed on the hinge of the winch, then the spacer shall was tarred. The game was hung upside down behind Achilles tendon, then pulled up with a winch and weighed to obtain a live weight (excluding only blood lost by the hit). First, the neck was cut off ventrally from the chest to the head (cranial), after that, the thoracic cavity was opened by ca. 3/4, thereby releasing the pressure on the diaphragm and releasing the blood trapped in the chest. Subsequently, the abdominal cavity was opened and the pelvic bone was exposed with a longitudinal section from the rectum to the chest cavity. Cutting the abdominal wall was done with caution and with fingers covered by the tip of the knife to the diaphragm. After the diaphragm was reached, it was cut, reaching the chest cavity. The thoracic cavity was opened by a subsequent cut of the last quarter of the chest. Then, the pelvic bone was cut according to the degree of ossification by the knife or the bone saw, thus opening the pelvic cavity. By small cuts and pulling in the cranial direction, the anal aperture, the rectum, the sexual and secretory organs from the pelvic cavity were released, releasing the kidneys, which were cut off and weighed on a stationary scale, then cut and weighed the spleen.

Subsequently, the remainder of the diaphragm was released from the chest, then cut and the liver was weighed. By cutting off the esophagus, the gastrointestinal tract with the defect from the thoracic cavity was separated. After that, the heart was cut off, and it was stripped of the pericardum and the cruor. Followed by the grip of the lungs and by the cranial thrust and the possible cleavage of the lungs, trachea, esophagus and larynx from the chest and neck of the game. A cut was made behind the larynx to separate it from the head. The lungs were cut off from the trachea and then weighed, and the outcast body, including the head and distal parts of the limbs, was weighed. Then the head was cut off between the occipital joint and the atlas, then the head was weighed. The separation of the distal parts of the limbs was performed in the carpal joint at the forelegs and in the tarsal joint at the pelvic limbs.

The age of the game was judged according to the degree of physical development and at the same time according to the degree of development and teeth wear. The game was divided according to body development and the level of denture development on the fawns up to 1 year of age, spikes and hinds up to two years of age and adult individuals.

The data obtained was processed, statistically evaluated and diagrams prepared in MS Excel. An analysis of the correlation of variables was performed. On the basis of the measured values, point charts with the exponential trend line were created, followed by a box-plot.

3. Results

The average weight of deer in this study (Table 1.) was 42.0 kg. This average weight includes not only adult individuals but also juveniles with a lower weight. The average weight after expelling organs (gralloch) was 1.2 kg, that is 74% of the total weight.

We expressed average values partitioned by age class and sex (Table 2). The average weight of the fawn, independent of sex, is 26 kg. Average weight of one year old deer is 45 kg, five year old is 88 kg, suggesting that male deer can gain 43 kg in four years.

Correlations between sika deer weight and all of the variables were also calculated (Table 3). There were several correlations between many of the variables. The strongest (positive) correlation was between total weight, weight after expelling organs, weight of heart and weight of livers. Weight values tend to grow along with increasing age (Fig. 2). There is a statistically significant

Table 1. Average weight values (kg) for sika deer regardless of sex or age (N = 63).

Type of weight	Average	Min	Max	Standard deviation	Coefficient of variance
Whole animal	42.02	12.50	95.50	18.32	43.61
After expelling organs	31.27	9.00	74.50	14.40	46.04
After iceing	26.54	7.00	61.00	12.25	46.16
Legs	1.01	0.45	1.78	0.28	27.70
Head	2.13	0.86	5.35	1.03	48.53
Liver	0.95	0.30	2.39	0.57	60.51
Kidneys	0.14	0.04	0.60	0.10	67.85
Lungs	0.72	0.21	1.68	0.30	41.52
Spleen	0.19	0.02	0.80	0.13	70.05
Heart	0.32	0.12	0.64	0.11	34.35

Table 2. Average weight values (kg) for sex and age groups of sika deer.

Sex and age groups	Total weight of individual	Weight								
		after expeling organs	after iceing	of legs	of head	of liver	of kidneys	of lungs	of spleen	
Male fawn	26.19	18.96	15.96	0.81	1.41	0.51	0.08	0.52	0.10	0.23
Female fawn	26.18	19.50	16.65	0.78	1.32	0.48	0.12	0.57	0.15	0.25
1-year-old deer	45.00	29.00	24.00	1.25	1.80	0.89	0.12	0.75	0.24	0.38
2-year-old deer	56.67	44.67	39.24	1.24	1.62	1.13	0.37	0.69	0.24	0.41
3-year-old deer	60.92	44.37	38.42	1.28	2.72	1.36	0.18	0.94	0.16	0.42
4-year-old dear	59.42	44.49	37.35	1.25	3.42	0.16	0.18	0.83	0.27	0.43
5-year-old dear	88.25	71.00	58.50	1.66	5.16	2.35	0.24	1.50	0.37	0.57
1-year-old doe	33.83	24.17	20.50	0.87	1.68	0.66	0.12	0.67	0.17	0.25
Older doe	46.10	34.00	29.00	0.96	2.08	0.72	0.12	0.92	0.20	0.34

Table 3. Correlation of sika deer weights (kg) – gray backgrounds indicate significant correlations at level of $p<0.05$ (N = 53).

Variable	Averages	Standart deviation	Total weight of the individual	Weight								
				after expeling organs	after iceing	of legs	of head	of liver	of kidneys	of lungs	of spleen	of heart
Total weight of the individual	43.16	18.33	—	0.98	0.98	0.89	0.86	0.95	0.39	0.68	0.46	0.91
Weight after expeling organs	32.15	14.41	0.98	—	1.00	0.89	0.86	0.93	0.41	0.67	0.45	0.91
Weight after iceing	27.23	12.12	0.98	1.00	—	0.88	0.83	0.92	0.42	0.66	0.45	0.90
Weight of legs	1.04	0.27	0.89	0.89	0.88	—	0.79	0.86	0.25	0.67	0.39	0.86
Weight of head	2.21	1.08	0.86	0.86	0.83	0.79	—	0.88	0.23	0.67	0.39	0.77
Weight of liver	0.97	0.59	0.95	0.93	0.92	0.86	0.88	—	0.34	0.64	0.52	0.88
Weight of kidneys	0.15	0.10	0.39	0.41	0.42	0.25	0.23	0.34	—	0.19	0.15	0.30
Weight of lungs	0.72	0.29	0.68	0.67	0.66	0.67	0.67	0.64	0.19	—	0.27	0.61
Weight of spleen	0.19	0.14	0.46	0.45	0.45	0.39	0.39	0.52	0.15	0.27	—	0.48
Weight of heart	0.33	0.11	0.91	0.91	0.90	0.86	0.77	0.88	0.30	0.61	0.48	—

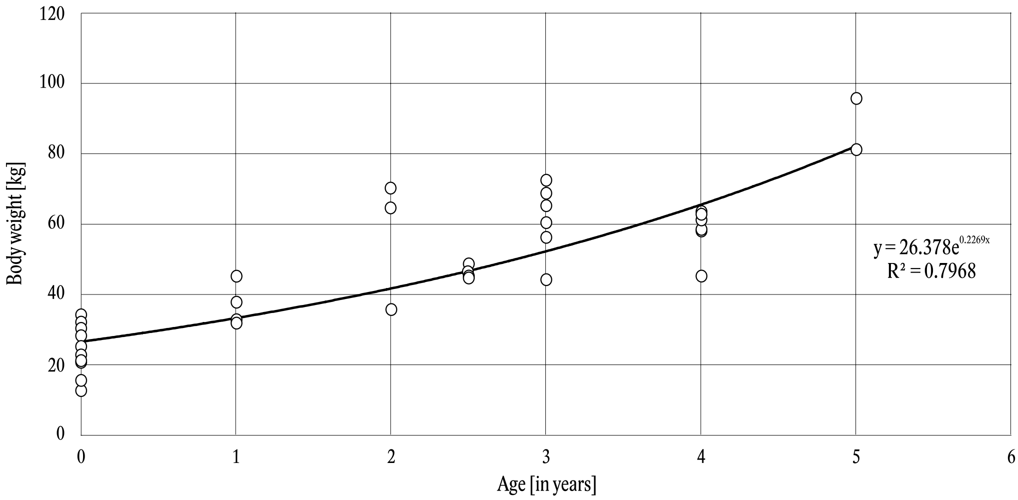

Fig. 2. Influence of age on the weight of sika deer (level of significance p<0.05). Individual points mean the weight of each individual at a certain age.

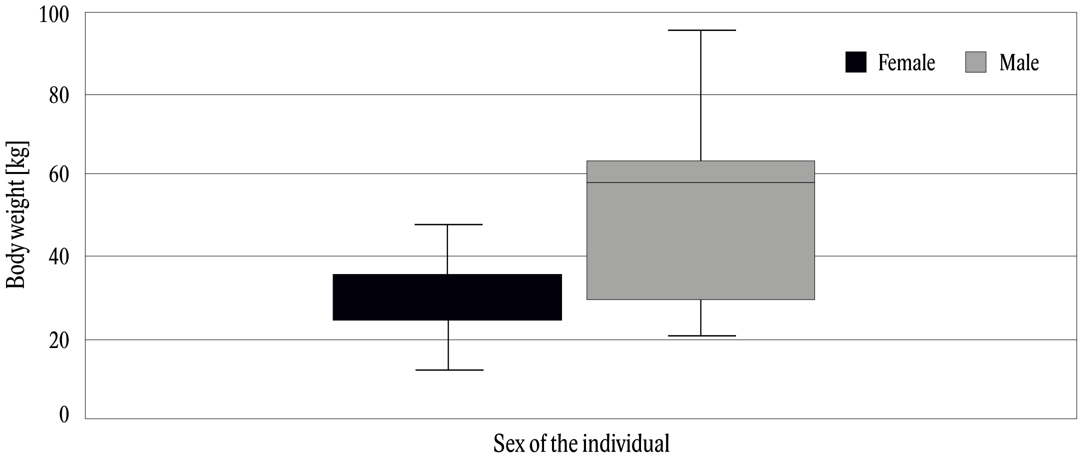

Fig 3. Comparison between male and female weights in sika deer. There are weights of the individuals, separated for female and male. The line in the box is median and the average weight is illustrated by the cross in the middle of the box. Maximal and minimal values are illustrated in the segments.

($r^2 = 0.9046$) positive correlation between age and total weight of the individual.

Sex has a significant effect on the weight of individual sika deer (Fig. 3). It is a manifestation of sexual dimorphism, which is evident in this species. Females (does) have an average around 40 kg, males have an average 62 kg, does have around 35% lower weight than males.

Head weight of male sika deer was affected by age (Fig. 4). In the first year of life the antlers have a lower weight, so it affects the total weight of the head. The head weight is increasing with increasing age, every year about 1 kg (Fig. 4). One year old deer had an average head weight around 1.5 kg and in five year old deer the head average head weighted around 5 kg.

4. Discussion

The average live weight for all deer combined was 42 kg, similar to the weight reported by Whitehead (1972) showing an average weight of 48 kg. For both measurements, gender and age differences were not taken into consideration, although in these circumstances the difference of 6 kg can be considered minimal.

The average live weight of fawns, does, and male deer was 26, 46 and 61 kg, respectively. The detected average for the fawns is at the lower edge of the range of weights reported by Jiřík et al. (1980) 25 – 35 kg for half-year olds. However, in this study we measured individuals that were nearly one year of age. The doe and male deer almost coincide with Lochman (1993), giving a live weight of 45 kg

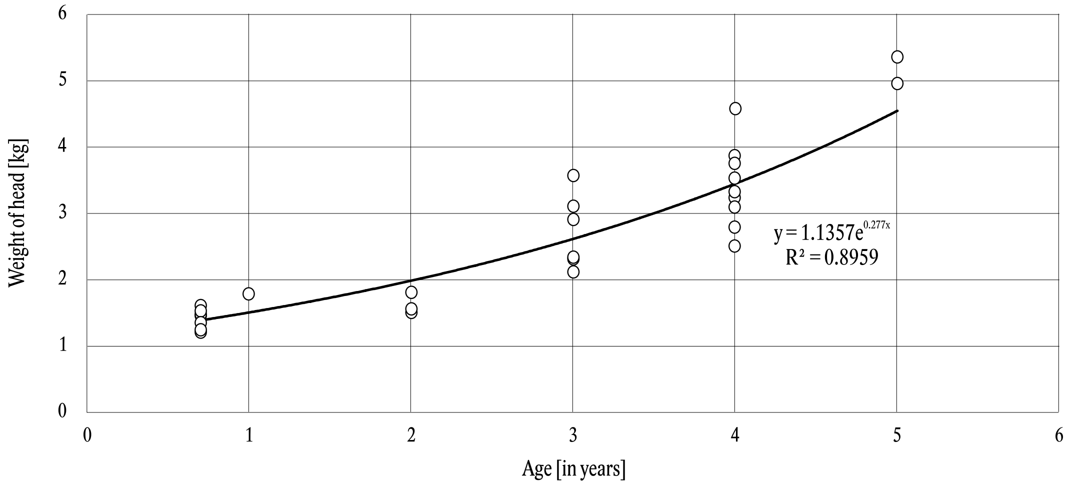

Fig. 4. Influence of age male sika deer on head weight (level of significance $p<0.05$). Individual points mean the weight of the head of each individual at a certain age.

and deer 55 kg. Ohdachi (2010) reports the live weights of deer and deer in the original Japanese homeland of 25 – 80 kg and 50 – 130 kg in deer, which corresponds to the data found in the work by Lochman (1993).

The average gralloched weight of fawns found in this study is 19.3 kg, which is a higher weight than Babička et al. (1997) 15.3 kg, Husák et al. (1986) in the district of Pilsen north 15.7 kg, and Bouzovsko 13 – 15 kg, smaller type of sika deer by Wolf (1999) weighed 13 kg, Uckermann (1972) in the regions Hochrheingebiet 17.6 kg and Arnsberg 15.8 kg and Feldhamer et al (1984) 13.2 – 15.4 kg. Lower weight can be justified by weighing pieces after iceing possibly without heads and legs, which are often not specified by the authors. In this study, the mean weight was also determined without head and legs and after iceing (16.4 kg), more similar to the stated weights. An alternative possibility of higher weight is the current hunting of older fawns after 15th January, which is only allowed after 2014. Similar weights as published in this study by Ueckermann (1972) for Ostangeln fawns 20 kg, Wolf (1999) 16 – 20 kg and Ježek et al. (2016), weighing 18.2 kg. These weights are almost identical and confirm the weight found in this study.

The gralloched weight of does was 34 kg, which is comparable to Ježek et al. (2016), which reported a weight of 30.6 kg, but does not indicate how game was weighed. It is probable that the weight is in the purchase state, with an average purchase weight of 29 kg. This weight is even more similar to the weights of Ježek et al. (2016) for the Kladská region of 28.8 kg and the Manětín area, where for 5 year olds, the weight was 29 kg. The weight of Manětín sika deer is identical to this study, and the value of Kladská is lower by 0.2 kg. This can be explained by the location of the area tested in this work between Kladska and Manětín, a population with similar living conditions and probable genetic similarity. Another comparable weight of hinds is given by Wolf (1999) in the Greater Siege of Litovelsko. It lists the weight of the hind 25 – 30 kg. The other authors Babička (1977), Husák et al., 1986, Feldhamer et al. (1984), Uckermann (1972) report a lower weight of approximately 10 kg compared to the gralloched weight in this study, and it can be argued that the milder winters in recent years, the inclusion of the Dybowski subspecies into the current genotype, and/or better adaptation (already "domesticated" game) to the conditions of the local environment can account for this difference.

The average weight of the deer without age difference was 46.7 kg. This weight is between 40 kg and 50 kg of Litovel´s sika described by Wolf (1999), also corresponds to the weight of 40 – 60 kg, reported by Jiřík et al. (1980), 35 – 55 kg, reported by Hanák (2015) and weight 33 – 78 kg by Heroldová & Zejda (2002), which is similar to the minimum and maximum values found in this work of 28 – 74.5 kg. The slightly lower values compared to this work indicate for the various age categories Babička et al. (1977) and Husák et al. (1986). Uckermann (1972) and Feldhamer et al. (1984), whose average weights are approximately 10 kg lower, the largest reported differences compared to other studies. This difference of about 20% may be due to different natural conditions or a genetic basis, since Feldhamer et al. (1984) weighed sika from the USA and Feldhamer et al. (1984) weighed German deer.

It is generally know, that the weight of the individual is decreasing in higher age. The average weight of hinds aged 1 – 2 years is 26 kg, the mean weight at the age of 3 – 4 years is 30.9 kg, 5 – 6 years old is 34 kg and in the case of 6 years old or more, the average weight drops to 31.6 kg. The average weight of the hinds without age and area difference is 30.6 kg. (Hanák 2015; Heroldová & Zejda 2002; Husák et al. 1986; Jiřík et al. 980; Wolf 1999). The Moravian population of sika deer weighed gralloched with the head (Heroldová & Zejda 2002) and determined weights of hinds ranged from 19 – 50 kg and deer have a total weight 33 – 78 kg. The height growth potential is more observed in the first month of life. Red deer male fawn in Hungary has already at 182 days of age 75.8 kg and female fawn 65.6 kg of live weight (Julianna et al. 2015).

Yokoyama et al. (2001) present that there is correlation between kidney mass and body mass 0.9. Results of this study are not consistent with the result of our study. Correlation between total weight and weight of the kidney is only 0.4 at level of significance $p<0.05$. That mean, that there was not significant dependency between these two variables.

The percentage of weight of the gralloched bodies compared to the total weight was 73.6% for the fawns, 73.8% for the does, 75.4% for the male deer and for 74% for all individuals without age and gender differentiation. The values found here are closest to Zima (1986), 72% for fawns, 74% for does and 75% for deer, the values for does and deer are the same, with a slight difference of 1.6% for fawns. Feldhamer et al. (1984) shows values for hind and deer with a difference of up to 3.5%, for the doe is 70, 2% and for deer 71.9%. Husák (1986) values, 66.2% for fawns, 66.5% for does and 66.1% for deer. The difference in deer is close to 10%, the lower percentage difference is for fawns and does about 7, 3%. A possible reason for such high differences can be the weight gain procedure that Husak et al. (1986) doesn´t explain, it is possible that the gralloched bodies are weighted only after iceing, the percentage of which in this work is 5.8% (0.5 – 11.9 kg).

5. Conclusion

Our study conducted in the microregion of Konstantinolázeňsko showed that the average total weight of sitka deer was 42 kg. The gralloched weight was 74% of the total weight after hunt. There was a correlation between the total weight and age – with the increasing age isalso increasing the weight of the individual. Results show sexual dimorphism of sika deer. Females (does) have an average around 40 kg, male (deer) have an average of 62 kg, does have around 35% lower weight than deer. There was also influence of age on the weight of head, which is increasing with higher age. Antlers are progressing throughout life, and in the first years of the life antlers grow faster. Five years old deer have the heaviest head, which also reflects the weight of the antlers. The correlation between the total (live) weight and other weights was significant ($p<0.05$) for the weight of the liver and heart.

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ORIGINAL PAPER

Effect of different management on quality and value production of pure beech stands in Slovakia

Igor Štefančík[1], Michal Bošeľa*[1, 2], Rudolf Petráš[1]

[1]*National Forest Centre - Forest Research Institute Zvolen, T. G. Masaryka 2175/22, SK – 960 92 Zvolen, Slovak Republic*
[2]*Technical University in Zvolen, Faculty of Forestry, T. G. Masaryka 24, SK – 960 53 Zvolen, Slovak Republic*

Abstract

Value production is one of the most important information for comparing different management strategies in forestry. Although the value production of forest stands is affected by various factors (stem and assortment quality, stem dimension, stem injury, price of assortments), thinning can be considered as one of the most important one. This paper aims at the evaluation of qualitative and value production in homogeneous beech stands, which were managed by two different thinning types for period of 45 to 55 years: (i) – heavy thinning from below (C grade according to the German forest research institutes released in 1902) and (ii) – Štefančík´s free-crown thinning. The third variant was control (iii) – subplot with no interventions. Silvicultural quality characteristics of the lower half of the stem were assessed using a 4-class scale (A – the best quality, D – the worst quality). Assortment structure (commercial quality) was estimated for each stem by an assortment model developed in the past. Nearly 3,000 individual trees aged from 83 to 105 years from 23 subplots established across the Slovakia territory were assessed. The highest volume of the best silvicultural quality of stems (A class) has been reached in forests where Štefančík´s free-crown thinning was applied (57 – 85%) while the lowest (22 – 56%) on subplots with no management. The proportion of two best commercial quality assortments (I + II) was highest in forests managed by heavy thinning from below (21 – 29%) and the lowest when no treatment was applied (7 – 19%). The highest value production (expressed in € ha^{-1}) was reached in the forests treated by free-crown thinning. Results suggested the overall positive impact of thinning on the increase of value production in beech forests. Particularly, the free-crown thinning focusing on selection of best quality trees should be preferred as it leads, besides its sufficient value production, to a higher vertical differentiation of the beech forests.

Key words: pure beech stands; thinnings; stem quality; assortment structure; value production

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1. Introduction

Qualitative and value production of forest stands are key aspects particularly connected with broad-leaved tree species (oak and beech). Recently, it has become particularly important because the financial evaluation (monetization) of thinnings realized during the whole tending period together with the assessment of mature stands entered a crucial role in assessing the effectiveness of performed tending. Quality of standing stems in forests may be assessed by the quality of stem by external growing traits such as stem straightness, number and size of knots, spiral grain, stem damage etc. (Štefančík 1974) or by the commercial timber quality, assessed by the use of assortment model (Petráš 1992).

Growth and development is affected by the site conditions characteristics (Vacek & Hejcman 2012; Vacek et al. 2014; Vladovič et al. 2014), stand conditions (Bartoš & Souček 2010; Jullien et al. 2013; Merganič et al. 2013), genetic properties and characteristics (Ducros et al. 1988; Hansen et al. 2003; Gömöry & Paule 2011; Gömöry et al. 2013), including an appropriate provenance (Novotný et al. 2015) and the way of forest management (Štefančík 1974, 2015; Mlinsek & Bakker 1990; Hein et al. 2007; Poleno & Vacek et al. 2009; Vacek et al. 2015).

Many authors found a positive impact of the long-term tending on the timber quality of beech stands (Šebík 1970; Štefančík 1974; Kató & Mülder 1983; Korpeľ 1988; Mlinsek & Bakker 1990). Particularly, selective thinnings (Šebík & Polák 1990; Štefančík et al. 1996; Cameron 2002) by the target trees method (Skovsgaard et al. 2006; Hein et al. 2007; Štefančík & Bošeľa 2014; Štefančík 2015) are the most appropriate. In addition,

*Corresponding author. Michal Bošeľa, e-mail: bosela@nlcsk.org

thinning increases the quality of beech timber (Keller et al. 1976; Ferrand 1982; Cameron 2002; Poljanec & Kadunc 2013).

Value production of beech stands is significantly reduced by a false heart and/or by wood rot (Knoke & Wenderoth 2001; Knoke 2003; Krpan et al. 2006), or by the occurrence of knots on the stem (Richter 2007). Despite the extensive research on beech stands from various aspects, there is a lack of knowledge about the value production of beech in pure (Sedmák & Hladík 2002; Utschig & Küsters 2003) or mixed stands (Petráš et al. 2015). In particular, it is questionable whether different management can significantly affect (increase) value production of beech stands in comparison to stands without any interventions.

Presented study focuses on the assessment of stem quality and value of assortments in pure beech stands that were exposed to two different thinning methods for the last 45 – 55 years. The hypothesis that stands with different thinning methods will produce different value production expressed by only last assessment of stem quality and assortment value and that subplots with no interventions are expected with the lowest value production was tested.

2. Materials and methods

2.1. Establishment of long-term research plots

Twenty three subplots at seven localities (plots) across Slovakia were established by the Prof. Dr. Ladislav Štefančík during 1959–1969 period in homogeneous, even-aged naturally regenerated beech forests in Slovakia (Fig. 1). At the time of their establishment, the forests were in a growth stage from small pole to pole timber. Table 1 shows basic site characteristics of the plots.

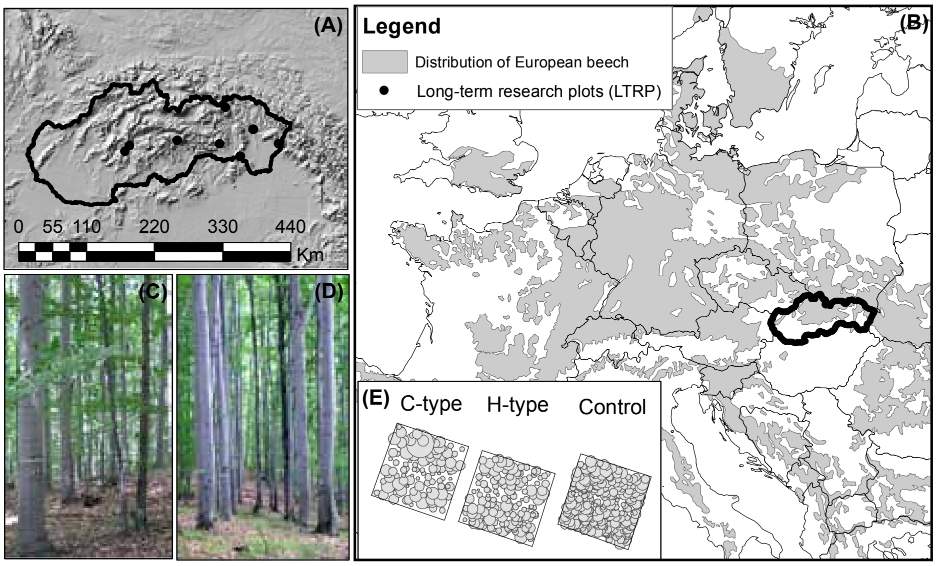

Fig. 1 (a) The distribution of the study localities across the Western Carpathians (Slovakia) used in this study, (b) the present distribution of European beech (source: Euforgen, 2015) with highlighted boarder of Slovakia, (c) beech forest in 2015 after applying the free crown thinning (thinning from above aimed at supporting the selected best-quality trees – all suppressed trees are subject to natural mortality only), (d) beech forest in 2015 after applying the heavy thinning from below (all suppressed and sub-dominant trees were removed), and (e) an example of placement of the research subplots in a locality including the spatial distribution of trees mesured in 2015 – the circle size represents crown projection area.

Table 1. Site characteristics for the 23 permanent research plots in European beech (*Fagus sylvatica* L.) included in the analysis.

Plot/subplot	Number of inventory cycles	First-last measurement	Age span [years]	Geographic position		Elevation a. s. l. [m]	Mean annual temperature [°C]	Mean annual precipitation [mm]	Soil unit
				E-longitude	N-latitude				
Jalna/C,H,0	12	1959–2012	36–89	48.55	18.95	610	6.2	800	Eutric Cambisol
Konus/C,H,0	12	1961–2014	30–83	48.78	22.30	510	6.5	900	Eutric Cambisol
Kalsa/C,H,0	12	1961–2014	37–90	48.58	21.48	520	6.0	790	Stagni-Eutric Cambisol
Kalsa/H2	10	1969–2014	45–90			520	6.0	790	
Zalobin/C,H,0	12	1962–2015	39–92	48.98	21.74	250	7.9	660	Stagni-Eutric Cambisol
Zlata Idka/C,H,0	12	1960–2013	40–93	48.74	21.01	700	6.7	780	Haplic Cambisol
Ciganka/C,H,H2,0	10	1967–2012	60–105	48.76	20.09	560	5.5	918	(Dystric)
Lukov/H,0	11	1962–2011	45–94	49.28	21.10	550	5.5	690	Haplic Cambisol
Lukov/C	10	1966–2011	49–94			550	5.5	690	(Dystric)

Comment: C – heavy thinning from below (C grade according to German forestry research institutes from 1902); H – the free crown thinning according to Stefancik (1984) principles, thinning interval of 4 or 5 years; H2 – the free crown thinning according to Štefančík (1984) principles, thinning interval of 10 years; 0 – control plot (no thinning).

No systematic interventions were performed in the forests until the establishmet of the plots. If there was some intervention, it was of the slight intensity only removing the suppressed trees – so-called wandering-selective felling (Štefančík 1974).

Each plot comprised of 3 to 5 subplots (mostly three), which were arranged next to each other (along the contour line), and separated from each other by a 15 m wide (the minimum width) isolation belt. The area of each subplot was 0.25 ha (50 × 50 m), with the exception for the plot Zalobin with the size of 0.20 ha (40 × 50 m). A 10 m wide transect, where heights of the all trees were measured, was established and evidenced through the center of each subplot.

All living trees with the diameter DBH ≥ 3.6 cm and trees which reached this threshold during the measurement period were fixed and numbered. One subplot (specified as 0) in each plot (locality) was left unmanaged as a control plot.

2.2. Field works

The following thinning types were applied on the subplots within each plot:

a) Heavy thinning from below (C grade according to the German forest research institutes released in 1902) (here recognized as C). All suppressed trees without tendency to support the target trees have been removed. The thinning intensity on this subplots ranged from 37 to 46% out of basal area total production. Thinning interval was the same as for subplot H.
a) The free crown thinning (thinning from above) with a 5-year (marked as H) or 10-year thinning interval (marked as H2) using the principles defined by Štefančík (1974, 1984). This thinning method focuses on identifying and supporting the best quality trees growing in the crown level of the stand (target trees). Thinning intensity for this method of thinning ranged from 35% to 48% out of basal area production. At first, 4-year thinning interval was used between the first and second and/or second and third intervention on all subplots (except for subplots H2). Later, it was a 5-year interval on the all subplots or 10-year interval (on subplots H2 only).

In addition to standard biometric measurements, trees were classified into the 1 – 5 tree vertical classes (using Kraft classification system). The quality traits of the bottom half of stem were assessed according to the following classification:

A – Straight, non-twisted stem, centric, without shape deformations and knots; suitable for sliced veneer production;

B – Stem with minor technical defects with solid and loose knots up to 4 cm (1 – 2 pieces per meter);

C – Stem with large technical defects, greater curvature, and twisted growth up to 4%, solid knots without limitation; suitable especially for lower quality saw logs or pulp;

D – Stem inferior to the class C, with the extensive rot, and only suitable as fuelwood.

2.3. Data processing

The analysis includes only the last inventory on the subplots in order to investigate the long-term effect (45 to 55 years) of the different thinning types on qualitative and value timber production. In total, 2,973 trees were assessed. First, the shares of A – D stem quality classes were defined for each subplot. Assortment structure was estimated by national assortment model (Petráš 1992), which gives the assortments percentage in dependence on the tree diameter (DBH), the stem quality, the stem damage and the stand age. Stem damage was not assessed. We assumed no stem injuries. Therefore the results are not real only theoretical.

Individual assortments represent log classes based on log quality and its diameter. Quality classes of logs are mainly characterized by their intended purpose:

I	sliced veneers, special sporting and technical goods,
II	peeled veneers, sporting goods,
III (A, B)	saw logs (IIIA – better quality, IIIB – worse quality),
V	pulpwood; chemical and mechanical processing for pulpwood and agglomerated boards production,
VI	fuelwood.

I – IIIB classes defined in the assortment tables model are also separated into 1 – 6+ diameter classes. (1 – 16 to 19 cm; 2 – 20 to 29 cm; 3 – 30 to 39 cm; 4 – 40 to 49 cm; 5 – 50 to 59 cm; 6+ more than 60 cm).

The estimated assortment value was calculated for each tree as the product of assortments volume and timber prices by log quality and diameter classes. Timber prices were taken from the state enterprise Forests of the Slovak Republic, Assortment price list published in 2013 (Table 2).

Table 2. Assortments prices (€ m^{-3}) by log quality and diameter classes.

Diameter class	Quality class					
	I	II	IIIA	IIIB	V	VI
1			51.5	50.5		
2		54.0	52.5	51.5		
3		103.0	69.5	57.5	43.0	44.0
4	201.0	108.0	71.5	59.5		
5	231.0	113.0	71.5	59.5		
6+	271.0	113.0	71.5	59.5		

Comment: Assortment prices for V and VI quality classes are the same for all diameter classes.

2.4. Statistical analyses

ANOVA was applied to test for the effects of thinning type on the proportion of the highest-quality stems, proportion of I+II and IIIA quality assortments as well as to test the effect on financial return per hectare and per cubic meter. The Bonferroni correction was used to counteract the problem of multiple comparisons. Simple linear and polynomial regression was used to investigate the effects of mean stand diameter, as a characterstic representing forest development, on the proportion of the highest-quality stems and potential financial return under different thinning type.

3. Results

3.1. Stem quality

The highest proportion of the best A quality stems (Fig. 2) was reached when applying the free crown thinning (H). It varied from 59 to 85%. On the subplots with heavy thinning from below (C), the proportion of the best quality stems varied in the range of 48 – 82%. However, the proportion was not found to be significantly different from the previous. The lowest proportion of the best quality stems (22 – 56%) was observed in the unmanaged forests (0) (Štefančík 2015).

3.2. Assortment structure

The highest proportion (21 – 28%) of the best quality assortments (I+II) was found on the subplots where the thinning from below was applied. The lowest proportion of such quality trees (6 – 19%) was observed on control subplots as well as in forests managed by free-crown thinning (4 – 22%). Similarly, the highest proportion of IIIA quality stems was reached in forests treated by heavy thinning from below. On the contrary, the free-crown thinning provided the lowest proportion of such stems.

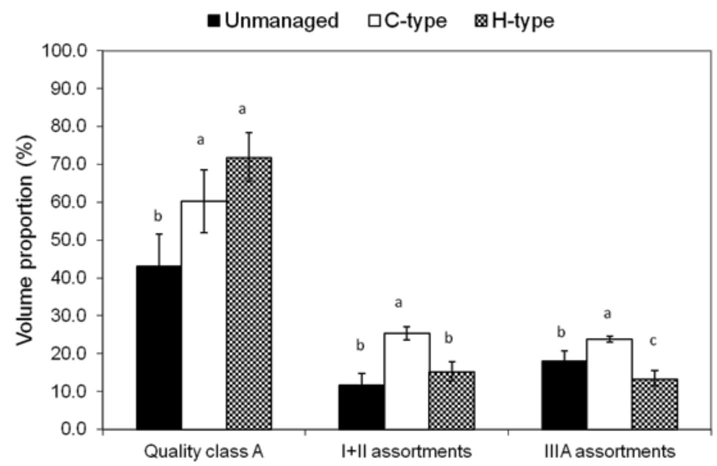

Fig. 2. Volume proportion of the highest quality (A) stems and I + II and IIIA assortments by the thinning types. Legend: C – type – subplot with heavy thinning from below (C – type according to the German forest research institutes released in 1902), H – type – subplot with free crown thinning (thinning from above) defined by Štefančík (1974), Unmanaged – control subplot (without interventions). Note: Different letters mean statistically significant difference ($p < 0.05$) within the quality categories.

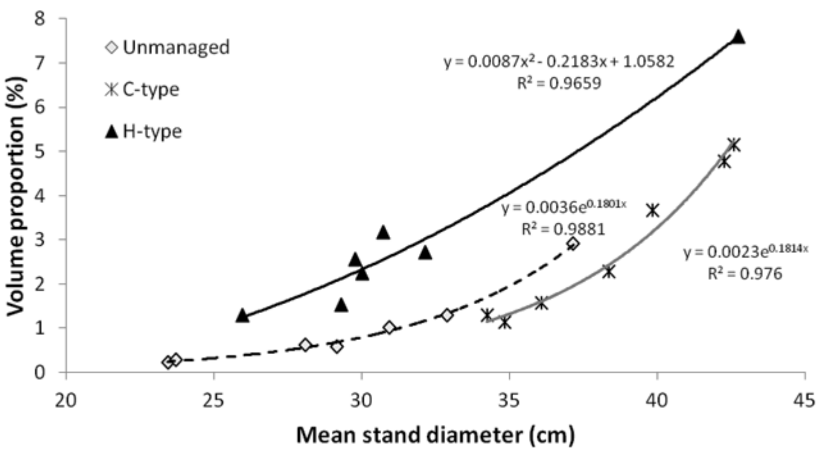

Fig. 3. Dependence of the volume proportion of best quality assortments (Class I) on the mean stand diameter (d_g).

In addition to stem quality, an assortment dimension (diameter) is another important feature for assigning the stems into certain assortment classes. The relationship between proportion of the best quality assortments (I. class) and the mean stand diameter largely differed between the thinning types (Fig. 3). On all subplots a modest increase of the most valuable assortments has been observed with increasing stem mean diameter. Best quality assortments was higher by 4 – 5% under the free crown thinning than on subplots with no tending at the same mean diameter (d_g).

3.3. Value production

Beech stands under free-crown thinning reached the highest value production (per hectare) (Fig. 4a, b). Stands managed by heavy thinning from below reached less and the control subplots least value production. The value is approximate as the value production has been calculated for undamaged subplots, so the real value was lower.

Mean stand diameter (Fig. 5) influences the stand value production. Differences are evident above the mean diameter of 30 cm. Stands with heavy thinning from below had in five (out of seven) plots the maximum diameters and also the highest value production (expressed by € ha^{-1}). Control subplots and subplots with free crown thinning showed approximately the same values.

Subplots with free crown thinning had the highest value production (Fig. 4b), when standardized to the value per one cubic meter (ranging from 71 to 82 € m^{-3}). Subplots with heavy thinning from below reached 68 – 76 € m^{-3}. The lowest value production (58 – 71 € m^{-3}) was found on the control subplots (without tending). Relationship between the value production (in € m^{-3}) and the mean diameter (d_g) highlighted the same trend of increasing production with the increase of mean diameter regardless to the applied thinning type (Fig. 6).

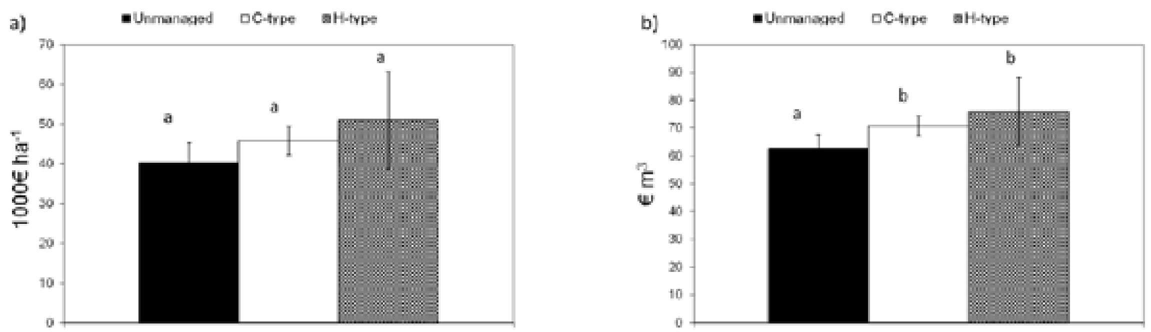

Fig. 4. Value production (a) in thousands € per hectare and (b) € per m^3 in different thinning types. Different letters mean statistically significant difference ($p < 0.05$).

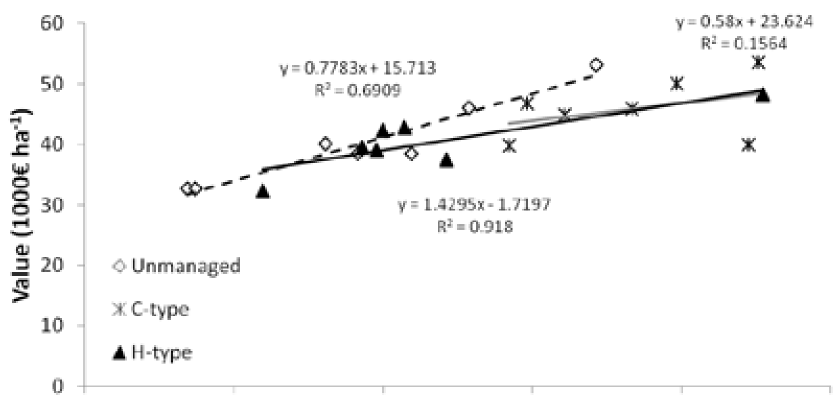

Fig. 5. Dependence of the value production (thousands € ha^{-1}) on the mean stand diameter on subplots with a different management.

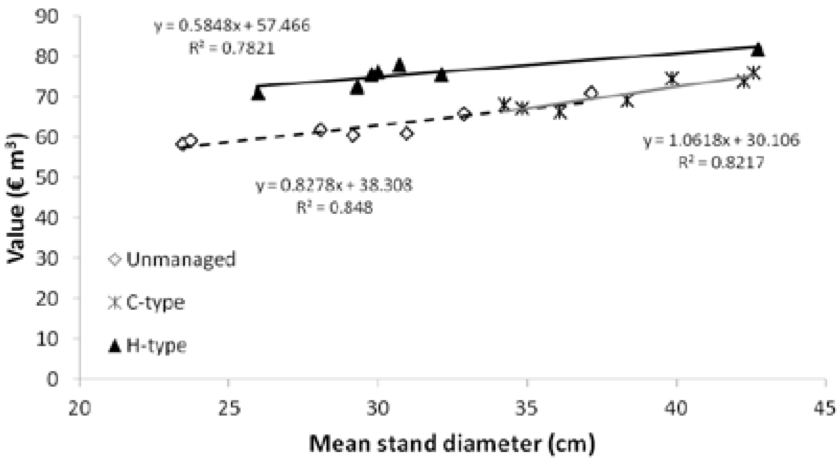

Fig. 6. Dependence of the value production (€ m^{-3}) on mean stand diameter (d_g) on subplots with different management.

4. Discussion

The highest percentage of best quality stems (class A) was reached by the free crown thinning. This thinning method is focused exclusively on individual cultivation of the highest quality trees (promising; target trees), which are selected in the stand´s crown and dominant level (Štefančík 1984). These are typically the thickest trees ($d_{1,3} \geq 45$ cm), which is necessary (in addition to qualitative characteristics) to meet the criteria of the most valuable assortments (class I). On the other hand, the highest proportion of the best quality assortments (class I + II) by volume was reached at heavy thinning from below. Contrary to thinning from above grows a stand as a whole by removing all suppressed trees and does not intervene into the crown level. Therefore it does not distinguish between individuals for their stem quality. Despite the fact that subplots with thinning from below are always characterized by highest mean diameter (Assmann 1968; Šebík & Polák 1990; Štefančík 2015) in comparison with other methods of thinning, the proportion of the best quality stem was the highest at free crown thinning. Thus, this suggest that not only dimension of stems is important (over 45 cm dbh) for assorting, but also their quality characteristics and stem damage in particular. We did not directly assess the damage separately for each stem in this study, but we considered stem damage when assessing the stem quality class. However, the assortment models used in our study (Petráš & Nociar 1991) were also based (in addition to the stem diameter and quality) on dependence on the stem damage and age. Therefore detected assortment structure can not be considered absolute, but for orientation. Presented research supports the finding, when the lowest proportion of best quality stems and assortments was found on plot Lukov (poor genetic quality of the stand) and Kalsa. It was confirmed by negative phenotypic traits (stem with deformation, greater curvature, twisted growth). As was already revealed in the past studies, a beech bark necrotic disease significantly caused later trunk rot (Štefančík & Leontovyč 1966; Štefančík 1974) occurred on this plot and also in Konus and Jalna. On these plot, the proportion of the highest quality stems (A + B) was even higher on control subplots (without interventions) than on the subplot with free crown thinning (Štefančík 2015). This is in accordance with the other studies (Štefančík 1974; Cicák & Mihál 2001; Cicák et al. 2003) that showed a higher rate of necrosis in managed forest stands in comparison to stands without interventions. Whereas, last interventions in the stands with thinning from below were minimal, necrosis was not reflected here. On the contrary, interventions in the stands managed by the free-crown thinning were performed even in the higher age (Štefančík 2015) to achieve the highest value increment (Assmann 1968). The occurrence of necrosis was also related to the social status of a tree, as the frequency increased with decreasing vertical position of the individuals in the stand level (Cicák & Mihál 2002). Such approach gives those stands an advantage, because the part of the stand is removed during the first interventions, contrary to the stands with free crown thinning, where the suppressed trees frequently occur at the higher age (Štefančík 2015).

Big proportion of the best quality stems, found in stands with performed free crown thinning is related to the highest number of target trees on these subplots (Štefančík 2015). At the same time, the merchantable volume was almost always higher in stands treated by heavy thinning from below and control subplots compared to the Štefančík´s free crown thinning. This observation thus supports the suggestion to focus on the qualitative aspects of the thinning in beech stands (Kató & Mülder 1983; Poljanec & Kadunc 2013; Štefančík & Bošeľa 2014) and/or on a certain number of the top quality trees (Štefančík 1974; Hein et al. 2007). In our research it was ranged from 44 to 164 individuals per hectare on subplots with heavy thinning from below and/or 68 to 184 trees on subplots with free crown thinning. However, when growing "mass quality" , i.e. the whole stand without the focus on the highest quality (target) individuals, better results were reached in the stands managed by heavy thinning from below (Štefančík 2015), as confirmed in our study (Fig. 2).

Our results are also consistent with those provided by Hladík & Sedmák (1996) who confirmed that the best quality was reached in the stands treated by thinning from above (reached the highest share of class A) while the lowest quality was found on control plots. The authors assumed that the value production in the stand with crown level interventions would be higher than in the stands under thinning from below. Similarly, Hein et al. (2007) showed in a 35-year experiment that the net present value of timber production in the stands with applied selection thinning was higher in comparison to the Assmann's optimal stand basal area regime. When expressed in € m^{-3}, our results support these findings.

The study by Poljanec & Kadunc (2013) showed that the quality of beech trees in Slovenia was highest at the DBH of 50 – 55 cm which is consistent with our findings, where the highest quality was observed at DBH of 41 – 50 cm. It was also suggested that beech timber value was positively affected by high harvesting intensity (Poljanec & Kadunc 2013), because managed stands had always better stem quality. Such conclusion confirm the importance of thinning in achieving higher quality of beech stands (Kató & Mülder 1983; Korpeľ 1988; Šebík & Polák 1990; Štefančík et al. 1996). In order to improve the quality structure of beech stands, beech would have to be grown in beech-dominated stands or clusters, and thinned at the "correct time" (Poljanec & Kadunc 2013). Based on our experience it should be at age of 20 to 40 years in dependence on site and stand conditions.

The more valuable assortments forester manages to grow, the higher is the value production (converting timber into money). This corresponded with our observation that the highest proportion of the best quality assortments was in the forest stands managed by the free-crown thinning. At the same time, there was with the highest value production. When comparing individual localities (sites), the highest production value was found in the Zalobin, which was again related to the highest production potential of this site (largest stem diameter dimensions) compared to other plots (Bošeľa et al. 2016; Štefančík 2015). It should be noted that the real value production would be lower, because we did not consider damage of the assessed trees (Petráš & Nociar 1991).

It should be highlighted that the determined production value is rather "theoretical" or "gross" because it does not take into account costs or yield during the whole observation period (over 50 years). Costs for interventions would be the highest in stands with free-crown thinning, where 10 – 12 interventions were performed and the lowest (zero) on the control subplots. On the other hand, yields during the tending period were zero on the control subplot. We can speak about the "pure" production value after the cost-benefit analysis throughout the whole research period.

5. Conclusion

A comparison of the production value of beech stands aged between 83 – 105 years and managed in two different ways for a long-term (over 50 years) demonstrated the positive impact of tending on the stand quality. Tending of beech stands should focus on selective quality, i.e. an optimal number of individuals of the highest quality (target trees). Growing of "mass quality" through the tending focused on the whole stand, not on individual trees could lead to a higher value production, provided that there were no damage. On the other hand, such method of thinning is less favourable for the production of the most valuable assortments. After 50 years of observations, the value production was highest (€ m^{-3}) in stands managed by Štefančík´s free-crown thinning in comparison with heavy thinning from below and control subplots (without tending).

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ORIGINAL PAPER

Impact of applied silvicultural systems on spatial pattern of hornbeam-oak forests

Zdeněk Vacek[1]*, Stanislav Vacek[1], Lukáš Bílek[1], Jan Král[1], Iva Ulbrichová[1], Jaroslav Simon[2], Daniel Bulušek[1]

[1]Czech University of Life Sciences Prague, Faculty of Forestry and Wood Sciences, Kamýcká 129, CZ – 165 21 Prague 6 - Suchdol, Czech Republic
[2]Mendel University in Brno, Department of Forest Management and Applied Geoinformatics, Zemědělská 3, CZ – 613 00 Brno, Czech Republic

Abstract

The spatial pattern of forest closely affects tree competition that drives the most of processes in forest ecosystems. Therefore, we focused on evaluation of the horizontal structure of high forest, coppice with standards and low forest in hornbeam-oak forests in the Protected Landscape Area Český kras (Czech Republic). The horizontal structure of tree layer individuals with crown projection centroids and natural regeneration was analysed for durmast oak (*Quercus petraea* (Matt.) Liebl.), European hornbeam (*Carpinus betulus* L.) and small-leaved linden (*Tilia cordata* Mill.) stands. Horizontal structure of the tree stems of the studied tree species in high forest was random, in oak it was moderately regular. In coppice with standards it was random in oak, in hornbeam and linden it was aggregated within 3 – 5 m and random up to a larger spacing. In low forest at a distance of 4 – 6 m the horizontal structure of the three studied tree species was aggregated while it was random at a larger spacing. The horizontal structure of natural regeneration was aggregated in all forest types. In coppice with standards and high forest, parent stand had significant negative effect on the natural regeneration at smaller distance (to 1.4 m from the stem). Crown centroids were more regularly distributed than tree stems, especially in low forest (2.0 m) and in linden (2.3 m). Our results contribute to existing knowledge about silvicultural systems and their impact on hornbeam-oak forests with implications for forest management and nature protection.

Key words: forest management; horizontal structure; forest dynamics; natural regeneration; Czech Republic

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1. Introduction

Analyses of the spatial distribution of trees in forest stands, either horizontal (regular, random and aggregated) or vertical (especially coenotic position), improve our knowledge of dynamic processes on the stand level (Pretzsch 2009; Vacek et al. 2015a). Spatial structure expresses the tree distribution within a space and at the same time it reflects local living conditions in the environs of any tree while these microsite conditions influence the dynamic natural processes such as growth, mortality and regeneration of forest stands and particular trees (Courbaud et al. 2001; Petritan et al 2007; Bulušek et al. 2016; Cukor et al. 2017).

Numerous methods of the spatial structure analysis were described in many studies of the forest ecosystem ecology (Goreaud 2000; Pommerening 2002; Goreaud & Pélissier 2003; Perry et al. 2006; Pommerening & Stoyan 2006; Vacek et al. 2014). The majority of the studies are aimed at the position of the stem base. These studies compare forest stands and their stand types on the basis of the analysis of particular tree species, tree classes, diameter at breast height or height with respect to their spatial structure (Song et al. 2004) or they examine changes in the spatio-temporal structure in relation to silvicultural practices or natural processes such as growth, regeneration and mortality (Vacek & Lepš 1996; Ward et al. 1996; Goreaud 2000; Moser et al. 2002; Montes et al. 2004).

The interactions of the overstorey and understorey structure were described by Paillet et al. (2010), who confirmed that a change in the overstorey characteristics, mainly due to management in forests, has a great influence on the species richness of several taxonomic groups. Nevertheless, the reaction of plant species on spatial

*Corresponding author. Zdeněk Vacek, e-mail: vacekz@fld.czu.cz

pattern in understorey is usually different (Bulušek et al. 2016; Slanař et al. 2017). For this reason, of crucial importance for sustainability is to understand the effect of a change in forest structure through forest management practices on understorey (Burrascano et al. 2011).

Coppice forest is one of the oldest forest systems known from many countries all around the world (Fujimori 2001). Coppices were used as a wood source until the second half of the 19th century (Peterken 1993). Since then, coppices have practically disappeared (Kopecký et al. 2013) because of gradual conversion of low forests to high forests, especially in central and northwestern Europe (Matthews 1991; Peterken 1993). The main reason for forest conversion was increasing demand for timber of higher quality (Hédl et al. 2010) and policy of nature conservation that considered the low forest system as undesirable at that time (Szabó 2010). On the contrary, the abandonment of this system can cause a reduction in species diversity (Spitzer et al. 2008) because of structure homogenization that limits mainly light-demanding species (Kopecký et al. 2013). Such a trend was proved by Vanhellemont et al. (2014), who demonstrated a decrease in the representation of light-demanding species and an increase in maple (*Acer platanoides* L.) and hazel (*Corylus avellana* L.).

Nowadays we see an increasing interest for coppicing (Mason & MacDonald 2002; Müllerová et al. 2015), which has three main reasons: i) increasing demand for firewood (Šplíchalová et al. 2012), ii) increasing interest in nature protection, biodiversity and landscaping (Fuller 1992; Gurnell et al. 1992; Spitzer et al. 2008; Kopecký et al. 2013), iii) small forest owners consider this form of forest management as more suitable for their properties. Even though the interest in coppicing has increased, there is still a lack of information on the influence of silvicultural systems of forests on their ecological characteristics, properties of tree species growth and their structure (Fürst et al. 2007; Vacík et al. 2009; Matula et al. 2012).

Very little knowledge is available especially of the horizontal distribution of tree stems and crowns in stands of different silvicultural systems, i.e. in low forest, coppice with standards and in high forest (Sumida et al. 2002; Pretzsch & Schütze 2005). In general, it is to state that aggregated spatial distribution of trees, which is a result of several stems that have developed from one stump, are usually typical of low forest, unlike high forests (Jancke et al. 2009).

The objective of this study was to evaluate the influence of silvicultural system and management on the spatial pattern of hornbeam-oak forests and its development in National Nature Reserve (NNR) Karlštejn in the last 12 years (2002–2014). The particular aims were to determine the horizontal, diameter and height structure of tree layer and regeneration individuals across the main tree species [durmast oak (*Quercus petraea* (Matt.) Liebl.), European hornbeam (*Carpinus betulus* L.) and small-leaved linden (*Tilia cordata* Mill.)] and analyse the crown plasticity of trees. We tested a hypothesis that aggregated distribution of individuals in the tree layer is typical of low forest and that in coppice with standards and in high forest with increasing number of generative individuals the distribution changes towards random or regular. When comparing tree stem bases and tree crowns, we expect more regular distribution in the latter case.

2. Material and methods

2.1. Study area

Study site is situated in the NNR Karlštejn in the Protected Landscape Area (PLA) Český kras in middle Bohemia (Fig. 1). The study was conducted on 3 permanent research plots (PRP) in the Doutnáč forest complex

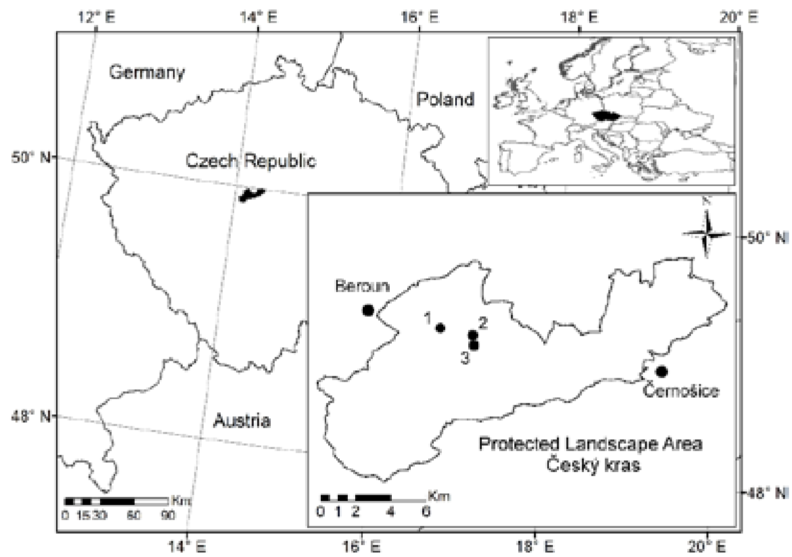

Fig. 1. Localization of hornbeam-oak forests on permanent research plots 1 – 3 in the locality Doutnáč, Protected Landscape Area Český kras.

Table 1. Basic site and stands characteristics of permanent research plots.

PRP	Tree species	Age	Height [m]	DBH [cm]	Stand volume [m^3 ha^{-1}]	Altitude [m]	Exposure	Slope [°]	Forest site type	Soil type	Forest form
1	Oak	83	17	19	68	405	NW	6	2W	Rendzina modal	High forest
	Beech		22	23	50						
	Linden		19	20	34						
	Hornbeam		16	17	18						
	Ash		22	24	12						
	Wild service tree		18	22	5						
	Maple		18	19	3						
2	Oak	107	17	22	58	433	NE	2	2A (2W)	Rendzina modal	Copicce with standards
	Linden		17	21	57						
	Hornbeam		15	16	18						
	Beech		20	24	22						
	Larch		21	29	15						
	Ash		18	18	8						
	Birch		19	23	2						
	Aspen		23	27	3						
3	Linden	86	18	19	58	415	SE	17	2W	Rendzina melanic	Low forest
	Hornbeam		16	15	42						
	Oak		17	19	37						
	Maple		18	18	5						
	Ash		18	18	3						

Note: oak – *Quercus petraea* (Matt.) Liebl., linden – *Tilia cordata* Mill., hornbeam – *Carpinus betulus* L., beech – *Fagus sylvatica* L., larch – *Larix decidua* Mill., ash – *Fraxinus excelsior* L., birch – *Betula pendula* Roth, aspen – *Populus tremula* L., wild service tree – *Sorbus torminalis* (L.) Crantz, maple – *Acer platanoides* L.; 2A – Stony-colluvial maple-beech-oak forest, 2W – Limestone beech-oak forest.

of 67.64 ha in size (Table 1). Approximately until the mid-20th century the forests of Karlštejn locality were managed as coppices with standards with a low share of the overstorey of standards and high intensity of felling in coppice forest and cattle grazing. After the NNR Karlštejn was declared in 1955, forest management activities were completely terminated in 2004.

Annual average temperature ranged between 8 – 9 °C and precipitation is around 560 mm (Tolasz et al. 2007). A territory of the study site is characterized by warm dry summer and cool dry winter with a narrow annual temperature range (group Cfb, Köppen 1936), where average length of the growing season is about 165 days. The geological bedrock is mainly composed of grey or red limestones. Prevailing soils are Rendzinas, Luvisols and Cambisols (Němeček et al. 2001). According to forest site type classification study area of hornbeam-oak forestsand scree forests belongs to *Fageto-Quercetum calcarium*.

2.2. Data collection

A theodolite was used for stem mapping within PRP 1 – 3 of 100 × 50 m (0.50 ha) in 2002. A FieldMap technology (IFER) was applied for a repeated measurement on PRP in 2014. During both measurements the position of all tree layer individuals of breast height diameter (DBH) ≥ 4 cm was localized. In the tree layer heights of the live crown base and crown perimeter were measured, minimally at 4 directions perpendicular to each other. DBH of the tree layer were measured with a metal calliper to the nearest mm while tree heights and heights of the live crown base were recorded with a laser Vertex hypsometer to the nearest 0.1 m.

Natural regeneration was mapped in 2014 on 10 × 50 transects on each PRP that were representative from the aspect of regeneration. For seedlings (measured all individuals 1 year and older) and saplings following characteristics were measured: position, height, height of the live crown base and crown width to the nearest cm.

2.3. Data analysis

For tree stems, crown centroids and natural regeneration, horizontal structure on particular plots was evaluated by Ripley's *L*-function (Ripley 1981) for all individuals and separately for the main tree species (durmast oak, European hornbeam and small-leaved linden). A test of the significance of deviations from the values expected for the random distribution of points was done by means of Monte Carlo simulations. The mean values of *L*-function were estimated as arithmetic means from *L*-functions computed for 1999 randomly generated point structures. Following stand structural indices based on a different type of calculation were computed: Hopkins-Skellam index (Hopkins & Skellam 1954), Pielou-Mountford index (Pielou 1959; Mountford 1961) and Clark-Evans index (Clark & Evans 1954). Among distribution indices based on the tree frequency in the particular quadrats David-Moore index (David & Moore 1954) was used. The quadrat size on PRP was 10 × 10 m (25 quadrats) and transects were divided into 80 quadrats (2.5 × 2.5 m each). The calculation of these characteristics was made using PointPro 2.1 software (Zahradník). Tab. 2 gives basic criteria of these indices. The relationship between spatial pattern of tree layer and natural regeneration were calculated by software R 3.1. (The R Foundation) by pair cross correlation function (Stoyan & Stoyan 1992).

Table 2. Overview of the indices describing the horizontal structure and their common interpretation.

Index	Reference	Mean value	Aggregation	Regularity
Index of non-randomness A	Hopkins & Skellam 1954	A = 0.5	A > 0.5	A < 0.5
Index of non-randomness α	Pielou 1959; Mountford 1961	α = 1	α > 1	α < 1
Index of aggregation R	Clark & Evans 1954	R = 1	R < 1	R > 1
Index of cluster size ICS	David & Moore 1954	ICS = 0	ICS > 0	ICS < 0

Statistical analyses were processed in the Statistica 12 software (StatSoft). The differences between tree crown plasticity of PRP and tree species were tested by one-way analysis of variance (ANOVA) and consequently tested by post-hoc comparison Tukey's HSD tests. In order to examine the interactions among stand characteristics and indices of horizontal structure, unconstrained principal component analysis (PCA) in Canoco 5.03 programme (Microcomputer Power) was applied. Data were centred and standardized before the analysis. The results of the PCA were visualized in the form of an ordination diagram.

3. Results

3.1. Tree layer

The diameter distribution clearly shows difference between the particular types of forest (Fig. 2). In the high forest (PRP 1), the lowest number of trees belongs to small diameter classes while this number is obviously the highest in low forest (PRP 3), and in coppice with standards (PRP 2) the values are rather closer to low forest even with higher variability. Left-sided shape of diameter classes with high density of trees is characterized for low forest. Contrary, low number of trees with gauss curve shape of diameter classes is typical for even aged high forest (Fig. 2).

The spatial pattern of tree layer of the low forest situated on PRP 3 was aggregated according to *A*, *α*, and *R* indices while it was random according to *ICS* index (Table 3). The *L*–function show that the highest intensity of aggregation occurred at tree distance of 0 to 3 m (Fig. 3). The tree layer of coppice with standards on PRP 2 was distributed randomly as shown identically by all computed structural indices (Tab. 3) and *L*–function (Fig. 3) with tendency to aggregation in 2014. The spatial pattern of trees of a high forest situated on PRP 1 was moderately regular according to *ICS* indices, while it was random according to A, *α* and R index (Fig. 3, Table 3). The regular and random pattern of the trees according to their distances was also indicated by the *L*–function (Fig. 3). In course of 12 years, the highest dynamics of horizontal structure was observed in coppice with standard and low forest, while high forest showed minimum changes in spatial pattern.

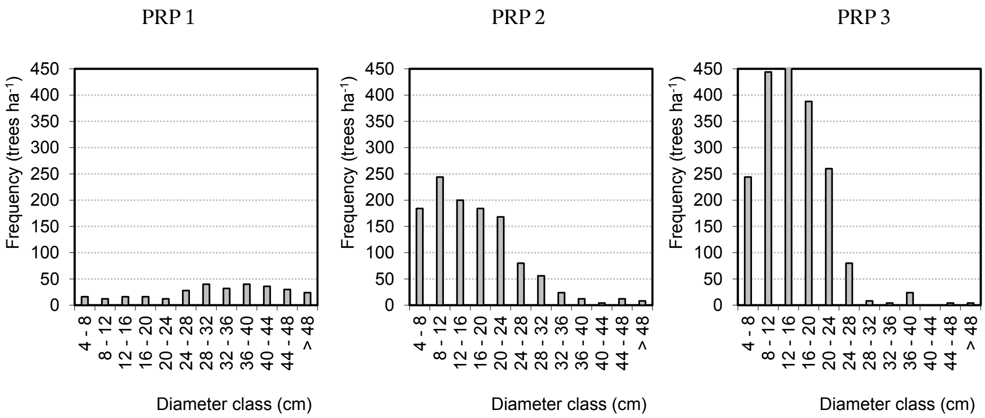

Fig. 2. Diameter structure of tree layer on permanent research plots 1 (high forest), 2 (coppice with standards) and 3 (low forest).

Table 3. Structural indices of stem bases for the main tree species and all tree individuals on permanent research plot 1 (high forest), 2 (coppice with standards) and 3 (low forest) in 2002 and 2014.

Index	Year	PRP 1				PRP 2				PRP 3			
		oak	hornbeam	linden	tree layer	oak	hornbeam	linden	tree layer	oak	hornbeam	linden	tree layer
A	2002	0.41	0.42	0.62	0.43	0.52	0.66^{A}	0.67^{A}	0.53	0.71^{A}	0.79^{A}	0.92^{A}	0.69^{A}
	2014	0.45	0.44	0.62	0.43	0.54	0.67^{A}	0.67^{A}	0.56^{A}	0.73^{A}	0.83^{A}	0.93^{A}	0.67^{A}
α	2002	0.90	0.98	1.75	0.92	1.16	1.37	1.54	1.15	1.68^{A}	1.87^{A}	2.81^{A}	1.44^{A}
	2014	0.99	1.06	1.76	0.95	1.25	1.30	2.07^{A}	1.17	1.86^{A}	2.08^{A}	2.93^{A}	1.39^{A}
R	2002	1.13	1.16	1.03	1.10	1.03	0.72^{A}	0.63^{A}	0.97	0.69^{A}	0.49^{A}	0.32^{A}	0.71^{A}
	2014	1.10	1.16	1.03	1.10	1.03	0.67^{A}	0.42^{A}	0.89^{A}	0.69^{A}	0.47^{A}	0.32^{A}	0.72^{A}
ICS	2002	−0.30	−0.27	0.01	-0.29^{R}	−0.07	0.24	0.84	0.15	0.53^{A}	1.21^{A}	2.73^{A}	0.25
	2014	−0.31	−0.23	0.01	-0.27^{R}	−0.07	0.25	1.81^{A}	0.45^{A}	0.64	1.10^{A}	2.68^{A}	0.21

Notes: $^{A, R}$ statistically significant (α = 0.05; A – aggregation, R – regularity).

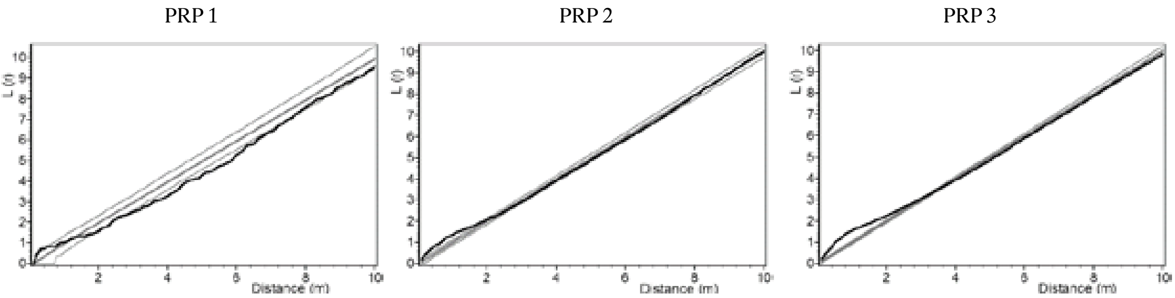

Fig. 3. Horizontal structure of tree layer on permanent research plots 1 (high forest), 2 (coppice with standards) and 3 (low forest) expressed by *L*–function; the bold grey line represents the mean course for random spatial distribution of trees and the two thinner central curves represent 95% interval of reliability; when the black line of tree distribution on plot is below this interval, it indicates a tendency of trees toward regular distribution, and if it is above this interval, it shows a tendency toward aggregation.

Horizontal structure of stem bases in the tree layer of the studied tree species (durmast oak, European hornbeam, small-leaved linden) in high forest on PRP 1 in oak was moderately regular at a spacing of 3 – 6 m (Fig. 4). The horizontal structure in hornbeam and linden was aggregated to a distance of 5.5 and 6 m, and farther it was also random. Horizontal structure in coppice with standards on PRP 2 was random in oak, aggregated in hornbeam and linden to a distance of 3 – 5 m and random at a larger spacing and tended toward random distribution in the course of dynamics. In low forest on PRP 3 in oak the horizontal structure of trees at a distance within 4 m was distinctly aggregated and indistinctly aggregated at a spacing of 4 – 8 m, and at a larger spacing it was random (Fig. 6). Only changes in horizontal structure occurred in the course of the studied 12 years.

The same information about horizontal structure of stem bases of the main tree species in the tree layer was provided by structural indices (Table 3). In high forest on PRP 1 the majority of the indices show regular tree distribution for most tree species across the forest stand. Only in linden the distribution was aggregated according to α and *ICS* indices while the *A* index shows this type of distribution in linden only. In coppice with standards on PRP 2 the majority of the indices suggest the aggregated distribution of trees for most woody species, and *R* and *ICS* indices indicate regular distribution in oak only. In low forest on PRP 3 the trees of all tree species were distributed in a significant aggregated pattern according to all indices.

3.2. Tree crown plasticity

A comparison of the indices of the centroids of horizontal crown projection areas with the centroids of stem base

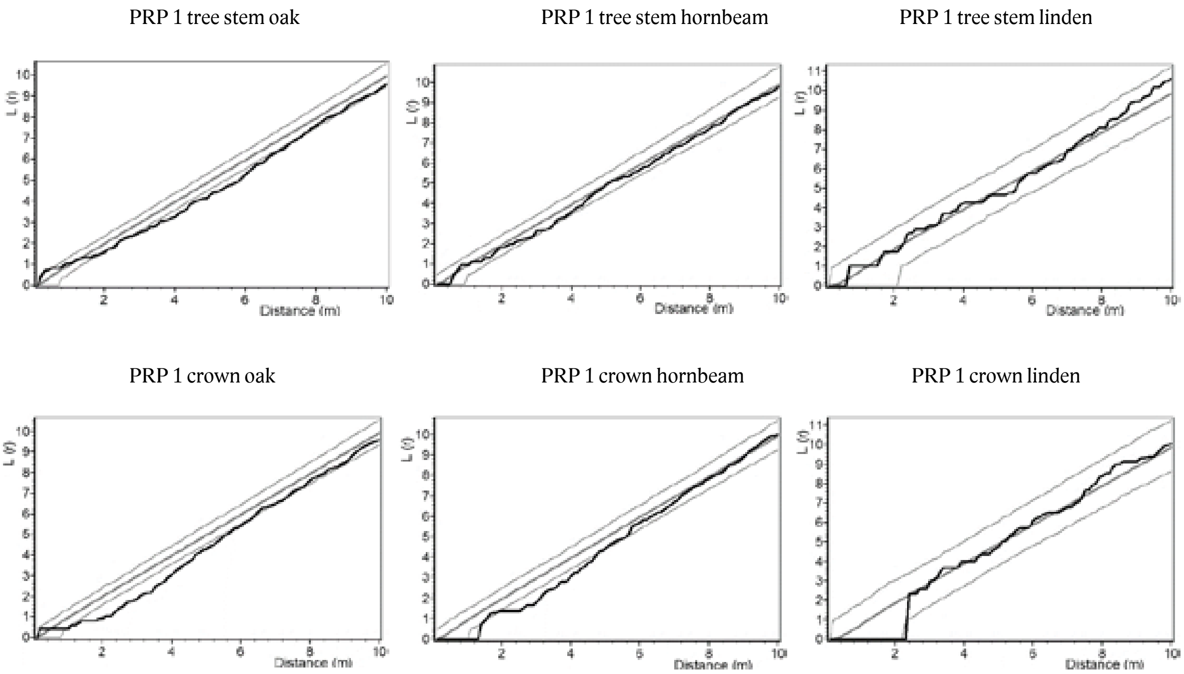

Fig. 4. Horizontal structure of tree stems and centres of crown projection areas of main tree species in high forest on permanent research plot 1 in 2014 expressed by *L*–function.

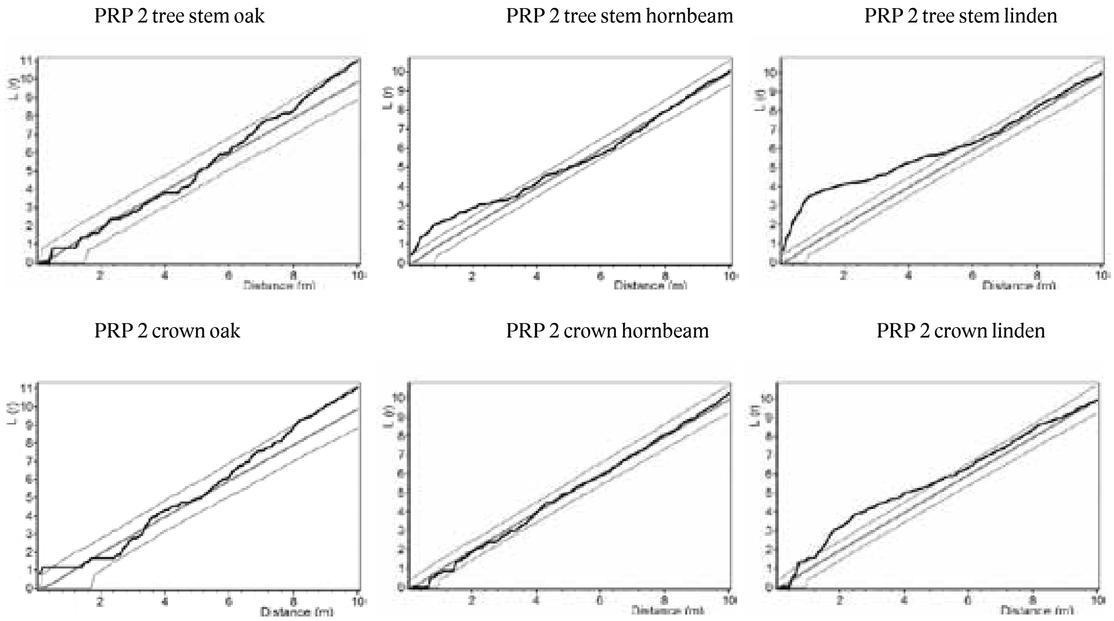

Fig. 5. Horizontal structure of tree stems and centres of crown projection areas of main tree species in coppice with standards on permanent research plot 2 in 2014 expressed by *L*–function.

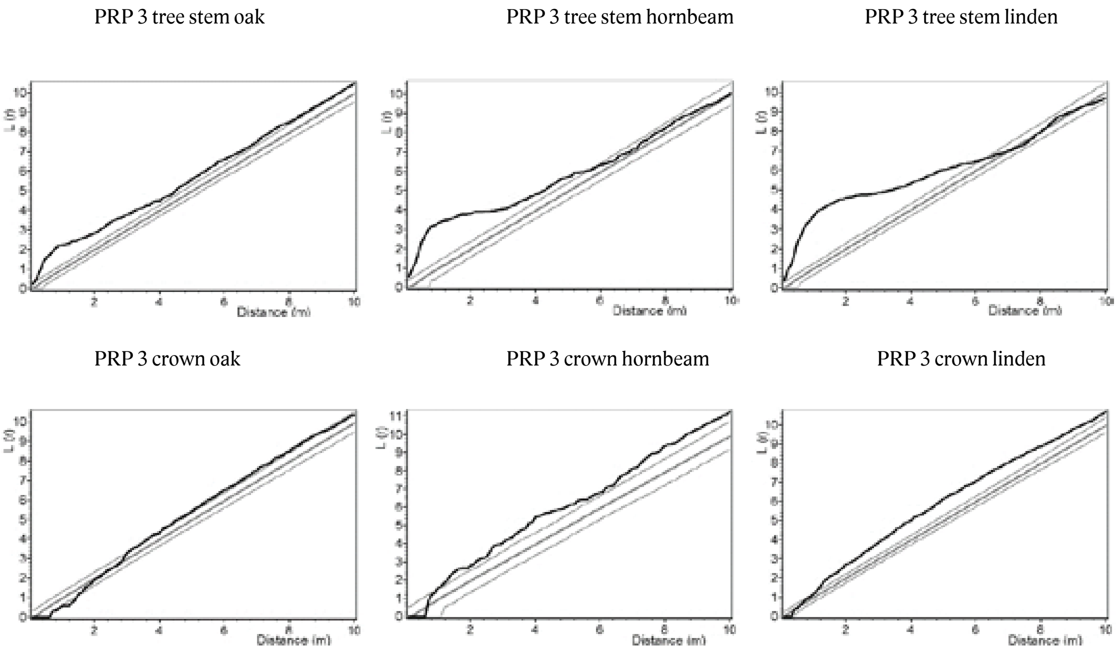

Fig. 6. Horizontal structure of tree stems and centres of crown projection areas of main tree species in low forest on permanent research plot 3 in 2014 expressed by *L*–function.

of trees shows a still larger shift towards regular structure (Table 4, Fig. 4 – 6.). Horizontal structure of crown centroids in high forest on PRP 1 was regular according all study indices, while the stems of trees were randomly distributed according to *A*, α and *R* indices. Similar situation occurred also in the low forest on PRP 3 and the coppice with standards on PRP 2, when the structure of the crown centroids was even regular according to *R* index (aggregation in tree layer).

In high forest on PRP 1 the arrangement of the crown centres according to the *L*–function was more regular than that of the stem bases, especially at a distance of 1.5 – 4.5 m (Fig. 4). In hornbeam the distribution of tree crowns was regular at a distance of 2 – 4.5 m while in the other cases their distribution was random similarly like in the stem bases. In linden the centres of crown projection areas were distributed randomly similarly like the stem bases. In coppice with standards on PRP 2 the

Table 4. Structural indices of centres of crown projection areas for the main tree species and all tree individuals on permanent research plot 1 (high forest), 2 (coppice with standards) and 3 (low forest) in 2014.

Index	Year	PRP 1				PRP 2				PRP 3			
		oak	hornbeam	linden	tree layer	oak	hornbeam	linden	tree layer	oak	hornbeam	linden	tree layer
A	2014	0.34^R	0.33^R	0.67^A	0.37^R	0.58	0.54	0.68^A	0.51	0.53	0.75^A	0.78^A	0.54
α	2014	0.81^R	0.78^R	2.08^A	0.83^R	1.46	1.11	1.42	1.01	1.26	2.20^A	2.33^A	1.13
R	2014	1.34^R	1.32^R	1.05	1.23^R	1.06	1.01	0.74^A	1.21^R	1.09	0.77^A	0.79^A	1.11
ICS	2014	-0.45^R	-0.42^R	0.03	-0.56^R	0.09	−0.18	0.54^A	0.02	−0.02	0.45^A	0.78^A	0.36^A

Notes: $^{A, R}$ statistically significant ($\alpha = 0.05$; A – aggregation, R – regularity).

distribution of oak crown centres was random according to the *L*–function, rather tending towards regularity at a distance of about 2.5 m (Fig. 5). In hornbeam the crown centres were distributed randomly, also at spacing within 3 m when the distribution of stem bases was aggregated. Similarly, like the stem bases, the centres of linden crowns at a spacing of 1.5 – 4.5 m are also distributed in an aggregated manner, at the other distances randomly. In low forest on PRP 3 the distribution of the oak crown centres to a distance of 1.5 m was moderately regular, at a distance of 1.5 – 3 m it was random and at larger distances it was on the border of randomness and aggregation (Fig. 6). In hornbeam and linden, the centres of crown projection areas were distributed in a distinctly less aggregated manner than the stem bases, particularly at spacing within 4 – 5 m. The crown centres at a distance above 6 m were an exception in linden that were arranged in an aggregated manner and the stem bases were distributed randomly.

The above described horizontal structure of the centres of crown projection areas of the study tree species was documented also by structural indices with some deviations (Table 4). On PRP 1 the tree distribution in most species (instead of linden) was regular across the forest stand according to the majority of the indices. On PRP 2 the majority of the indices show the random distribution of the centres of crown projection areas of trees in most tree species across the forest stand. Only in linden the distribution was aggregated. On PRP 3 the crown centres were distributed in aggregated manner almost in hornbeam and linden according to the studied indices. Oak was an exception in which the distribution of the crown centres was random.

Table 5 shows the values of distances of the crown projection area centres from the stem base on PRP according to the main woody species in 2014. The largest deviations of the crown centre from stem bases were determined in low forest where the average deviation of all tree species was 2.0 m, followed by coppice with standards – 1.2 m, and the smallest deviation was found out in high forest – 1.0 m. The differences were statistically significant ($P < 0.01$) only between low forest and coppice with standards on the one hand and high forest on the other.

Generally, higher degree of aggregation (higher for stems than crowns) was documented in low forest. The same trend was shown in coppice with standards in the case of linden and hornbeam. Oppositely, random to regular distribution for both stems and crown was shown in the case of high forest.

Table 5. The values of distances of the crown projection centres from the stem base for the main tree species and all tree individuals on permanent research plot 1 (high forest), 2 (coppice with standards) and 3 (low forest) and in 2014.

PRP	Forest form	Species	Distance [m]		
			average	minimum	maximal
1	High forest	Oak	1.0^a	0.0	5.0
		Hornbeam	1.1^a	0.1	4.9
		Linden	1.0^a	0.0	2.7
		Tree layer	1.0^A	0.0	5.0
2	Coppice with standards	Oak	1.1^a	0.1	3.8
		Hornbeam	1.2^a	0.2	4.7
		Linden	1.4^a	0.1	4.8
		Tree layer	1.2^A	0.1	4.8
3	Low forest	Oak	2.0^{ab}	0.2	4.9
		Hornbeam	1.6^a	0.1	4.1
		Linden	2.3^b	0.1	4.6
		Tree layer	1.9^B	0.1	4.9

Notes: significant differences ($P < 0.05$) among tree species on each PRP separately are indicated by small different letters and among all tree layer on three PRP are indicated by capital different letters.

3.3. Natural regeneration

Vertical structure of recruits for particular PRP 1–3 is given in Fig. 7. The height distribution clearly shows the opposite situation with recruits density compared to diameter structure of tree layer that is also related to the particular types of forest (Fig. 2). The lowest number of recruits with poor vertical structure was observed in low forest, while high forest shows rich natural regeneration characterized by high height differentiation.

According to the computed indices on PRP in locality Doutnáč the horizontal structure of natural regeneration on all PRP was aggregated with tendency to randomness (Table 6). The highest aggregation was observed in high forest. The clumpy distribution of recruits according to their distance is also documented by the *L*–function (Fig. 8). In term of tree species, the horizontal structure of natural generative regeneration was mostly aggregated according to the *L*–function, only sporadically it was random at a spacing of 5 – 10 m. Prevailing aggregated distribution of recruits was also confirmed by structural indices. They document that the pattern of natural generative regeneration was random only exceptionally (Table 6).

Results of pair cross correlation analysis showed that relationship between spatial pattern of tree layer and natural regeneration was negative (regular) at smaller distance on PRP 1 and 2 (from stem base to 1.4 m; Fig. 9). In low forest spatial pattern of all natural regeneration individuals in relation to canopy trees was evaluated as aggregated (positive relationship). Spatial pattern at

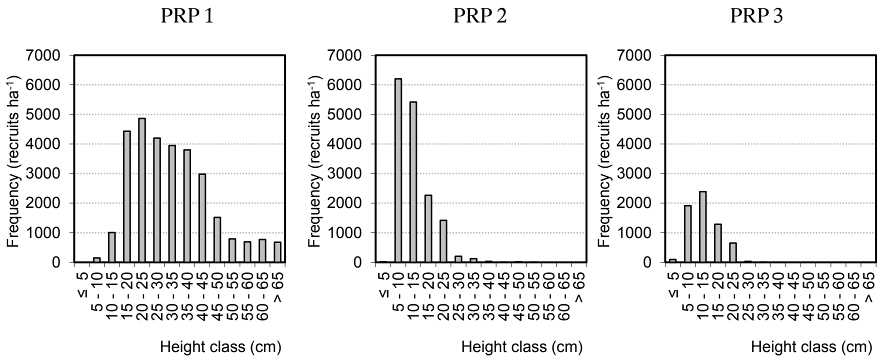

Fig. 7. Height structure of natural regeneration on permanent research plots 1 (high forest), 2 (coppice with standards) and 3 (low forest).

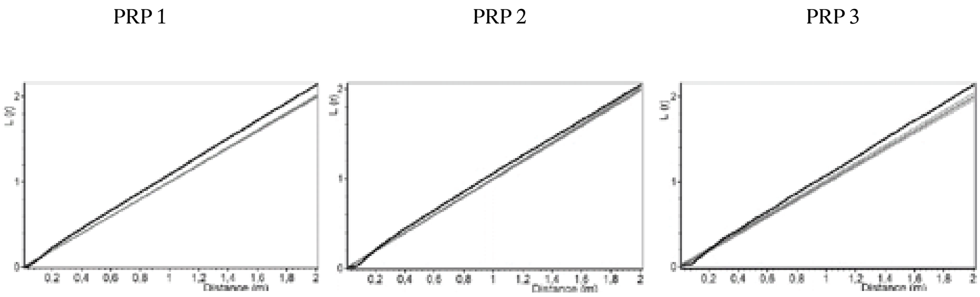

Fig. 8. Horizontal structure of natural regeneration on permanent research plots 1 (high forest), 2 (coppice with standards) and 3 (low forest) and expressed by *L*–function.

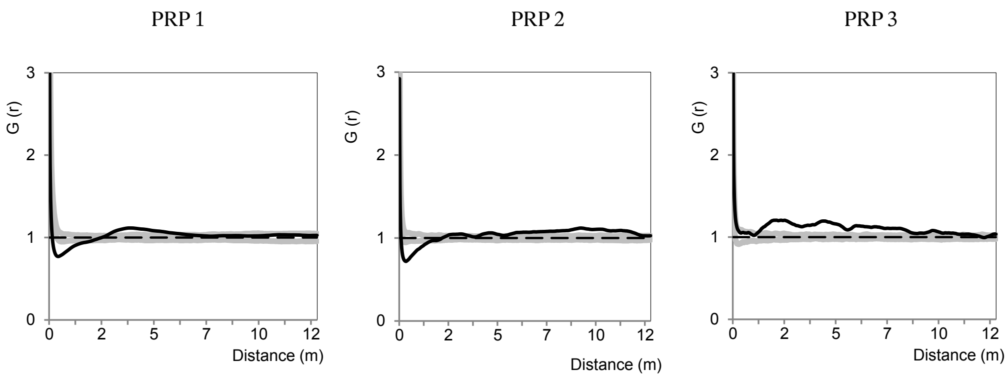

Fig. 9. Spatial relations of natural regeneration and the tree layer on the permanent research plots 1 – 3 expressed by the pair correlation function; the black line depicts the pair correlation function *G(r)* for real distances between individuals on the permanent research plots; two grey curves illustrate the 95% confidence interval for the random spatial pattern; *r* – radius defining distance between the selected points (trees and nature regeneration); G*(r)* > 1 indicates a clustering at distances *r*, while *G(r)* < 1 indicates a regularity in the respective distances *r*.

Table 6. Structural indices of natural generative regeneration for the main tree species and all tree individuals on permanent research plot 1 (high forest), 2 (coppice with standards) and 3 (low forest) in 2014.

Index	Year	PRP 1				PRP 2				PRP 3			
		oak	hornbeam	linden	regeneration	oak	hornbeam	linden	regeneration	oak	hornbeam	linden	regeneration
A	2014	0.61^A	0.71^A	0.86^A	0.60^A	0.63	0.71^A	0.66^A	0.52	0.59	0.90^A	0.42	0.55^A
α	2014	1.60^A	3.21^A	1.96	1.58^A	2.13^A	3.81^A	2.11^A	1.09	1.35	4.55^A	1.01	1.23^A
R	2014	1.03	0.88	0.44^A	0.92^A	0.92	0.92	0.99	0.95^A	0.95	0.70^A	1.15	1.02
ICS	2014	0.71^A	0.05	0.24^A	0.22^A	0.22^A	0.12	0.15^A	0.14^A	0.07	0.19	0.03	0.16^A

Notes: $^{A, R}$ statistically significant (α = 0.05; A – aggregation, R – regularity).

higher distances across the all plots was mostly random (no relationship).

3.4. Interactions of stand characteristics and horizontal structure

Results of the PCA analysis are presented in the form of an ordination diagram in Fig. 10. The first ordination axis explains 50.0% of the variability of data, the first two axes explain together 78.1% and the first four axes explain together 93.1% of the variability of data. The first x-axis represents horizontal structure of tree layer and crown centroids. The second y-axis represents production parameters, resp. canopy (crown projection area), stand volume, mean height and DBH. Canopy and number of trees were positively correlated with one another, while these parameters were negatively correlated with DBH and height of trees. Distance of the crown projection centres from the stem base was positively correlated with A and α aggregation indices (negatively with R index). This crown to stem distance increased with increasing aggregation of the stand. Moreover, aggregation indices of crown centroids were regularly distributed than tree stems. In terms of tree species, linden showed the greatest crown plasticity and tendency to aggregate structure, instead, the distribution of oak directed to regularity. The forest management had the greatest effect on the spatial pattern compared to tree species and stand parameters. Horizontal structure of the high forest directed to regularity, while the distribution of the low forest was highly aggregated.

4. Discussion

Our results confirmed, that the spatial pattern is an important aspect of the stand structure with regard to forest management (Bílek et al. 2011; Li et al. 2014; Slanař et al. 2017). Moreover it determines a microclimate in the forest stand, circulation of gaseous substances released and taken up by trees and other plants in the forest stand, stem shape and the mutual interactions with neighbouring trees (Mizunaga & Umeki 2001). Spatial pattern of forest stands influences many crucial ecosystem processes (Song et al. 2004; Pretzsch 2009) and horizontal structure plays a crucial role in interactions between the particular species and layers in plant communities (Dieckmann et al. 2000; Ngo Bieng et al. 2013), which also results from our study. These interactions participate in influencing the particular ecological processes such as growth, regeneration or mortality (Begon et al. 2006).

Relatively heterogeneous pattern was revealed on the studied plots according to structural indices: random representation prevailed in high forest and in coppice with standards, in low forest aggregated structure prevailed especially at a smaller spacing. These results are consistent with Jancke et al. (2009), who presented mostly aggregated distribution for low forests and random distribution for high forests. Results suggesting the random distribution of trees were also reported by Hui et al. (2007) or Li et al. (2012). Finally, the spatial pattern is strongly affected by site conditions (Vacek et al. 2015; Králíček et al. 2017). Structure influences the formation of the stand mosaic pattern in relation to the availability of light (Lhotka & Loewenstein 2008), water and nutrients

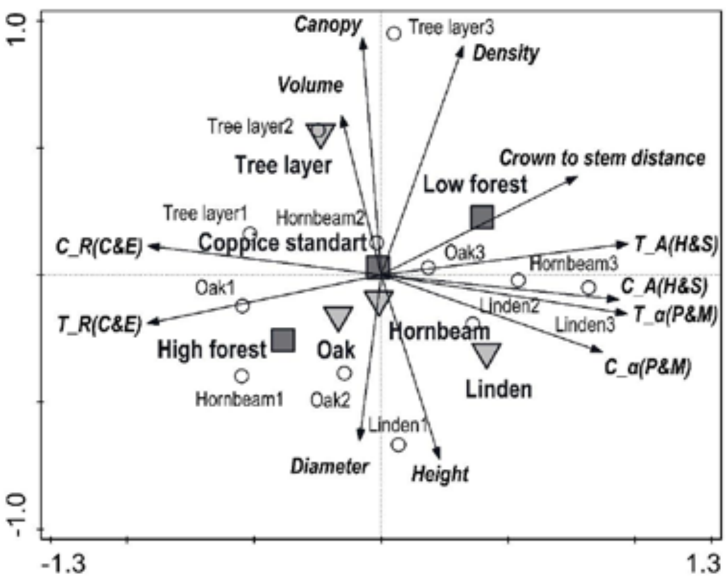

Fig. 10. Ordination diagram showing results of the PCA analysis of relationships between stand characteristics (*Density* number of live trees, *Diameter* mean quadratic diameter at breast height, *Height* mean height, *Volume*, *Canopy* crown projection area), and horizontal indices of tree layer (T) and Crowns (C) [*A (H&S)* Hopkins-Skellam index, *R (C&E)* Clark-Evans index, α *(P&M)* Pielou-Mountford index]. Code abbreviation: ■ forest form (*Low forest*, *Coppice with standards*, *High forest*); ▼ tree species (*Oak*, *Hornbeam*, *Linden*, *Tree layer*), • tree species and number of plots (1, 2, 3).

within the entire forest ecosystem (Prescott 2002; Lang et al. 2012).

Our results are also consistent with results of Petritan et al. (2014), who reported random distribution for dominant trees in the forest stand, aggregated distribution at a distance of 8-12 m for middle storey and highly aggregated distribution for the lowest storey. The random spatial pattern of the tree layer is typical of the majority of high forest stands at the stage of optimum. Similar results were obtained in mixed forests in protected areas of middle Europe (Szwagrzyk & Czerwczak M. 1993; Králíček et al. 2017; Vacek et al. 2016, 2017, 2018). Jancke et al. (2009) presented highly aggregated structure with two peaks for low forest when the one peak is at a distance of ca. 1 m and the other peak is at 5.6 m while the second peak is explained by the distance of stumps from which the low forest has sprouted. Aggregated structure was also reported by Getzin et al. (2008), who explained this structure on the basis of biotope heterogeneity; in our case this pattern of structure can be explained particularly by a different silvicultural system applied in the past. Similarly like in other studies of natural regeneration (Nagel et al. 2006; Ambrož et al. 2015), the spatial pattern of regeneration was aggregated. Aggregated structure for recruits can be further supported by limited (heavy) seed dispersal of some tree species (Getzin et al. 2008; Packham et al. 2012). Parent stand had significant effect on the spatial pattern of natural regeneration (Vacek et al. 2015b; Králíček et al. 2017). Negative interaction at smaller distances was observed in high forest and coppice with standards, but no relationship with tendency to aggregation was in low forest. Same situation because of vegetative regeneration was documented in Krkonoše Mountains (Bulušek et al. 2017). Microsite (Šticha et al. 2010; Vacek et al. 2015b), germination rate, seedling survival (Petritan et al. 2004), seed predation and dispersal by animals (Mosandl & Kleinert 1998) are other factors that can influence spatial pattern of young trees.

With respect to the relatively short observation period (Kucbel et al. 2012) of 12 years, the results of our study show dynamics in the horizontal structure of the tree layer of studied tree species but more pronounced differences were revealed between stem and crown spatial pattern in the same period. Crown plasticity allows more effective utilization of growth space, which provides a potential to maintain the high productivity of forest (Schröter et al. 2012; Bulušek et al. 2017). In our study, distances between crown centroids and stem base ranged from 1.0 m in high forest to 2.0 m in low forest; the highest mean distance was observed in linden on PRP 3 (2.3 m). For example within this range, displacement about 1.5 m was observed in beech forests in Czech Republic and Poland (Bulušek et al. 2017). Similarly, high crown plasticity was reported also by Olesen (2001) who documented also higher regularity of crown distribution compared to stems.

According to various research results (Li & Li 2003; Kint 2005; Zhao et al. 2009) the present structure of studied forest stands will change, nevertheless changes in horizontal structure are rather slow. More pronounced changes can be expected in vertical and diameter structure with ongoing natural regeneration and its development. On the other hand, with abandonment of forest management, spontaneous development of stands will probably lead to a certain unification of stand structural characteristics in a broader scale.

5. Conclusion

The study significantly confirms the hypothesis about the influence of forest management on the spatial pattern of hornbeam-oak forests and their stand structural characteristics. Doutnáč locality in the NNR Karlštejn has a heterogeneous structure of tree layers and natural regeneration on the studied plots as result of different silvicultural systems applied in the past. However, slightly heterogeneous habitat (slope, exposure) and stand conditions (age) of the compared plots must be considered when interpreting the present results. Despite this, we see evident tendencies in stand development for particular management systems. Generally, higher degree of aggregation was documented in low forest. The same trend was shown in coppice with standards in the case of linden and hornbeam. In the case of high forest, random to regular distribution for both stems and crown was shown. Crown centroids of trees were more regularly distributed than tree stems, especially in linden. Oppositely small crown plasticity was observed in oak. Saplings and seedlings were mostly aggregated, but with increasing size of recruits their spatial distribution mainly in the case of high forest tends to be random.

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ORIGINAL PAPER

Efficiency of the Slovak forestry in comparison to other European countries: An application of Data Envelopment Analysis

Miroslav Kovalčík

National Forest Centre - Forest Research Institute Zvolen, T. G. Masaryka 2175/22, SK – 960 92 Zvolen, Slovak Republic

Abstract

Efficiency improvement is important for increasing the competitiveness of any sector and the same is essential for the forestry sector. A non-parametric approach – Data Envelopment Analysis (DEA) was used for the assessment of forestry efficiency. The paper presents the results of the efficiency evaluation of forestry in European countries using DEA. One basic and two modified models (*labour* and *wood sale*) were proposed, based on available input and output data from Integrated Environmental and Economic Accounts for Forests and specific conditions of forestry also. The sample size was 22 countries and the data for 2005–2008 was processed. Obtained results show average efficiency in the range of 69 – 90% (depending on the model). Based on the results of the analysis following can be concluded: Slovak forestry achieved under average efficiency in comparison to other European countries, there were great differences in efficiency among individual countries; state of economy (advanced countries and countries with economy in transition) and region did not influence the efficiency statistically significant.

Key words: efficiency assessment; Data Envelopment Analysis; forestry sector; labour model; wood sale model

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1. Introduction

In the early 1990s, the states of Middle and Eastern Europe began to transform their economy to a market-oriented. This fact influenced whole economy as well as the forestry sector. Until 1990, the state managed all forests in Slovakia central planed the wood flow from producers to consumers. After 1990 due to restitution, the forestry sector was fragmented with increasing of the number of forest land owners and related decentralization of production activities. The process of forest land restitutions has not been completed yet. It stagnates mainly at small private forest owners. Other problem regarding to great number of small forest land owners and resulting land communities without legal subjectivity, is the restricted use of financial resources from the European funds and low interest to associate the small forest land owners. All these facts have influenced efficiency of forestry in a serious way. Therefore the question is how efficient is the Slovak forestry in comparison to other European countries?

Measuring and improving efficiency is important to encourage progress in any organization (Sowlati 2005). It has received increasing attention also in the forestry sector. Time and capital are essentially the largest inputs within forestry. In other words, forestry is a capital-intensive activity with very long production periods. This capital-intensity is fundamentally reflected in the efficiency analysis of forestry investments and in the evaluation of forest properties (Saastamoinen & Matero 2006). Other sector specific problems of performance measurement are: uniformity of product and production capacities within wood production, forests are ecosystems as well as production systems, product and benefit multiplicity, joint production and multiple use, geographical and biological variety and others.

Efficiency is in general defined as a quotient or ratio of outputs being produced to inputs being needed (Oesten & Roeder 2001). This quotient of aggregated outputs to aggregated inputs [1] is needed to determinate the efficiency for each production unit (Hoffmann 2006).

$$P_k = \frac{\textit{Aggregated outputs}}{\textit{Aggregated inputs}} \qquad [1]$$

where: P_k – efficiency of the production unit k.

Different methods and approaches have been used to evaluate the efficiency of production process. They are based on different principles and functions. In general, the evaluation of the efficiency is based on a production function, which specifies the relationship between the observed inputs and outputs. The production frontier

*Corresponding author. Miroslav Kovalčík, e-mail: kovalcik@nlcsk.org

indicates the maximum output that is possible to be produced under different input's combination and the ratio of the unit's output to the maximum possible outputs gives the measured efficiency. Those approaches, in which the production function is either known or estimated statistically, are the *parametric approaches***.** The disadvantages of these parametric approaches are that an explicit functional form of inputs and output is needed. General known are also the principles, in which the performance is being evaluated on the ground of a ratio of received revenues to spent costs (Cost Benefit Analysis). In many situations, the functional form of the production function is not known or it is difficult to estimate. Therefore it is desirable to compare single production units to real achievable production. This is possible by using non-parametric approaches. Farrell's method of computing the efficient function from a set of observation was the foundation for *non-parametric approaches* in measuring efficiency and productivity. In the non-parametric approaches, no assumptions are made about the form of the production function. Instead, a best practice function is built empirically from the observed inputs and outputs. This is the main advantage of this group of methods (Sowlati 2005). Detailed classification of different methods and approaches for evaluation of efficiency describe Schefczyk & Gerpott (1994). Evaluation methods can be systematized on the basis of three main criteria: 1. deterministic versus stochastic character of method, 2. parametric or non-parametric methods and 3. evaluation of efficiency by using mathematical programming models versus statistical approaches. Choice of the appropriate method and the way of the efficiency evaluation depend mainly on availability of data and the form of variables to be evaluated.

Although the first paper written on DEA appeared in 1978, and it has been applied in different areas since then, the forestry community has been slow in adapting the method and applying it to measure the efficiency of forest related activities (Sowlati 2005). There are few applications of DEA in forestry and forestry-related sectors, e.g. Kao & Yang 1991, 1992; LeBel 1996; Shiba 1997; LeBel & Stuart 1998; Yin 1998, 1999; Kao 2000; Hanninen & Viitala 2003; Bogetoft et al. 2003; Nyrud & Baardsen 2003; Hoffmann & Sekot 2004; Hofmann 2006; Sekot & Hoffmann 2007; Kovalčík 2007.

This explorative study assessed efficiency of forestry in European countries by using non-parametric approach – Data Envelopment analysis (DEA), compared the Slovak forestry efficiency according to other European countries and analysed differences in efficiency of individual countries or groups of countries.

2. Methods and material

2.1. Models of Data Envelopment Analysis being used

Data Envelopment Analysis (DEA) is a relatively new technique in productivity management for measuring efficiency of many homogenous entities. It is a linear programming method that can consider many inputs and outputs simultaneously to measure the relative efficiencies of the units to be evaluated, termed in this case decision making units (DMUs). In particular, the DEA models do not require the assignment of predetermined weights to input and output factors. In contradiction to the parametric approach, DEA does not require any assumptions about the production form. DEA models have been effectively applied for measuring the relative efficiency of the production units in many fields (Liu 2005).

The DEA approach was developed by Charnes et al. (1978) being called Charnes-Cooper-Rhodes (CCR) model. This model produces an efficiency frontier based on the concept of Pareto optimum under the assumption of constant return to scale. Later, Banker et al. (1984) developed the Banker-Charnes-Cooper (BCC) model that produces variable returns to scale efficiency frontier to measure the technical efficiency.

The use of both models allows the measurement of scale efficiency: for each production unit scale efficiency is the ratio between CCR and BCC efficiencies. Identical CCR and BCC results imply that the unit operates at an optimal scale. Main problem of non-parametric approaches is to find out the corresponding weights by using linear programming in order to maximize the ratio. To determine the efficiency of *s* units *s* linear programming problems must be solved to obtain the value of the weights (c_i) associated with inputs (x_i), as well as the value of weights (p_j) associated with outputs (y_j). Assuming *m* inputs and *n* outputs and transforming the fractional programming model into a linear programming model (Diaz-Balteiro et al. 2006). Let the unit *k* to be evaluated on any trial be designated as unit *o* where *o* ranges over 1, 2 ... *s*. The input orientated CCR model [2] can be formulated as follows (Charnes et al. 1978; Cooper et al. 2003):

$$\max p_1 y_{1,o} + \ldots + p_n y_{n,o}$$

subject to:

$$\begin{aligned} & c_1 x_{1,o} + \ldots c_m x_{m,o} = 1 \\ & p_1 y_{1,k} + \ldots + p_n y_{n,k} - c_1 x_{1,k} - \ldots - c_m p_{m,k} \leq 0 \; (k = 1 \ldots s) \\ & c_1, c_2, \ldots c_m \geq 0 \\ & p_1, p_2, \ldots p_n \geq 0 \end{aligned} \qquad [2]$$

The input orientated BCC model [3] has following form (Banker et al. 1984; Cooper et al. 2003), where p_o is the variable allowing identification of the nature of the returns of scale. This model does not predetermine if the value of this variable is positive (increasing returns) or is negative (decreasing returns):

$$\max p_1y_{1,o} + \ldots + p_ny_{n,o} - p_o$$

subject to:

$$\begin{aligned} & c_1x_{1,o} + \ldots c_mx_{m,o} = 1 \\ & p_1y_{1,k} + \ldots + p_ny_{n,k} - c_1x_{1,k} - \ldots - c_mp_{m,k} - p_o \leq 0 \ (k = 1 \ldots s) \\ & c_1, c_2, \ldots c_m \geq 0 \\ & p_1, p_2, \ldots p_n \geq 0 \end{aligned} \quad [3]$$

The outcome of DEA models is an efficiency score equals to one for efficient units and less than one for inefficient units. So, for inefficient units a ranking is given but for efficient ones no ranking can be given (Azizi et al. 2007). In non-parametric methods many units are calculated as efficient. To rank the relative efficient units, Andersen & Petersen (1993) developed a modified DEA model. Basic idea of this model is the exclusion of the evaluated unit from the analysis, it is excluded from the constrains. The unit under evaluation is being compared with linear combination of all other analysed units and efficiency can be higher than one (so called "*superefficiency*"). Modified model from Andersen & Petersen (1993) is otherwise identical with CCR- and BCC-model. More detail reviews of the DEA methodology are presented by Charnes et al. 1978; Banker et al. 1984; Seiford & Trall 1990; Ali & Seiford 1993; Cooper et al. 2003; Sengupta 2003.

Determining appropriate returns to scale is crucial for logging businesses to retain and enhance their competitiveness. Evidence regarding the nature of returns to scale in logging industry is mixed. Several studies suggested increasing returns to scale in this industry, whereas others indicated decreasing returns to scale. However, literature on returns to scale in the logging industry is limited (Stuart et al. 2010). Therefore both, the CCR- and the BCC-models were applied in this analysis to decompose the total efficiency and to evaluate the scale efficiency. The input-oriented models have been chosen, because inputs can be altered by management decisions and it is more difficult at outputs in forestry.

The calculation of the overall efficiency was performed by using computer program EMS. This program is able to compute the overall efficiency by input-, output- and non-orientated DEA models under assumption of constant, variable, non-increasing and non-decreasing return to scale (Scheel 2000). It is also able to compute the superefficiency via a modified model from Andersen & Petersen (1993). Overall efficiency of individual countries was further analysed according to other into analysis not included variables such as state of the economy and regional characteristics. This process is known as two stage approach (Timmer 1971).

2.2. Statistical testing of differences in efficiency

Testing of efficiency differences between the single groups of the countries was carried out by non-parametric statistical tests, because sample size was less than 50 and these tests do not require normal distribution function. Their disadvantage is the lower power of the statistical test. Statistical testing of difference significance was done by Mann-Whitney U test (in case of two independent interval and binary variables) and by Kruskal-Wallis test (in case of independent interval and nominal variables)[1].

Null hypothesis (there are no differences between the samples to be tested) and alternative hypothesis (there are significant differences in efficiency of the samples) were defined. Significant level was $\alpha = 0.05$. If the *p* value was less than the chosen significance level, then the null hypothesis was rejected and the alternative hypothesis was accepted. Statistical tests were done by program Statistika CZ, version 9.

2.3. Models being proposed

One basic and two modified models (labour and wood sale) were proposed, based on available input and output data. The task of the *basic model* was an overall efficiency comparison of input-output transformation. All variables are recorded in monetary units and as the inputs were chosen: *intermediate consumption (I_1), compensation of employees (I_2), fixed capital consumption, other taxes on production, interests and rents paid (I_3),* and as the output: *total output of the forestry, other subsidies on production and interest receivable (O).*

Labour input is still important indicator of forestry intensity, therefore the *labour model* was proposed, where the input (I_2) was recorded in technical units (number of employees). Through comparison of the basic model to the labour model, the labour productivity in technical units partially can be assessed and we can respond to the question of the influence of the staff compensation on the efficiency in individual countries.

In the *wood sale model* the output were divided into two parts: revenues from wood sale (O_1) and other revenues (O_2). In first variant [wood sale model 1] the wood sale was expressed in cubic metres and in the second variant [wood sale model 2] all variables were recorded in monetary units. Based on comparison of these two variants, the question of successful timber trade can be valuated.

2.4. Data source

The results of Integrated Environmental and Economic Accounts for Forests (IEEAF) from Eurostat database were used as a data source. The question is whether all countries applied the rules of IEEAF; therefore the data was transformed according to rules of Economic Accounts for Forestry (EAF). The sample size was 22 countries (as decision making units) and data for 2005–

[1] According to the type of variables it is possible to use One-Way ANOVA, but for non-normal data it is more suitable to use also non-parametric tests such as Kruskal-Waliss H test (Rimarčík 2007).

Table 1. Main features of variables included in the analysis.

Variable	Unit	Mean	Standard deviation	Min	Max
Intermediate consumption	(€/hectare)	104.88	90.06	5.56	317.36
Average labour input	(No. of empl./ 1000 hectares)	5.49	4.41	0.71	20.86
Compensation of employees	(€/hectare)	64.98	53.30	5.04	214.34
Fixed capital consumption, other taxes on production, interests and rents paid	(€/hectare)	32.56	30.62	0.12	125.30
Total output of the forestry	(€/hectare)	234.63	168.79	22.95	535.80
Wood sale	(m^3/hectare)	3.36	1.74	0.33	6.74
Revenues from wood sale	(€/hectare)	138.70	97.94	8.73	383.82
Other revenues	(€/hectare)	95.94	117.09	4.74	474.45

2008 was processed. All monetary values were expressed in euros; therefore no transformation from national currencies to euros was needed. Of course it is necessary to take in account the limited validity and consistency of the data, which may restrict the significance of results. Within the efficiency assessment in forestry is needed to avoid the extreme values and to include required number of units to be evaluated. Therefore five-year averages from 2005 to 2008 were calculated for each input and output variables. In this way, the value variation typical for the forestry sector was eliminated through the calculation of the mean, whereby the financial data were corrected by the country specific inflation (Harmonised Index of Consumer Prices – HICP) before calculating mean value. All input's and output's values were reduced by extension of the forests available for wood supply – FAWS (European Commission 2009). In this way, it is possible to compare this data per hectare as well as other indicators of IEEAF or EAF directly. Input data files were prepared in MS Excel. Main features of the variables included in the analysis are presented in Table 1.

Table 2. Efficiency of the forestry in European countries – basic model.

Country	CCR	R	BCC	R	SE	RTS
Slovakia	54.35%	18	62.68%	19	86.71%	DRS
Austria	100%	7	100%	7	100%	CRS
Bulgaria	100%	4	100%	8	100%	CRS
Switzerland	47.30%	20	100%	1	47.30%	DRS
Cyprus	23.16%	22	31.72%	22	73.01%	IRS
Germany	68.95%	14	100%	13	68.95%	DRS
Finland	100%	6	100%	10	100%	CRS
France	60.08%	16	63.11%	18	95.20%	DRS
Greece	100%	3	100%	3	100%	CRS
Hungary	100%	2	100%	4	100%	CRS
Italy	99.95%	9	100%	12	99.95%	IRS
Lithuania	65.07%	15	65.56%	17	99.25%	IRS
Netherlands	57.76%	17	100%	9	57.76%	DRS
Norway	69.79%	13	78.01%	16	89.46%	IRS
Portugal	85.05%	10	88.77%	14	95.81%	DRS
Romania	53.62%	19	55.26%	21	97.03%	DRS
Slovenia	78.62%	11	79.37%	15	99.06%	IRS
Great Britain	41.66%	21	55.84%	20	74.61%	DRS
Poland	100%	1	100%	2	100%	CRS
Czech Republic	77.81%	12	100%	6	77.81%	DRS
Sweden	100%	8	100%	11	100%	CRS
Spain	100%	5	100%	5	100%	CRS

Where: CCR – efficiency by the CCR-model, R – ranking based on superefficiency, BCC – efficiency by the BCC-model, SE – scale efficiency, RTS – return to scale, DRS – decreasing returns to scale, IRS – increasing returns to scale, CRS – constant returns to scale.

3. Results

3.1. Results of the basic model

By the CCR model, the average technical efficiency is 76.51%: Efficient countries are: Austria, Bulgaria, Finland, Greece, Hungary, Poland, Sweden and Spain. By the BCC model, these countries are also efficient: Switzerland, Germany, Italy, Netherlands and Czech Republic. The average efficiency is 85.47%. When applying the BCC model, more countries are efficient meaning that the models with variable returns to scale do systematically yield higher scores in comparison to the models under assumption of constant return to scale. Average scale efficiency is 82% (Table 2).

3.2. Target values

As it was mentioned, Data Envelopment analysis is based on linear programming and this fact allows of calculating the target values of inputs (in case of input orientated models) or outputs (in case of output orientated models) for each inefficient DMU. Target values for Slovakia are shown in Table 3. From the target values follows that all inputs should be lowered about 46% according to CCR- model and about 36% according to BCC-model to be efficient. It means the reducing the labour cost from 128 mil.€ to app. 64 mil.€, or to app. 64 mil.€, respectively.

Table 3. Target values of inputs for Slovakia by basic model.

	I_1	I_2	I_3	Efficiency
		€/hectare		%
Actual values	135.0	77.5	52.1	—
Target values by CCR model	73.4	42.3	28.4	54.35
Change in %	−46	−46	−46	—
Target values by BCC model	86.6	49.5	33.1	62.68
Change in %	−36	−36	−36	—

Where: I_1 – intermediate consumption; I_2 – compensation of employees; I_3 – fixed capital consumption, other taxes on production, interests and rents paid.

3.3. Labour productivity

Labour input is still important indicator of forestry intensity and also consequential cost item. Labour cost and number of employees per hectare vary in evaluated countries.

If we compare results of basic and labour model, it is possible to consider labour productivity and level of employee's compensation in individual countries. In general, labour productivity is measured as a ratio of output to the labour input (hour worked, numbers of employees or labour cost). Based on this comparison it is feasible to divide the countries into three groups. In first group are the countries, in which the technical productivity of labour is higher than economic; it means compensation of employees influences the efficiency negatively and do not correspond to technical productivity of labour. Switzerland, Germany, Netherlands, United Kingdom and Czech Republic are included in the first group. In the second group, the technical and economic labour productivity are the same. In this group are Cyprus, Finland, Greece, Italy, Poland Sweden and Spain. The third group is created from countries, in which the efficiency of the technical model is lower than economic model and it means there is room for higher wages at the comparable efficiency level. It is the biggest group: Slovakia, Austria, Bulgaria, France, Hungary, Lithuania, Norway, Portugal, Romania and Slovenia. Countries with economy in transition (except Poland and Czech Republic) belong to the third group.

3.4. Wood sale

Forestry receives majority of its incomes from the sale of wood and timber in most countries. The share of income from timber sales in this sample is around 76% and there are great differences in single countries. The share ranges from 53% in Netherlands to 95% in Lithuania. Based on results of this model and its variants, the question of successful timber trade can be valuated.

3.5. Efficiency according to the regional typology

Individual countries have different conditions concerning production characteristics (forest characteristics, forest types, intensity of production regimes, technology and so on), consumption characteristics (type and size of industry), general regional characteristics and other political, environmental, and social factors (Rametsteiner et al. 2006). They introduce and more in detail describe 7 regional types: globalized regions (Nordic–Baltic region), wood production oriented regions (Central Europe), plantation-oriented regions (Western Europe), broader, multifunctional forestry oriented regions (Western Europe), urban society service influenced regions (North-western Europe), countries in transition (Eastern Europe), low forest management intensity regions (Southern Europe).

Table 4. Efficiency of the forestry in European countries – labour model.

Country	Technical variant					Economic variant				
	CCR	R	BCC	R	SE	CCR	R	BCC	R	SE
Slovakia	44.13%	17	62.51%	16	70.60%	54.35%	18	62.68%	19	86.71%
Austria	83.97%	9	100.00%	5	83.97%	100.00%	7	100.00%	7	100.00%
Bulgaria	38.76%	20	43.17%	19	89.78%	100.00%	4	100.00%	8	100.00%
Switzerland	52.44%	15	100.00%	1	52.44%	47.30%	20	100.00%	1	47.30%
Cyprus	23.16%	22	31.72%	22	73.01%	23.16%	22	31.72%	22	73.01%
Germany	90.73%	7	100.00%	11	90.73%	68.95%	14	100.00%	13	68.95%
Finland	100.00%	5	100.00%	8	100.00%	100.00%	6	100.00%	10	100.00%
France	58.85%	14	65.15%	14	90.33%	60.08%	16	63.11%	18	95.20%
Greece	100.00%	3	100.00%	3	100.00%	100.00%	3	100.00%	3	100.00%
Hungary	35.52%	21	38.74%	21	91.69%	100.00%	2	100.00%	4	100.00%
Italy	99.95%	6	100.00%	10	99.95%	99.95%	9	100.00%	12	99.95%
Lithuania	42.34%	19	42.38%	20	99.91%	65.07%	15	65.56%	17	99.25%
Netherlands	85.59%	8	100.00%	7	85.59%	57.76%	17	100.00%	9	57.76%
Norway	58.88%	13	88.92%	12	66.22%	69.79%	13	78.01%	16	89.46%
Portugal	63.56%	11	88.77%	13	71.60%	85.05%	10	88.77%	14	95.81%
Romania	48.17%	16	55.26%	18	87.17%	53.62%	19	55.26%	21	97.03%
Slovenia	62.97%	12	64.12%	15	98.21%	78.62%	11	79.37%	15	99.06%
Great Britain	43.09%	18	55.84%	17	77.17%	41.66%	21	55.84%	20	74.61%
Poland	100.00%	1	100.00%	2	100.00%	100.00%	1	100.00%	2	100.00%
Czech republic	78.63%	10	100.00%	9	78.63%	77.81%	12	100.00%	6	77.81%
Sweden	100.00%	4	100.00%	6	100.00%	100.00%	8	100.00%	11	100.00%
Spain	100.00%	2	100.00%	4	100.00%	100.00%	5	100.00%	5	100.00%

Where: CCR – efficiency by the CCR-model, R – ranking based on superefficiency, BCC – efficiency by the BCC-model, SE – scale efficiency, RS – return to scale, DRS – decreasing returns to scale, IRS – increasing returns to scale, CRS – constant returns to scale.

Table 5. Efficiency of the forestry in European countries – wood sale model.

Country	Technical variant					Economic variant				
	CCR	R	BCC	R	SE	CCR	R	BCC	R	SE
Slovakia	55.73%	18	78.29%	18	71.18%	62.17%	17	69.48%	18	89.48%
Austria	85.09%	13	100.00%	10	85.09%	100.00%	7	100.00%	1	100.00%
Bulgaria	100.00%	5	100.00%	7	100.00%	100.00%	5	100.00%	9	100.00%
Switzerland	51.92%	20	69.42%	19	74.79%	53.00%	20	100.00%	2	53.00%
Cyprus	25.59%	22	43.09%	22	59.39%	24.78%	22	43.09%	22	57.51%
Germany	61.40%	17	100.00%	12	61.40%	78.52%	15	100.00%	12	78.52%
Finland	100.00%	10	100.00%	13	100.00%	100.00%	9	100.00%	13	100.00%
France	55.02%	19	59.25%	21	92.86%	61.33%	18	63.42%	19	96.70%
Greece	100.00%	4	100.00%	4	100.00%	100.00%	4	100.00%	6	100.00%
Hungary	100.00%	2	100.00%	5	100.00%	100.00%	2	100.00%	7	100.00%
Italy	97.79%	11	100.00%	14	97.79%	100.00%	11	100.00%	14	100.00%
Lithuania	100.00%	8	100.00%	11	100.00%	91.81%	12	100.00%	15	91.81%
Netherlands	100.00%	9	100.00%	1	100.00%	100.00%	10	100.00%	3	100.00%
Norway	76.04%	15	84.23%	16	90.28%	71.51%	16	78.15%	17	91.50%
Portugal	100.00%	7	100.00%	8	100.00%	100.00%	8	100.00%	10	100.00%
Romania	71.71%	16	100.00%	15	71.71%	55.51%	19	61.87%	20	89.72%
Slovenia	81.73%	14	81.86%	17	99.84%	87.98%	14	93.28%	16	94.32%
Great Britain	42.63%	21	59.93%	20	71.13%	41.83%	21	57.51%	21	72.74%
Poland	100.00%	1	100.00%	3	100.00%	100.00%	1	100.00%	5	100.00%
Czech Republic	86.88%	12	100.00%	2	86.88%	89.56%	13	100.00%	4	89.56%
Sweden	100.00%	6	100.00%	9	100.00%	100.00%	6	100.00%	11	100.00%
Spain	100.00%	3	100.00%	6	100.00%	100.00%	3	100.00%	8	100.00%

Where: CCR – efficiency by the CCR-model, R – ranking based on superefficiency, BCC – efficiency by the BCC-model, SE – scale efficiency, RS – returns to scale, DRS – decreasing returns to scale, IRS – increasing returns to scale, CRS – constant returns to scale.

For purposes of this analysis, some regional types were integrated and slightly modified. Four groups were created based on this typology and the countries assigned: 1. regions dominated by restitution issues "countries in transition"[2], regions dominated by low forest management intensity and with high importance of non-wood forest products[3], regions with multifunctional forestry[4], production regions based on plantations and globalized pulp and paper industry-orientated countries[5]. In this case non-parametric test for independent groups (Kruskal-Wallis H test) was used. The initial view would indicate that it is possible to see differences among individual groups, but they are not statistically significant in all cases. The most efficient were countries with low management intensity in basic and labour model and pulp and paper industry-orientated countries in wood sale models (Table 6).

3.6. Efficiency according to the state of economy

Another possibility is to divide the countries according to the state of their economy, into advanced countries and countries with economy in transition and then to analyse efficiency. In comparison of descriptive characteristics (mean, median, standard deviation, range and skewness) it is also possible to see differences (Table 7). The differences were not statistically significant in all models at the significant level $\alpha = 0.05$, except labour model and efficiency by BBC-model ($p = 0.048$).

Table 6. Differences in efficiency among individual groups of countries.

Efficiency – CCR model	n	Basic model	Labour model	Wood sale model 1	Wood sale model 2
Countries in transition	5	81.59	53.32	85.49	83.54
Countries with low management intensity	5	81.63	77.33	84.68	84.96
Countries with multifunctional forestry	4	63.54	70.16	63.81	70.60
Pulp and paper industry-orientated countries	8	76.61	72.11	85.69	86.64
H(3, n=22)		2.12	2.72	3.92	3.58
p value		0.547	0.437	0.271	0.311
Efficiency – BCC model	n	Basic model	Labour model	Wood sale model 1	Wood sale model 2
Countries in transition	5	83.59	59.94	95.66	86.27
Countries with low management intensity	5	84.10	84.10	88.62	88.62
Countries with multifunctional forestry	4	90.78	91.29	82.17	90.86
Pulp and paper industry-orientated countries	8	84.85	81.41	90.75	91.12
H(3, n=22)		0.50	4.23	1.35	0.32
p value		0.919	0.237	0.718	0.956

Where: wood sale model 1 – technical variant, wood sale model 2 – economic variant.

[2] Slovakia, Hungary, Romania, Bulgaria, Poland.
[3] Greece, Italy, Spain, Portugal, Cyprus.
[4] Germany, France, Switzerland, Czech Republic.
[5] Finland, Sweden, Norway, United Kingdom, Netherlands, Austria, Slovenia.

Table 7. Differences in efficiency according to the state of economy.

Efficiency – CCR model	n	Basic model	Labour model	Wood sale model 1	Wood sale model 2
Countries in transition	8	78.68	56.32	87.01	85.88
Advanced countries	14	75.26	75.73	78.25	80.78
p value		0.811	0.076	0.495	0.946
Efficiency – BCC model	n	Basic model	Labour model	Wood sale model 1	Wood sale model 2
Countries in transition	8	82.86	63.27	95.02	90.58
Advanced countries	14	86.96	87.89	86.85	88.73
p value		0.585	0.048	0.539	0.891

Where: wood sale model 1 – technical variant, wood sale model 2 – economic variant.

4. Discussion

Experience with application of DEA has shown that t can be appropriate approach to efficiency evaluation and an alternative and completing method for performance measurements using other methods and approaches also. Obtained results show average efficiency in range of 69 – 90% (depending on the model). It was comparable to those in similar analysis using DEA in wood-based industry (Yin 1998, 1999; Kao 2000; Nyrud & Baardsen 2003; Diaz-Balteiro et al. 2006).

This paper is based on the best available data, but there are still uncertainties. Especially the limited validity and consistency of the data may restrict the significance of the results and it is also questionable to what extend are the national methodologies in applying either the Economic Accounts for Forestry or Integrated Environmental and Economic Accounts for Forests and their practical rules. Main problem of applying either the system of Economic Accounts for Forestry or system of Integrated Environmental and Economic Accounts for Forests is data availability at national level.

According to the first group, efficiency results are probably influenced by high social and health fund contribution and the resulting higher labour cost. Other reasons for differences between technical and economic models could be the insufficient application of new ecological technologies, small-scale forest ownership and the resulting effective forest property management, and so on. Important factor could be also the amount of intermediate consumption, in which various shares of forestry services in individual countries could be included.

The efficiency of the groups created according to regional classification is comparable to the index of globalization estimated by Rametsteiner et al. (2006), which was lowest in "countries in transition" and similar in other groups.

5. Conclusions

The purpose of this study was to determine to what extend the efficiency of Slovak forestry is different in comparison to other European countries. Based on the efficiency analysis, the following results can be concluded:

– There are great differences in efficiency among individual countries; it could be caused by different approaches to forest management, providing of forest services to public, supporting of forestry, share of public ownership, policy goals and other realities.
– Based on the results of the labour model it is feasible to divide the countries into three groups: in first group was the compensation of employees higher than the technical productivity of labour, in the second group these factors were the same or similar and in the third one was room for higher wages at the comparable efficiency.
– The state of economy (advanced countries and countries with economy in transition) and region do not have statistically significant influence on efficiency.
– Slovak forestry has achieved less than average efficiency in comparison to other European countries; main causes are probably: obsolete technologies, machines and devices used, lower utilization of harvestor technologies, lower support from public sources, environmental and natural conditions, but on the other hand lower wages in Slovak forestry than in most EU countries influenced the efficiency in a positive way.

All conclusions are based on simplified analysis and valid for this sample. The results can be different for another sample size. It is connected with the main disadvantages of this method, which are: inclusion or exclusion of variables can affect the results significantly, the number of efficient firms on the frontier tends to increase with the number of inputs and output variables, Such analysis can be extended and modified according to specific conditions and requests.

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ORIGINAL PAPER

Communities of woody vegetation and wood destroying fungi in natural and semi-natural forests of Kyiv city, Ukraine

Olena Blinkova[1]*, Oleksandra Ivanenko[2]

[1]National University of Life and Environmental Sciences of Ukraine, 03041, Kyiv, 15, Heroyiv Oborony st., Ukraine
[2]Institute for evolutionary ecology of the National Academy of Sciences of Ukraine, 03143, Kyiv, 37, Lebedeva st., Ukraine

Abstract
Selected forestry parameters were investigated in the system of trees and wood-destroying fungi in the natural forests of the Kyiv city on a gradient of recreational transformation. We investigated the vitality, age compositions, and health condition of woody plants (11 species), and species, systematic, trophic and spatial compositions of xylotrophic fungi (51 species, 224 findings of xylotrophs representing 34 genera, 20 families, 7 orders of divisions Basidiomycota; class Agaricomycetes). The results showed that communities of woody vegetation and xylotrophic fungi in forests depend on the degree of recreational transformation of the environment. Vitality, age compositions and health condition of trees altered species composition of xylotrophs.

Key words: consortium relation; natural forests; woody plants; xylotrophic fungi

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1. Introduction

Communities of woody vegetation and wood-destroying (xylotrophic) fungi of forest ecosystem play significant role in issue of evolutionary ecology. The actuality of the objects is stipulated by the core role of forests in biosphere stability, preservation of landscape and especially biotic variety (Mirkin & Naumova 1998). Xylotrophic fungi are decomposers, obligatory components of woody vegetation. Xylomycobiota shows the high sensitivity to environmental changes (Schmidt 2006). In other cases, they cause of root and stem rot, negatively affect the health condition of trees. Due to this, the study of communities of these organisms in phytocoenoses of natural origin is expedient. Problems of relationship between the communities of woody vegetation and wood-destroying fungi in urban conditions have long attracted the attention of scientists. The composition of xylotrophic fungi is a reflection of parameters of natural forest development and state, which evidences the unity of components at all hierarchic levels of their inter-links. In the phytocoenoses, which are not durable for anthropogenic or natural reasons, the resistance of biota species to negative influence is significantly diminished and in general, the attrition of the weakest plants and the reformation of species composition and ecosystem structures increases (Arefev 2010). Thus, the communities of woody vegetation and xylotrophic fungi is an important basis for correct indicating the state of forest ecosystems, has not been sufficiently studied so far. This concerns the necessity of complex analysis of evolutionally formed consortium relation between woody vegetation and xylotrophic fungi. The compositions of xylotrophic fungi and woody vegetation are reflection of parameters of artificial phytocoenoses' development and state (Blinkova & Ivanenko 2014, 2016). Due to the impact of urbanization on natural ecosystems, forests in Kyiv have undergone an intensive recreational transformation, which is manifested in breach of structural and functional integrity of phytocoenoses' organisation. This in turn essentially affects the functioning of communities of the dominant woody species and xylotrophic fungi in urban ecosystem. It is also notable that there is few data on communities of wood-destroying fungi and woody vegetation from the territory of natural and semi-natural forests of Kyiv. The aim of the study was to describe communities of woody vegetation and xylomyco-complex of natural and semi-natural forests in urban conditions depending on the degree of recreational transformation of the environment.

*Corresponding author. Olena Blinkova, e-mail: elena.blinkova@gmail.com, phone: +38 0637 413 247

2. Materials and methods

2.1. Study site

Communities of trees and xylotrophic fungi in the urban conditions of Kyiv were studied in natural and semi-natural forests belonging to the nature reserve fund of Ukraine (Table 1). The forests were selected for the analyses since human impact is maximised in these objects. Kyiv is located on the right and left banks of the Dnipro river at the border between the Forest-Steppe zone and the Polissya of Ukraine following the geo-botanical division of Ukraine. The area of the city is 835.6 km², of which 31.300 ha are natural and semi-natural forests. The average annual temperature over the period 2014–2015 was 8.6 °C. The vegetation season (> 5 °C) lasted 204 days and started on April 10. The climate is of a semi-continental type for the Forest-Steppe zone. The geomorphologic structure of Kyiv belongs to 3 geomorphologic zones: South Polissya, Dnipro, Azov-Dnipro (Bilyk 1977). Soddy-podzolic soils, gray forest soils and sod meadow soils are the main soil types in Kyiv (Gavrilyuk 1956). In the survey conducted 15 – 30 September 2015 we distinguished four localities of forests in Kyiv city (Table 1).

2.2. Description of methods

Within each studied forests, the mapping of dominant tree vegetation was carried out on experimental plots (EP1-EP4). The experimental plots that are representative of the forests were chosen by reconnaissance method of study. Each experimental plot was established according to detailed route-method of study (Dilis 1974; Vasilevich 1992; Mirkin 1998). The area of each experimental plot was 0.5 – 0.7 ha. Taking into account basic characteristics of recreational changes of elements of structural and functional organization of forests in Kyiv EP was divided according to the degree of the recreational transformation rate from minimal to maximal consequences. In general, the stages of recreational transformation were appraised according to Rysin (2003; Table 2).

2.2.1 Tree health conditions assessment and vitaly structure

The health condition of trees (category of state trees) was appraised in accordance with the Sanitary Forest Regulation in Ukraine (2016). In order to avoid the influence of the irregular intensity of sylvicultural practice upon the index of stand state, for each category of states the weighted average Kraft classes (WAKC; vitality composition of tree vegetation) was calculated as the sum of the number of trees of each Kraft class was multiplied by stand state index (I–V), divided by the total number trees in a certain category of state (Eytungen 1949). For each stand, forest mensuration parameters were estimated: age (A); average weighted diameter (D_{ave}), height (H_{ave}), fluctuations range (D_{min}–D_{max}; H_{min}–H_{max}) and standard deviation (S.D.), stand density (N), stand basal area as a sum of tree areas (G_n). Morpho-metric parameters were calculated by an optical altimeter Suunto PM-5 and callipers Waldmeister 100 alu. Mechanical damaged woody plants were the trees and bushes that have cut or sawn live branch, injure on the stem reaching cambium or prominent features of such damage independent of time such were inflicted.

Table 1. General characteristics of studied forests.

No. EP*	Name of tract	GPS coordinates	Year established	Affiliation to the nature reserve fund	Area [ha]	Dominant tree vegetation
1	Holosiivskyi lis	50°22′01′′N, 30°30′30′′E	2007	National Natural Park "Holosiivskyi"	1879.43	*Acer platanoides* L., *Carpinus betulus* L., *Quercus robur* L., *Tilia cordata* Mill., *Ulmus glabra* Huds.
2	Teremky	50°21′40′′N, 30°27′15′′E	2007	National Natural Park "Holosiivskyi"	93.8	*Carpinus betulus* L., *Prunus avium* L., *Quercus robur* L.
3	Lysa Hora	50°23′42′′N, 30°32′53′′E	1994	Historical and cultural monument-museum "Kyivska fortetsia"	137.1	*Acer campestre* L., *A. platanoides* L., *Carpinus betulus* L., *Fraxinus excelsior* L., *Quercus robur* L., *Tilia cordata* Mill.
4	Bila dibrova	50°54′68′′N, 30°67′22′′E	1978	Reserve of local importance "Bila dibrova"	3.0	*Acer platanoides* L., *Betula pendula* Roth, *Pinus sylvestris* L., *Prunus avium* L., *Quercus robur* L., *Sambucus nigra* L.

*The location of experimental plots.

Table 2. Stages of recreational digression establishment.

Digression stage	State of		
	Herbaceous cover and leaf-litter	Tree stratum and undergrowth	Soil surface
1	full species composition of herbaceous plant, projective cover is 90 – 100%, leaf-litter is not broken	trees are healthy, undergrowth is numerous and different ages	I stage of digression
2	appearance of ruderal, pratal herbaceous species, projective cover is 80 – 90%, leaf-litter begins to trample down	trees are weakened, undergrowth is numerous but not different ages	II stage of digression
3	share of ruderal, pratal herbaceous species is 5 – 10%, projective cover is 70 – 80%, leaf-litter is trample down	trees are weakened or heavily weakened, undergrowth is limited	III stage of digression
4	share of ruderal or pratal herbaceous species is 10 – 20%, projective cover is 50 – 70%, leaf-litter begins to deteriorate	trees are heavily weakened, low viability of undergrowth is located clumps	IV stage of digression
5	share of ruderal or pratal herbaceous species are dominating species, projective cover is 0 – 50% , leaf-litter is completely absent	trees are heavily weakened or wilting with significant mechanical damage, undergrowth is absent	V stage of digression

2.2.2 Soil surface layer and herbaceous cover assessment

The state of soil surface layer was showed according to the following categories: 1 – undisturbed soil; 2 – weakened mulch (single passes); 3 – footpath in mulch; 4 – footpath or road without mulch; 5 – footpath or road with washaways; 6 – deposition and washaways made by recreants descending on steep slopes. The stages of digression of soil surface layer were the following: I – under which the 3rd, 4th, 5th and 6th categories of disturbance cover up to 2% of the area of experimental plot; II – from 2% to 10% of area; III –10% – 25% of area; IV –26% – 40% of area; V – over 40% of the site area (Polyakov 2009). Clogging of solid waste of the soil surface was defined as the share clogging area of the total area of the experimental plot.

As for herbaceous cover taxa nomenclature was adopted according to Cherepanov (1995). The species composition and total projective cover of dominant herbaceous plants was determined.

2.2.3 Data collection and determination of fungi

According to Arefev (2010) the measuring unit is a host tree, on which carpophores of certain fungi species were detected. The collection of factual evidence was carried out during the period of visible growth and formation of carpophores of xylotrophic fungi in the vegetation period. Every detected species was photographed. Photographs were taken with Nikon Coolpix L830 digital camera. The species that were easily identified "in oculo nudo" and did not require additional micro-morphological studies were not included in exsiccates. The determination of fungi species was assessed with the methods of Clémençon (2009), Koukol et al. (2014). The scientific names of fungi and their macrosystems are according to MycoBank (Robert et al. 2005). Author´s names of species of fungi are according to Kirk & Ansell (1992).

2.2.4 Assessment of trophic and spatial compositions of fungi

Analysis of trophic composition of xylomycobiota was done by the distribution of wood destroying fungi by trees. We distinguished four trophic groups of xylotrophs: eurytrophes of II rank (consorts of coniferous and deciduous trees), eurytrophes of II rank on coniferous trees, eurytrophes of II rank on deciduous trees and stenotrophes (consorts of only one genus of woody plants). The dead substrate of the host tree of xylotrophic fungi was divided into deadwood, falling wood (branches and stems) and stump depending on the morpho-metric parameters. Analysis of spatial composition of xylomycobiota was effected by the distribution of wood destroying fungi by root, ground, boot, stem and photosynthesising myco-horizons (Blinkova & Ivanenko 2016).

2.2.5 Statistical analyses

Menhinik's Index was used for determining the xylomyco-biota species richness. Shannon's Index of diversity was used for the generalised assessment of wood-destroying fungi diversity. Pielou's Index was used for the generalized assessment of equitability of xylomycobiota (Schmidt 1980). The similarity of formed community "tree-xylomycobiota was studied using cluster analysis (Origin. 2015. Origin 8.6. OriginLab Corp., Northampton, MA) by the weighted average indicators of investigated species and fungi at each experimental plots. The standardized Euclidean distance was selected for the assessment of distance.

3. Results

Our assessment in the studied area showed that forests ranked by the effects of human impact and, accordingly, stages of recreational digression of territory: 1 – "Holosiivskyi lis", 2 – "Bila dibrova", 3 – "Lysa Hora„" 4 – "Teremky".

The mycological study detected altogether 51 species of macromycetes (224 findings of xylotrophic fungi), 34 genera, 20 families, 7 orders of division Basidiomycota (class Agaricomycetes) at all experimental plots (Appendix 1). In general, 451 individuals (11 species) of woody plants were studied.

3.1. Assessment results at the tract "Holosiivskyi lis"

The tract EP1 (0.7 ha) is an array of natural hornbeam oakery on gray forest loams. The first storey composed of *Quercus robur* L. and *Carpinus betulus* L. The second storey composed of *Tilia cordata* Mill., *Acer platanoides* L., *Ulmus glabra* Huds. The stand parameters of trees were followed (Table 3). The understorey was composed biogroups of *Corylus avellana* L., *Euonymus europaeus* L., *Euonymus verrucosa* Scop., and *Crataegus oxyacantha* L. The herbaceous vegetation was composed primarily of miscellaneous herbs. Projected cover of herbaceous storey was 93.5%. *Asperula odorata* L., *Brachypodium sylvaticum* L., *Carex sylvatica* L., *Lamium galeobdolon* Subsp., *Poa nemoralis* L., *Polygonatum odoratum* (Mill.) Druce, *Sanicula europaea* L., *Stellaria holostea* L. were dominated. Mechanically damaged trees were not registered. The total indicator of the state soil surface was I stage of digression. The overall stage of recreational transformation was I. At EP1 we detected 25 species (68, findings) of wood-destroying fungi presented 22 genera, 13 families, 7 orders on 5 species of trees. 70.6% findings of fungi were eurytrophes of II rank on deciduous trees and 22.1% – eurytrophes of I rank. Stenotrophes (7.3%, findings) was represented by only one species: *Fistulina hepatica* (Schaeff.) With. (Appendix 1). At EP1 the maximum number of wood-destroying fungi (44.1%, findings) were occurred in the ground myco-horizon, and 26.5% in the stem myco-horizon, 16.2% in the photosynthesising myco-horizon, 13.2% in the stumps myco-horizon (Appendix 2). 9 species of xylotrophic fungi were detected on *Quercus robur* L. Among them there were three parasite species, and their share in the phytocoenosis comprised only 10.0%: *Fistulina hepatica* (Schaeff.) With. (on tree of I Kraft class, II–III state categories; one deadwood; stumps, D_{ave} = 105.0 cm), *Inocutis dryophila* (Berk.) Fiasson et Niemelä (on tree of III Kraft class, IV state category) and *Phellinus robustus* (P. Karst.) Bourdot et Galzin (on trees of I Kraft class, III–IV state categories; one deadwood).

The analysis of the vitality of *Quercus robur* L. showed that 64.7% findings of wood-destroying fungi occurred mainly on trees of I Kraft class (64.0%, trees). The lowest number of fungi (5.9%, findings) occurred on trees of III Kraft class (12.0%, trees). The shares of trees of II and III Kraft classes were the same. WAKC of wilting trees (1.8) showed that the share of trees of I and II classes Kraft in this category gradually increased (Table 4). The analysis of the health conditions of *Quercus robur* L. revealed that the stands were heavily weakened (I = 1.68).

The proportion of healthy trees was below 24.0%. Others were weakened trees to varying degrees, including 5.5% recently dead stands. The greatest number of xylotrophs (29.4%, findings) occurred on 8.0% trees of IV state category. An equal distribution of xylotrophs (23.5%, findings) was detected on weakened (38.0%, trees) and heavily weakened trees (24.5%, trees). We also observed *Laetiporus sulphureus* (Bull.) Murrill on fallen wood (stems, D_{ave} = 67.5 cm) of *Quercus robur* L. 16 species of fungi were detected on *Carpinus betulus* L. The analysis of the vitality of *Carpinus betulus* L. showed that approximately one half of the wood-destroying fungi (47.1%, findings) occurred on trees of II Kraft class (26.2%, trees). An equal distribution of xylotrophs (17.6%, findings) was detected on IV and V Kraft classes (26.2% and 7.1%, trees). Only one species, *Vuilleminia comedens* (Nees) Maire (5.9%, findings), occurred on trees of III Kraft class (12.0%, trees). WAKC of heavily weakened individuals of *Carpinus betulus* L. (3.2 – 3.4) showed that drying of trees was natural process compared to the distribution of WAKC of *Quercus robur* L. The analysis of the health conditions of *Carpinus betulus* L. showed that the stands were healthy (I = 1.45) unlike *Quercus robur* L. The proportion of healthy trees was 38.1% and of the wilting ones was less 3.1%. An equal distribution of xylotrophs (29.4%, findings) was detected on weakened (16.7%, trees) and recently dead trees (16.7%, trees). On healthy trees of *Carpinus betulus* L. we registered carpophores of *Fomes fomentarius* (L.) Fr. (11.8%, findings). On fallen wood of *Carpinus betulus* L. (stems, logs, D_{ave} = 16.5 – 46.5 cm) we observed 12 species of wood-destroying fungi. *Bjerkandera adusta* (Willd.) P.Karst., *Pluteus cervinus* (Schaeff.) P.Kumm., *Schizopora paradoxa* (Schrad.) Donk, *Stereum subtomentosum* Pouzar, *Trichaptum biforme* (Fr.) Ryvarden preferred the broken area. *Auricularia auricula-judae* (Bull.) Quél., *Cerrena unicolor* (Bull.) Murrill, *Daedaleopsis tricolor* (Bull.) Bondartsev et Singer, *Fomes fomentarius* (L.) Fr., *Stereum hirsutum* (Willd.) Pers. and *Trametes gibbosa* (Pers.) Fr. developing on integral bark.

Table 3. Characteristic of dominant woody vegetation.

No. EP	Species	A, y.	N, pcs.	D_{ave}, cm	D_{min} – D_{max}; S.D.	H_{ave}, m	H_{min}–H_{max}; S.D.	P	G_n m^2ha^{-1}
1	*Q. robur*	80 – 100	162	88.4	72.1 – 122.1; 9.77	17.8	14.9 – 19.1;1.95		194.2
	C. betulus	60 – 80	194	29.7	24.5 – 39.7; 5.73	16.8	15.1 – 19.0;1.93		99.3
	T. cordata	60 – 80	69	33.2	22.5 – 37.4; 7.48	15.0	13.1 – 16.9;1.68		52.3
	A. platanoides	40 – 60	104	29.8	21.9 – 39.5; 6.13	14.1	13.0 – 15.84; 1.78	0.6 – 0.7	663.1
	U. glabra	60 – 80	75	32.5	24.7 – 45.3; 7.92	16.7	14.5 – 18.14 2.02		43.0
2	*Q. robur*	60 – 80	137	53.8	46.1 – 80.5; 9.98	19.3	17.2 – 21.5; 1.65	0.7 – 0.8	119.8
	P. sylvestris	60 – 80	148	36.8	26.5 – 40.1; 7.04	18.1	15.4 – 19.9; 1.86		101.5
	A. platanoides	20 – 40	58	16.3	12.5 – 19.1; 7.25	12.1	10.7 – 13.6; 1.14		29.7
3	*Q. robur*	60 – 80	97	56.7	44.1 – 69.5; 5.03	18.2	14.5 – 19.9; 2.14	0.8 – 0.9	98.4
	C. betulus	60 – 80	56	22.5	19.8 – 31.3; 4.98	17.0	14.5 – 18.4; 1.25		48.1
	A. platanoides	40 – 60	87	24.1	17.5 – 29.7; 6.48	14.9	12.8017.5; 2.35		64.1
	T. cordata	60 – 80	39	30.1	25.3 – 38.5; 8.26	14.8	12.8 – 18.0; 1.84		28.1
	F. excelsior	40 – 60	30	22.1	17.5 – 28.3; 5.74	15.1	13.9 – 16.8; 1.45		32.3
4	*Q. robur*	60 – 80	155	76.2	60.4 – 94.2; 8.12	19.1	16.4 – 24.3; 2.17	0.6 – 0.7	135.6
	A. platanoides	40 – 60	125	31.2	23.8 – 41.4; 8.55	15.3	13.7 – 18.0;1.95		78.5
	P. avium	40 – 60	44	34.8	25.1 – 40.1; 5.14	15.1	12.9 – 18.2; 2.27		25.3

Table 4. The health conditions of *Quercus robur* L. and the share of findings of wood destroying fungi.

EP	The health conditions*														
	I			II			III			IV			V		
	WAKC	%, trees	%, findings	WAKC	%, trees	%, findings	WAKC	%, trees	%, findings	WAKC	%, trees	%, findings	WAKC	%, trees	%, findings
1	1.5	24.0	6.0	2.1	38.0	23.5	3.0	24.5	23.5	1.8	8.0	29.4	4.0	5.5	17.6
2	2.0	21.4	23.9	2,5	39.3	42.8	2.3	10.7	11.1	3.0	21.4	11.1	4.5	7.2	11.1
3	1.3	13.9	14.3	1.3	36.1	14.3	2.2	38.8	42.8	3.3	5.6	28.6	4.0	5.6	0
4	1.4	37.9	11.2	1.4	25.8	18.5	2.7	16.7	18.5	2.4	16.7	33.3	2.7	2.9	18.5

Xylaria polymorpha (Pers.) Grev. developing in clasters on rotten wood of *Carpinus betulus* L.

Wood-destroying fungi recorded on *Tilia cordata* Mill. (*Fomes fomentarius* (L.) Fr., on stem of living tree of I Kraft class, V state category), *Acer platanoides* L. (*Dendrothele acerina* (Pers.) P.A. Lemke, on stem base of living tree of I–II Kraft classes, I–II state categories) and *Ulmus glabra* Huds. (*Dendrothele alliacea* (Quél.) P.A. Lemke, on stem base of living tree of I–II Kraft classes, I, III state categories) occurring only a few. On fallen wood (stems, D_{ave} = 19.5 cm) we registered *Schizopora flavipora* (Berk. et M.A. Curtis ex Cooke) Ryvarden and *Stereum subtomentosum* Pouzar. The plantings of *Tilia cordata* Mill., *Acer platanoides* L. and *Ulmus glabra* Huds. were healthy (I = 1.25; I = 1.34; I = 1.21).

3.2 Assessment results at the tract "Bila dibrova"

The tract EP2 has a low sandy hill, which are the remnants of upland terraces Dnipro and Desna. The first storey consisted of *Quercus robur* L. and *Pinus sylvestris* L.. The second storey composed of *Acer platanoides* L. (Table 3). The understorey was composed biogroups of *Corylus avellana* L., *Frangula alnus* Mill., *Sambucus nigra* L., *Sorbus aucuparia* L., *Cerasus avium* L., and *Rubus fruticous* L. The total projected cover of herbaceous storey was 80.0%. *Convallaria majalis* L., *Driopteris filix-mas* L., *Geranium sanguineum* L., *Stellaria nemorum* L., *Polygonatum multiflorum* (L.) All. were dominated. The mechanical damage of trees was not observed. The soil surface was in II stage of degradation. The overall stage of recreational transformation was II. In total, we detected we detected 29 species (72, findings) of wood destroying fungi from 23 genera, 15 families, and 6 orders on 6 species of trees. 61.1% findings of fungi were eurytrophes of II rank on deciduous trees and 36.1% – eurytrophes of I rank. Eurytrophes of II rank on coniferous trees (2.8%, findings) was represented by only one species *Heterobasidion annosum* (Fr.) Bref. (Appendix 1). At EP2 the 59.7% findings of wood destroying fungi were occurred in the ground myco-horizon (Appendix 2). On *Quercus robur* L. we detected 5 species of xylotrophic fungi. The analysis of health conditions of *Quercus robur* L. showed that the stands were weakened (I = 2.45). The proportion of healthy and the wilting trees was the same (21.4%). The share of recently dead stands were minimal at EP2 (7.2%). WAKC of healthy trees was 2.0 (Table 4). The maximum number of xylotrophs was recorded on *Quercus robur* L. trees of II state category (42.8%). The same number of xylotrophs (11.1%) was recorded on the trees of III and IV state categories. The analysis of vitality revealed that one third of findings (33.3%) were detected on trees in I Kraft development class (with 48.1% frequency at the plot). The smallest number of observations (3.8%) was recorded on trees in III Kraft development class. The proportion of xylotrophic fungi that developed in II, IV, V Kraft development classes ranged from 16.7% to 22.2%. Besides, the dead substrate of the three categories was also detected at the EP2 (Fig. 1). It should be noted that the biggest number of species and findings of xylotrophic fungi on dead substrate coincides with the falling wood of *Quercus robur* L. No wood destroying fungi were detected on trees of *Acer platanoides* L. (I = 1.35) and *Pinus sylvestris* L. (I = 2.42). Only developing of *Trametes ochracea* (Pers.) Gilb. et Ryvarden and *Trametes versicolor* (L.) Lloyd was detected on branches of *Acer platanoides* L. On stumps (D_{ave} = 50.6 cm) of *Pinus sylvestris* L. was detected 5 species of xylotrophic fungi. Wood-destroying fungi on understorey were found on the bark and saw cut of *Cerasus avium* L. (10 species; branches, D_{ave} = 7.8 cm; stems, D_{ave} = 17.9 cm) and on the bark of *Sambucus nigra* L. (2 species; branches, D_{ave} = 3.2 cm).

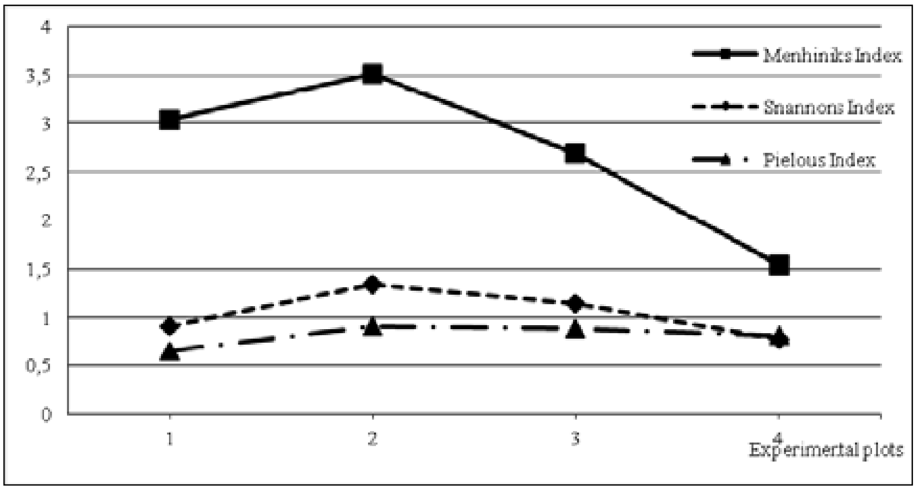

Fig. 1. Species richness of xylomyco-biota.

3.3. Assessment results at the tract Tract "Lysa Hora"

The tract EP3 is represented by hornbeam-oak forest, which was formed in place of cleared space of oak. The first storey consisted of *Quercus robur* L. and *Carpinus betulus* L. The second storey composed of *Acer platanoides* L., *Tilia cordata* Mill., and *Fraxinus excelsior* L. (Table 3). The undergrowth was poorly developed, sometimes represented by biogroups of *Sambucus nigra* L. and *Euonymus verrucosa* Scop. The herbaceous storey was represented by ruderal species. The projected cover of herbaceous storey was less than 35.0%. The total indicator of the state soil surface was III stage of digression. The total area of mechanical damage of trees was 0.32 m^2. The overall stage of recreational transformation was III. At EP3 we detected 19 species (50, findings) of wood destroying fungi from 13 genera, 10 families, and 5 orders on six species of trees. 74.0% findings of fungi were eurytrophes of II rank on deciduous trees and 16.0% – eurytrophes of I rank. Stenotrophes (10.0%, findings) was represented by *Fistulina hepatica* (Schaeff.) With. and *Peniophora rufomarginata* (Pers.) Bourdot et Galzin (Appendix 1). At EP3 the maximum number of wood destroying fungi (34.0%, findings) were occurred in the ground myco-horizon (Appendix 2). On *Quercus robur* L. we detected 5 species of xylotrophic fungi. The analysis of health conditions of *Quercus robur* L. showed that the stands were weakened (I = 2.41) too. The proportion of healthy trees was 13.4% (Table 4). The share of weakened (36.1%) and heavily weakened (38.8%) were almost equal. WAKC of wilting and recently dead trees of *Quercus robur* L. were 3.3 and 3.4 accordingly. 42.8% of findings of xylotrophic fungi was recorded on trees of II state category. The same number of xylotrophs (11.1%) was detected on the trees of I and II state categories (14.3%). The analysis of the vitality was quite predictable: 57.1% findings occurred mainly on 58.3% trees of I Kraft class. The analysis of the vitality of *Quercus robur* L. showed that the 64.7% findings of fungi occurred mainly on trees of I Kraft class (64.0%, trees). The lowest number of fungi (5.9%, findings) occurred on trees of III Kraft class (12.0%, trees). WAKC of wilting trees (1.8) showed that the share of trees in I, II Kraft classes gradually increased (Table 4).

On *Carpinus betulus* L. we detected 7 species of xylotrophic fungi. The same findings of xylotrophic fungi (30.0%) was detected on healthy trees (60.0%) and recently dead trees (4.0%). Value of WAKC of healthy individuals were not exceed 1.2 – 1.4. The developing of 5 species of xylotrophic fungi was detected on falling wood (branches, D_{ave} = 2.7 cm) of *Carpinus betulus* L. On stems (D_{ave} = 20.5 cm) of *Pinus sylvestris* L. was detected *Stereum hirsutum* (Willd.) Pers. One species of xylotrophic fungi were detected on individuals of second storey: *Acer platanoides* L. (*Dendrothele acerina* (Pers.) P.A. Lemke; 11 findings; I, III, V Kraft classes; I-III state categories), *Tilia cordata* L. (*Peniophora rufomarginata* (Pers.) Bourdot et Galzin; 1 finding; III Kraft class; II state category). The analysis of health conditions of *Acer platanoides* L. showed that the stands were healthy I = 1.37). The share of healthy trees was more than half (57.7%), wilting individuals were only 3.9%. *Tilia cordata* L. (I = 2.75) and *Fraxinus excelsior* L. (I = 1.65) had worse health condition compared to *Acer platanoides* L. Only *Peniophora cinerea* (Pers.) Cooke was recorded on deadwood of *Acer platanoides* L.

3.4. Assessment results at the tract "Teremky"

The tract EP4 was located in the Tract "Teremky„ on the outskirts of the city. The first storey consisted of one *Quercus robur* L. and the second storey composed of *Acer platanoides* L. and *Prunus avium* (L.) (Table 3). The projected cover of herbaceous storey was less than 35.0%. Ruderal and pratal species were dominated at EP4. The indicator species (only *Asarum europaeum* L., 0.5%) were recorded around butt of *Quercus robur* L. Mechanically damaged were registered only on stems of *Quercus robur* L. The total indicator of the state soil surface was IV stage of digression. The clogging of the soil's surface was about 7.5%. The overall stage of recreational transformation was IV.

At EP4 we detected 9 species (34, findings) of wood destroying fungi represented nine genera, seven families, four orders. 88.3% findings of fungi were eurytrophes of II rank on deciduous trees and 8.8% – eurytrophes of I rank. Stenotrophes (2.9%, findings) were represented by only one species: *Stereum gausapatum* (Fr.) (Appendix 1). The greatest number of the identified xylotrophic fungi (41.1%, findings) was founded in the photosynthesising myco-horizon and 35.3% – in the stem myco-horizon, while in the ground and the butt myco-horizons we detected the same number of wood destroying fungi (11.8%, findings) (Appendix 2). On *Quercus robur* L. we detected 6 species of xylotrophic fungi. We recorded only one biotrophic species – *Phellinus robustus* (P. Karst.) Bourdot et Galzin. Their frequency et EP4 was 11.0% (II, IV–V state category). The investigated stands of *Quercus robur* L. were weakened (I = 2.11). The proportion of healthy trees was 37.9% despite the high stage of recreational transformation. The maximum number of xylotrophs (33.3%, findings) was recorded on *Quercus robur* L. trees of IV state category, while their share in EP was only 16.7%. Share of fungi was equal on trees of II–III, V state categories – 18.5%. The analysis of the vitality of *Quercus robur* L. revealed that wood destroying fungi occurred mainly on *Quercus robur* L. trees of I Kraft class (48.0%, findings; 63,6%, trees); and the proportion of xylotrophic fungi in II and III Kraft classes was the same (26.0%, findings; 16.7%, trees). WAKC of wilting and recently dead stands were 2.4 and 2.6.

On living trees of *Acer platanoides* L. (I = 1.55) we detected only one species – *Dendrothele acerina* (Pers.) P. A. Lemke (80.0%, findings; 46.2%, trees of II state category). Analysis of the relationship between the findings of *Dendrothele acerina* (Pers.) P. A. Lemke on *Acer platanoides* L. and vitality of stands showed that 60.0% of the findings dedicated to the trees in I Kraft class (11.5%). Xylomycobiota was absent on individuals of *Acer platanoides* L. in III Kraft class (26.9%, trees). No wood destroying fungi were developed on trees in in IV Kraft class (7.8%, trees), V Kraft class (34.6%, trees) and *Prunus avium* (L.). The developing of 2 species (2, findings) of *Peniophora quercina* (Pers.) Cooke and *Vuilleminia comedens* (Nees) Maire) was detected on falling wood.

3.5. Species richness of wood destroying fungi

Analysis of species richness of wood destroying fungi of investigated forests in urban conditions on gradient of recreational transformation showed that the EP1 had species richest diversity. In general, species variety of xylotrophic macromycetes at experimental plots caused by existence of species with wide substrate preferendum. It is also associated with the development of stenotrophic fungi. Value of Menhinik's Index is increasing on gradient of recreational transformation. Interrelation between the degree of recreational transformation and value of Shannon's Index is not established. Assessment of equitability of xylomycobiota showed that value of Pielou's Index is decreasing on gradient of recreational transformation (Fig. 1). Distribution of xylomycobiota by categories of substrates showed that 31.3% of the findings were registered in *Quercus robur* L. (I–IV categories of state), 68.7% – in the dead substrates. Findings of xylomycobionts on *Carpinus betulus* L. were dominated in the dead substrates too (86.7%), the maximum number of findings of xylotrophic fungi on trees was at EP1. Findings of xylomycobionts on *Acer platanoides* L. were dominated in living trees (62.5%). Wood destroying fungi on *Pinus sylvestris* L. were registered only on old dead substrates. Distribution of xylomyco-biota by myco-horizons showed that the maximum number of findings were concentrated in the ground myco-horizon (38.4%), while the minimum – in the stem base myco-horizon (11.8%). The findings of xylotrophic fungi on root myco-horizon were unrecorded. Analysis of trophic composition of xylomycobiota at all EP showed that the greatest number of eurytrophes of II rank on deciduous species (88.3%) detected at EP4; eurytrophes of I rank (36.1%) – at EP2; eurytrophes of II rank on coniferous species (2.8%) – only at EP2. The average share of stenotrophes at the ecoprofile was 5.05%.

3.6. Peculiarities of studied consortium

It is clear accordingly, recreational transformation of EP that consortium relations of *Quercus robur* L. at EP1 and EP2 are more similar to each other (Fig. 2 a). In addition, consortium relations of EP3 and EP4 are more similar to each other. Analyses of formed consortium relations of *Acer platanoides* L. showed that consortium relations of EP2 and EP4 are more similar to each other too (Fig. 2 b). Such distribution confirmed our data on the absence of a direct relationship between the degree of recreational transformation of the territory and state of community of *Acer*-xylomycokomplex (Blinkova & Ivanenko 2016). Obtained results regarding the similarities of clusters, comparison of compositions of trees and fungi in the formed communities in the forests depending on the recreational transformation of environment in urban conditions require further researches. Analyse of dead substrate of the host tree of xylotrophic fungi showed that the biggest number of species were developed on deadwood (D_{ave} = 10.0 – 50.0 cm; 17 species) at EP2 (Fig. 3). Maximum number of species on stumps were recorded at EP2 too. Maximum number of species on branches and stems (D_{ave} = 5.0 – 10.0 cm) were recorded at EP1. It should be noted that the biggest number of findings of xylotrophic fungi on dead substrate coincides with the deadwood at EP1 (15 findings) and EP2 (13 findings)

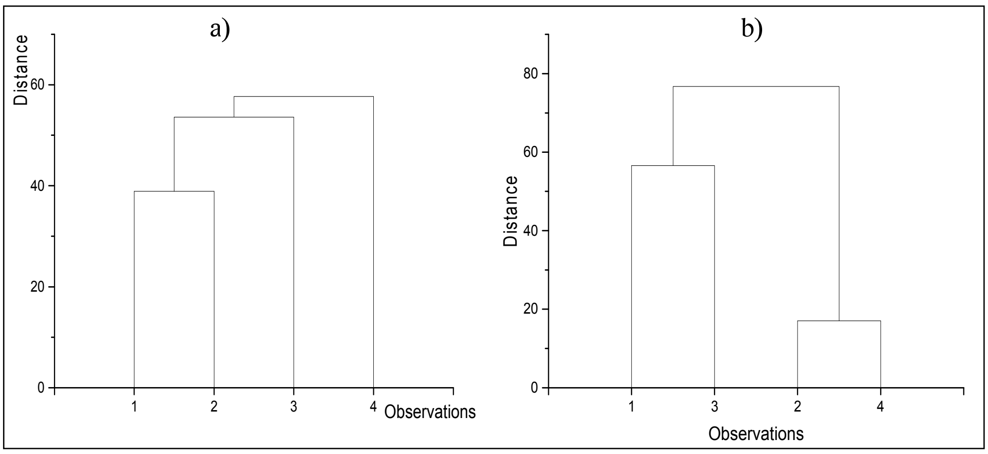

Fig. 2. Clustering dendrogram of ecological links of *Quercus robur* L. (a) and *Acer platanoides* L. (b) in natural and seminatural forests (EP1–EP4).

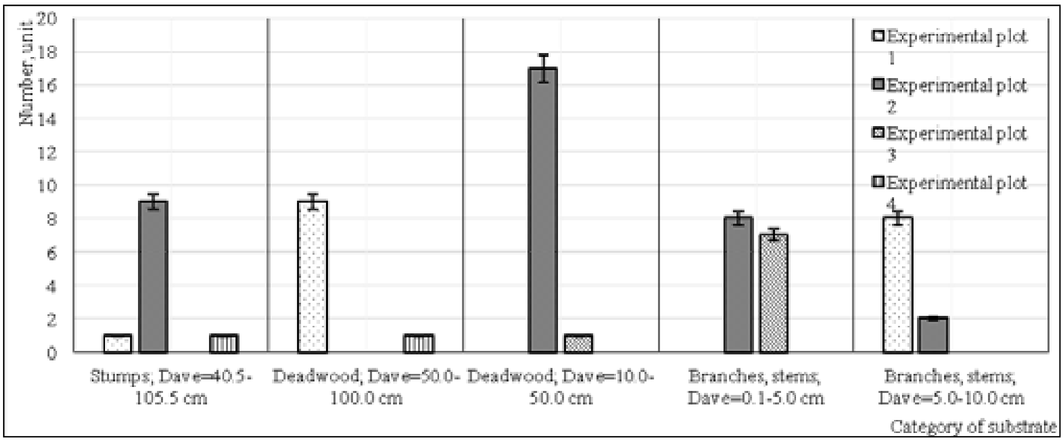

Fig. 3. Number of observed species of xylotrophic fungi on experimental plots in individual substrate categories.

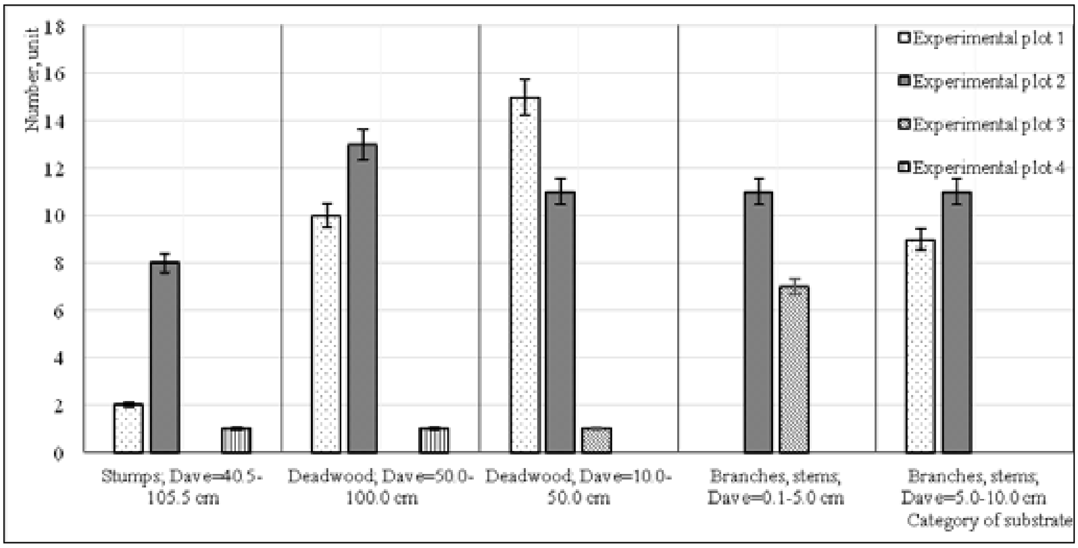

Fig. 4. Number of observed findings of xylotrophic fungi on experimental plots in individual substrate categories.

(Fig. 4). Minimum number of findings at the ecoprofile were assigned to stumps (only 1 – 8 findings). The close relationships between the distributions of fungi in various categories of dead substrate depending on recreational transformation of territory were not found.

4. Discussion

The diversity patterns of fungi along the geographical gradient appear to be influenced by management related factors (forest history, dead wood availability and continuity, habitat fragmentation). An increase in the abundance of dead wood in forests will benefit diversity (Odor et al. 2006). Previous publications shown that the some species are highly specialized in their resource use and suffer from loss of connectivity at three spatial scales (along the large-scale gradient, at the landscape scale and at the scale of a forest stand) (Norden et al. 2013). Conservation of fungi requires that substantial amounts of dead wood is left for natural decay in a variety of natural forest environments representing different tree species, so that heterogeneity in dead wood types is secured (Heilmann-Clausen et al. 2005).

Our distribution by myco-horizons on macro level evidences that xylomycobiota develops more in the ground myco-horizon. Depending on species composition of forests also the composition of xylotrophs is changing. It has been proved that the composition of xylotrophic fungi in studied recreational transformed forests are not balanced, as dispersal of xylotrophic fungi in them is limited by lesser quantity of available live and dead rooting substrate, by greater openness of canopy of the stand, by less protected properties of the herbaceous cover, digression of the soil surface layer.

The importance of different fractions of deadwood for species diversity of wood-inhabiting fungi was investigated in many studies. Category of substrate (living trees or deadwood) is essential for developing of xylotrophic fungi. The number of species varied in different deadwood and decay substrate. The different stages of decay and the different substrate of deadwood had significantly different species richness of xylotrophic fungi (Sefidi & Etemad 2015). The results of other studies indicated the morphometric parameters and category of dead wood describe the greatest variance of numbers of species. The differences in deadwood profiles among the habitat types can be considered the main source of variation. The high qualitative diversity of deadwood substrates in natural forests creates multiple ecological niches for individual fungal species to occupy. The natural forest structure and dynamics provide, in turn, variable microclimatic conditions to meet the demands of wood destroying fungi (Norden et al. 2004; Sefidi&Etemad 2015). Species number per tree increased significantly with increasing tree diameter, pointing out large trees to be most valuable for fungal diversity if single samples are compared. These are interpreted to reflect a combination of two factors: firstly, small diameter represent a larger surface area per volume and hence more space for fungal carpophors, than large diameter (Heilmann-Clausen & Christensen 2004). Fungal species richness in small-diameter deadwood was highest in recreational transformed forests (Juutilainen et al. 2016). Our results indicate that type of substrate (living trees or dead substrate) and morphometric parameters of deadwood substrate are very important factors affecting fungal community compositions. Moreover, this study showed that the biggest number of species and findings were recorded on deadwood compared to living trees. The highest value for richness and evenness indices calculated in large diameter dead wood.

Many scientists were focused on diversity and host preference of wood decaying fungi in urban areas. Compared of frequency and diversity of wood decaying fungi in natural forest of the town of Zvolen showed that the highest diversity and the highest incidence of wood decaying fungi were detected in area with minimum of the human impact on the forest (Sliacka 2013). Our results showed that state of communities of tree vegetation and xylotrophic fungi of natural and semi-natural forests in urban conditions depends on the degree of recreational transformation of the territory. The species richness of xylomycobiota at forests increases by the recreational transformation, which are evidences by the values of Menhinik's Index. Our data on changes in the condition of woody plants due to recreational transformation are correlated with the results of studies by other authors. The case study of Kyiv city has established that as increases the recreational transformation of natural and semi-natural forests, the interrelation of trophic, ecological and systematic compositions of xylotrophic fungi and vital, age compositions and health condition of woody vegetation is lost similar for our data to parks (Blinkova & Ivanenko 2016). The biggest number of findings of xylotrophs is detected on living trees of *Quercus robur* L. In general, health condition of dominating woody species in urban conditions is decreasing from the healthy to the heavily weakened. Our results show that under the categories of substrates of broad-leaved tree species, it has been established that 62.9% of findings of wood-destroying fungi is detected on living trees of I–IV state categories. Xylotrophs on coniferous species have been detected only on stumps of *Pinus sylvestris* L. Hence, inter-links between tree vegetation and xylotrophic fungi are significantly influenced by human activities.

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Appendix 1. Taxonomic and trophic compositions of wood destroying fungi at all experimental plots.

Order	Family	Species	Trophic groups*	No. EP
Agaricales	Fistulinaceae	*Fistulina hepatica* (Schaeff.) With.	S	1, 3
	Physalacriaceae	*Cylindrobasidium evolvens* (Fr.) Jülich	E2d	3
	Pluteaceae	*Pluteus cervinus* (Schaeff.) P.Kumm.	E1	1, 2
	Pterulaceae	*Radulomyces molaris* (Chaillet ex Fr.) Christ.	E2d	3
	Schizophyllaceae	*Schizophyllum commune* Fr.	E1	1
Auriculariales	Auriculariaceae	*Auricularia auricula-judae* (Bull.) Quél.	E1	1, 2
Corticiales	Corticiaceae	*Corticium roseum* Pers.	EI	3
		Dendrothele acerina (Pers.) P. A. Lemke	E2d	1, 3, 4
		D. alliacea (Quél.) P. A. Lemke	E2d	1
		Vuilleminia comedens (Nees) Maire	E2d	1, 2, 3, 4
Hymenochaetales	Hymenochaetaceae	*Hymenochaete rubiginosa* (Dicks.) Lév.	E2d	2
		Inocutis dryophila (Berk.) Fiasson et Niemelä	E2d	1
		Inonotus hispidus (Bull.) P. Karst.	E2d	3
		I. radiatus (Sowerby) P. Karst.	E2d	1
		Phellinus ferruginosus (Schad.) Pat.	E1	2, 3
		P. robustus (P. Karst.) Bourdot et Galzin	E2d	1, 2, 3, 4
		P. tuberculosus (Baumg.) Niemelä	E2d	2
	Schizoporaceae	*Schizopora flavipora* (Berk. et M.A. Curtis ex Cooke) Ryvarden	E1	1
		S. paradoxa (Schrad.) Donk	E1	1, 2, 3, 4
	Tubulicrinaceae	*Hyphodontia sambuci* (Pers.) J. Erikss.	E2d	2
Polyporales	Fomitopsidaceae	*Antrodia serialis* (Fr.) Donk	E1	2
		Laetiporus sulphureus (Bull.) Murrill	E1	1, 3
	Ganodermataceae	*Ganoderma lipsiense* (Batsch) G.F. Atk.	E1	2
		G. lucidum (Curtis) P. Karst.	E1	4
	Meruliaceae	*Bjerkandera adusta* (Willd.) P.Karst.	E1	1, 2
		Phlebia radiata Fr.	E2d	1, 2
		*P. tremellosa (*Schrad.) Nakasone et Burds.	E1	2, 4
	Phanerochaetaceae	*Irpex lacteus* (Fr.) Fr.	E2d	2
		Steccherinum fimbriatum (Pers.) J. Erikss.	E1	2
		S. ochraceum (Pers. ex J.F. Gmel.) Gray	E1	2
	Polyporaceae	*Cerrena unicolor* (Bull.) Murrill	E2d	1, 2, 3
		Daedaleopsis confragosa (Bolton) J. Schröt.	E2d	2
		D. confragosa var. *tricolor* (Bull.) Bondartsev et Singer	E2d	1, 4
		Fomes fomentarius (L.) Fr.	E2d	1, 2
		Lenzites betulina (L.) Fr.	E2d	2
		Polyporus alveolaris (DC.) Bondartsev et Singer	E2d	1, 2, 3
		P. squamosus (Huds.) Fr.	E2d	2
		P. tuberaster (Jacq. ex Pers.) Fr.	E2d	3
		Trametes gibbosa (Pers.) Fr.	E2d	1
		T. ochracea (Pers.) Gilb. Et Ryvarden	E1	2
		T.versicolor (L.) Lloyd	E1	2
		Trichaptum biforme (Fr.) Ryvarden	E2d	1
Russulales	Amylostereaceae	*Artomyces pyxidatus* (Pers.) Jülich	E2d	2
	Bondarzewiaceae	*Heterobasidion annosum* (Fr.) Bref.	E2c	2
	Peniophoraceae	*Peniophora cinerea* (Pers.) Cooke	E2d	3
		P. laeta (Fr.) Donk	E2d	3
		P. quercina (Pers.) Cooke	E2d	1, 2, 3, 4
		P. rufomarginata (Pers.) Bourdot et Galzin	S	3
	Stereaceae	*Stereum gausapatum* (Fr.) Fr.	S	4
		S. hirsutum (Willd.) Pers.	E2d	1, 2, 3
		S. subtomentosum Pouzar	E2d	1
Xylariales	Xylariaceae	*Xylaria polymorpha* (Pers.) Grev.	E2d	1

Note:* Eurytrophes of I rank (E1), eurytrophes of II rank on deciduous trees (E2d), eurytrophes of II rank on coniferous trees (E2c), stenotrophes (S).

Appendix 2. Distribution of xylotrophic fungi by myco-horizons at all experimental plots.

No.	Fungi-consorts	Trees-edificators of consortium	Myco-horizons*				
			1	2	3	4	5
1	*Antrodia serialis* (Fr.) Donk.	*Pinus sylvestris* L. (1)	—	—	1/2.7	—	—
2	*Artomyces pyxidatus* (Pers.) Jülich	*Pinus sylvestris* L. (1)	—	—	1/2.7	—	—
3	*Auricularia auricula-judae* (Bull.) Quél.	*Carpinus betulus* L. (1), *Sambucus nigra* L. (1)	—	1/1.1	—	1/2.0	—
4	*Bjerkandera adusta* (Willd.) P. Karst.	*Carpinus betulus* L. (4), *Quercus robur* L. (4)	—	6/6.5	1/2.7	1/2.0	—
5	*Cerrena unicolor* (Bull.) Murrill	*Carpinus betulus* L. (2), *Prunus avium* L. (1), *Quercus robur* L. (2)	—	4/4.3	—	1/2.0	—
6	*Corticium roseum* Pers.	*Carpinus betulus* L. (1)	—	1/1.1	—	—	—
7	*Cylindrobasidium evolvens* (Fr.) Jülich	*Carpinus betulus* L. (1)	—	1/1.1	—	—	—
8	*Daedaleopsis confragosa* (Bolton) J. Schröt.	*Prunus avium* L. (2)	—	2/2.2	—	—	—
9	*D. confragosa* var. *tricolor* (Bull.) Bondartsev et Singer	*Carpinus betulus* L. (1), *Prunus avium* (L.) L. (1)	—	2/2.2	—	—	—
10	*Dendrothele acerina* (Pers.) P. A. Lemke	*Acer platanoides* L. (21)	—	—	8/21.6	13/26.5	—
11	*D. alliacea* (Quél.) P. A. Lemke	*Ulmus glabra* Huds. (3)	—	—	—	3/6.1	—
12	*Fistulina hepatica* (Schaeff.) With.	*Quercus robur* L. (8)	—	—	8/21.6	—	—
13	*Fomes fomentarius* (L.) Fr.	*Carpinus betulus* L. (9), *Prunus avium* (L.) L. (1), *Quercus robur* L. (1), *Tilia cordata* Mill. (1)	—	5/5.4	3/8.1	2/4.1	2/4.4
14	*Ganoderma lipsiense* (Batsch) G.F. Atk.	*Quercus robur* L. (1), *Prunus avium* ~~(L.)~~ L. (1)	—	1/1.1	1/2.7	—	—
15	*G. lucidum* (Curtis) P. Karst.	*Quercus robur* L. (1)	—	—	1/2.7	—	—
16	*Heterobasidion annosum* (Fr.) Bref.	*Pinus sylvestris* L. (2)	—	—	2/5.4	—	—
17	*Hymenochaete rubiginosa* (Dicks.) Lév.	*Quercus robur* L. (7)	—	2/2.2	5/13.5	—	—
18	*Hyphodontia sambuci* (Pers.) J. Erikss.	*Sambucus nigra* L. (1)	—	—	1/2.7	—	—
19	*Inocutis dryophila* (Berk.) Fiasson et Niemelä	*Quercus robur* L. (1)	—	—	—	1/2.0	—
20	*Inonotus hispidus* (Bull.) P. Karst.	*Fraxinus excelsior* L. (1)	—	—	—	1/2.0	—
21	*I. radiatus* (Sowerby) P. Karst.	*Quercus robur* L. (1)	—	—	1/2.7	—	—
22	*Irpex lacteus* (Fr.) Fr.	*Prunus avium* L. (2), *Quercus robur* L. (2)	—	4/4.3	—	—	—
23	*Lenzites betulina* (L.) Fr.	*Betula pendula* Roth (1)	—	1/1.1	—	—	—
24	*Laetiporus sulphureus* (Bull.) Murrill	*Quercus robur* L. (5)	—	2/2.2	1/2.7	2/4.1	—
25	*Peniophora cinerea* (Pers.) Cooke	*Acer platanoides* L. (1)	—	—	—	—	1/2.2
26	*P. laeta* (Fr.) Donk	*Carpinus betulus* L. (2)	—	2/2.2	—	—	—
27	*P. quercina* (Pers.) Cooke	*Quercus robur* L. (11)	—	6/6.5	—	—	5/11.1
28	*P. rufomarginata* (Pers.) Bourdot et Galzin	*Tilia cordata* Mill. (2)	—	—	—	—	2/4.4
29	*Phellinus ferruginosus* (Schad.) Pat.	*Prunus avium* L. (1), *Quercus robur* L. (1)	—	1/1.1	—	—	1/2.2
30	*P. robustus* (P. Karst.) Bourdot et Galzin	*Quercus robur* L. (24)	—	1/1.1	—	14/28.6	9/20.0
31	*P. tuberculosus* (Baumg.) Niemelä	*Prunus avium* L. (1)	—	—	—	1/2.0	—
32	*Phlebia radiata* Fr.	*Carpinus betulus* L. (1), *Prunus avium* (L.) L. (1)	—	1/1.1	—	1/2.0	—
33	*P. tremellosa* (Schrad.) Nakasone et Burds.	*Prunus avium* L. (1), *Quercus robur* L. (1)	—	1/1.1	1/2.7	—	—
34	*Pluteus cervinus* (Schaeff.) P.Kumm.	*Carpinus betulus* L. (1), *Pinus sylvestris* L. (1), *Quercus robur* L. (2)	—	2/2.2	2/5.4	—	—
35	*Polyporus alveolaris* (DC.) Bondartsev et Singer	*Carpinus betulus* L. (3), *Prunus avium* (L.) L. (1), *Quercus robur* L. (1)	—	5/5.4	—	—	—
36	*P. squamosus* (Huds.) Fr.	*Prunus avium* L. (1)	—	1/1.1	—	—	—
37	*P. tuberaster* (Jacq. ex Pers.) Fr.	*Acer campestre* L. (1)	—	1/1.1	—	—	—
38	*Radulomyces molaris* (Chaillet ex Fr.) Christ.	*Carpinus betulus* L. (1), *Quercus robur* L. (2)	—	1/1.1	—	—	2/4.4
39	*Schizophyllum commune* Fr.	*Carpinus betulus* L. (2)	—	1/1.1	—	1/2.0	—
40	*Schizopora flavipora* (Berk. et M.A. Curtis ex Cooke) Ryvarden	*Tilia cordata* Mill. (1)	—	1/1.1	—	—	—
41	*S. paradoxa* (Schrad.) Donk	*Carpinus betulus* L. (4), *Quercus robur* L. (5)	—	4/4.3	—	1/2.0	4/8.9
42	*Steccherinum fimbriatum* (Pers.) J. Erikss.	*Pinus sylvestris* L. (1)	—	1/1.1	—	—	—
43	*S. ochraceum* (Pers. ex J.F. Gmel.) Gray	*Quercus robur* L. (1)	—	1/1.1	—	—	—
44	*Stereum gausapatum* (Fr.) Fr.	*Quercus robur* L. (1)	—	—	—	1/2.0	—
45	*S. hirsutum* (Willd.) Pers.	*Carpinus betulus* L. (8), *Quercus robur* L. (3)	—	7/7.5	—	4/8.2	—
46	*S. subtomentosum* Pouzar	*Carpinus betulus* L. (1), *Tilia cordata* Mill. (1), *Ulmus glabra* Huds. (1)	—	3/3.2	—	—	—
47	*Trametes gibbosa* (Pers.) Fr.	*Carpinus betulus* L. (2)	—	2/2.2	—	—	—
48	*T. ochracea* (Pers.) Gilb. Et Ryvarden	*Acer platanoides* L. (1), *Prunus avium* ~~(L.)~~ L. (1)	—	2/2.2	—	—	—
49	*T. versicolor* (L.) Lloyd	*Acer platanoides* L. (1), *Prunus avium* ~~(L.)~~ L. (4), *Quercus robur* L. (3)	—	7/7.5	—	1/2.0	—
50	*Trichaptum biforme* (Fr.) Ryvarden	*Carpinus betulus* L. (1)	—	1/1.1	—	—	—
51	*Vuilleminia comedens* (Nees) Maire	*Carpinus betulus* L. (5), *Quercus robur* L. (22)	—	8/8.6	—	—	19/42.2
52	*Xylaria polymorpha* (Pers.) Grev.	*Carpinus betulus* L. (1)	—	1/1.1	—	—	—
All together species /findings:		11/224	0/0	36/93	15/37	17/49	9/45
% of species /findings:			0/0	70.6/41.5	29.4/16.5	33.3/21.9	17.6/20.1

Note: * – pcs./%; 1 – root; 2 – ground; 3 – boot; 4 – stem; 5 – photosynthesizing myco-horizon; "–" – not detected.

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Hollow tree fire is a useless forest fire category

Ivan Chromek[1], Karolina Lukášová[2*], Roman Berčák[2], Jan Vaněk[2], Jaroslav Holuša[2]

[1]Technical University in Zvolen, Faculty of Wood Sciences and Technology, T. G. Masaryka 2117/24, SK – 960 53 Zvolen, Slovak Republic
[2]Czech University of Life Sciences Prague, Faculty of Forestry and Wood Sciences, Kamýcká 129, CZ – 165 00 Prague 6 – Suchdol, Czech Republic

Abstract

In the Czech Republic and Slovakia, the term "hollow tree fire" was first used in a publication in 1956 without being well defined and was then uncritically used in other publications. The term refers to fires occurring in the rotted, inner trunks of trees. The main aim of the current study was to determine whether the term should be considered a useful category for the statistical analysis of forest fires. The nature and causes of fires from 2006–2015 were assessed by performing a detailed analysis of the Fire Rescue Service of the Czech Republic (FRS CR) database. The database included a total of 7,256 fires in the natural environment, but only 18 of these were hollow tree fires. Most hollow tree fires were initiated by human carelessness, and only three were initiated by lightning. Based on our critical consideration of fire attributes, hollow tree fires should not be considered a category of forest fire. The presence of rotten trees is, however, a serious problem because such trees represent long-lasting sources of fire in forest stands and because they complicate firefighting. The numbers of rotten trees in forests is increasing, and firefighters should be made aware of the complications of extinguishing fires involving rotten trees in forests.

Keywords: rot; damage; firefighting; Norvay spruce; central Europe

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1. Introduction

The term forest fire refers to fire that breaks out in and spreads through forests and other wooded land or that breaks out in nonwooded land and spreads to forests and other wooded land. The definition of "forest fire" excludes prescribed or controlled burning, which is usually conducted to reduce or eliminate the accumulated fuel on the ground (Regulation (EC) No 2152/2003 of the European Parliament). More generally, a forest fire is a complex of physico-chemical phenomena involving burning, gas exchange, and heat transfer processes that change in space and time. Forest fires have negative effects on all of the social functions of forests (Chromek 2006).

In the Czech Republic and Slovakia, forest fires are assigned to one of four categories (Nechleba 1927; Nestěrov 1949; Hendrych 1956; Pfeffer et al. 1961; Kunt 1967; Forst 1970; Stolina et al. 1985, 2001; Hlaváč 2003, 2005; Krakovský 2004; Chromek 2006; Francl 2007; Kula & Jankovská 2013; Hlaváč & Chromek 2016; see Table 1): surface fires ("pozemní požár" in Czech), ground fires ("podzemní požár"), crown fires ("korunový požár"), and hollow tree fires ("požár dutého stromu").

In 2005, another kind of forest fire, a "calamity area fire", was described (Hlaváč et al. 2005). This kind of forest fire results from many broken trees after storm winds and anthropogenic ignition, factors that were responsible for the severe fire in the High Tatras Mts in 2005. This kind of forest fire has not been recognized as a new category of fire, although its legitimacy was very well reasoned (Hlaváč et al. 2005).

The areas affected by surface fires, ground fires, crown fires, and calamity area fires are quantified annually at the national level in the Czech Republic and Slovakia (vulhm.cz; los.sk) as well as at the European level The European Forest Fire Information System – EFFIS. In contrast to these kinds of fires, which damage thousands of hectares, "hollow tree fires" initially affect only individual trees (Hendrych 1956; Pfeffer et al. 1961; Krakovský 2004; see Table 1) and cause negligible damage and loss. The Czech term for this kind of fire is "požár dutého stromu", and the term "hollow tree fire" will be used in this paper. This term was first used but was not

**Corresponding author. Karolina Lukášová, e-mail: lukasovak@fld.czu.cz, phone: +420 737 322 550*

clearly defined by Hendrych (1956). Since that time, the term hollow tree fire has been used without critical evaluation in many publications (Table 1).

Table 1. Overview of publications describing hollow tree fires and other kinds of forest fires in the Czech Republic and Slovakia. In the Hollow tree fires column, + or - indicates that hollow tree fires were or were not described, respectively. In the Types of forest fires column, + or - indicates that the type of fire was or was not indicated, respectively.

Author	Year of publication	Hollow tree fires	Types of forest fires
Kučera	1914	–	–
Nechleba	1927	–	+
Barchánek	1932	–	–
Pfeffer	1938	–	–
Felix	1948	–	–
M. M.	1948	–	–
Něštěrov	1949	–	+
Turček & Lehotan	1949	–	–
Hendrych	1956	+	+
Pfeffer	1961	+	+
Hodr	1963	+	+
Kunt	1967	+	+
Forst	1970	+	+
Kula	1981	–	–
Stolina	1985	+	+
Kula	1985a	–	–
Kula	1985b	–	–
Pohořelý & Vilhelm	1996	–	+
Stolina et al.	2001	+	+
Křístek	2002	+	+
Hlaváč	2003	+	+
Franc	2004	–	–
Krakovský	2004	+	+
Sloup & Raba	2004	–	–
Sviták	2004	–	–
Tomášek	2004	–	–
Hlaváč	2005a	+	+
Hlaváč	2005b	+	+
Hlaváč et al.	2005	–	–
Chromek	2006	–	+
Francl	2007	–	+
Tomášek	2007	–	–
Hlaváč et al.	2009	–	–
Kula & Jankovská	2013	–	+
Hlaváč & Chromek	2016	+	+
Machander	2016	–	–

Given the need for detailed analyses of the causes and natures of fires, the question arises as to whether the hollow tree fire should be recognized as a category of forest fire. The aim of this work is to quantify this kind of fire in the Czech Republic and to determine whether it warrants being recognized as a category of forest fire. The significance of rotten trees is also considered.

2. Material and methods

The database of fires from the territory of the Czech Republic for the period 2006–2015 was studied. The forest fire database was provided by the Fire Rescue Service of the Czech Republic, which is hereafter abbreviated FRS CR. The database contains information for all natural environmental fires in the territory of the Czech Republic, with the exception of areas controlled by the military or by the Ministry of Defense.

The unadjusted database contained a large amount of information on each individual fire. The data include information about the fire category, the level of alarm that was announced, the date and time of the announcement, the date and time when the fire was extinguished, the location of the fire (region, district, municipality, part of municipality, coordinates), and ownership of damaged property (state, private, etc.). The data also include information on the intervention (number of fire units, fire area, direct damage, etc.), specification of fire location (fire in the natural environment, fire outside a building, etc.), initiator, cause, and comments.

We also searched online resources through Google.com search engines using the keywords "požár" (fire), "strom" (tree), and "dutý" (hollow) as a single search term (Appendix A1).

3. Results

Between 2006 and 2015, the FRS CR database included records for 7,256 fires in the natural environment. Only 18 of the 7,256 (i.e., 0.25%) could be considered hollow tree fires, and these involved a total area of 26 m^2 in forest stands. Most hollow tree fires in forest stands were recorded in 2007 and were usually started by human carelessness involving matches or lighters cases; hollow tree fires were started by lightening in only three cases. Most of the hollow tree fires required < 3 h to extinguish (Table 2).

The hollow tree fires involved beech (*Fagus sylvatica* L.) in four cases, Norway spruce (*Picea abies* L. [Karst.]) in two cases, and unrecorded species in the other cases. All 18 fires were reported between 8 am and 24 pm (Fig. 1). The fires occurred from April to December but most occurred in July (Fig. 2). The registered total damage was CZK 6,000 (approximately EUR 230), and assets valued at CZK 770,000 (EUR 29,468) were saved.

According to the FRS CR database and internet sources (Appendix A1), 11 other cases of hollow tree fires were recorded between 2006 and 2015 outside of forests[1]; these most often occurred in urban areas or parks (five cases in 2015 in total). The hollow tree fires were distributed randomly of the Czech Republic from 2006 to 2015 (Fig. 3).

[1] Forests are defined as land with tree crown cover (or equivalent stocking level) of more than 10% and area of more than 0.5 ha. The trees should be able to reach a minimum height of 5 m at maturity in situ. (Regulation (EC) No 2152/2003 of the European Parliament).

Table 2. Information on hollow tree fires occurring in forests in the Czech Republic from 2006 to 2015.

	Details	Number of fires
Year of occurence	2006	1
	2007	5
	2008	1
	2009	2
	2010	0
	2011	0
	2012	2
	2013	2
	2014	2
	2015	3
Initiator	Matches, lighters*	6
	Cigarette butt	2
	Atmospheric discharge**	3
	Unresolved	7
Maximum extinguishing time	30 minutes	2
	1 hour	7
	3 hours	8
	12 hours	1

*In two cases, the fires were ignited by children under 15; one case involved intentional ignition.
**lightning.

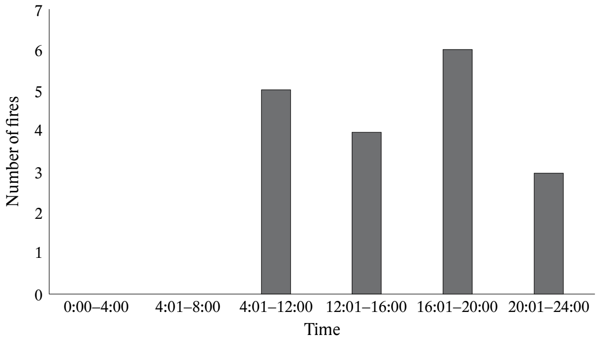

Fig. 1. Number of hollow tree fires in the Czech forests from 2006–2015 as affected by time of day.

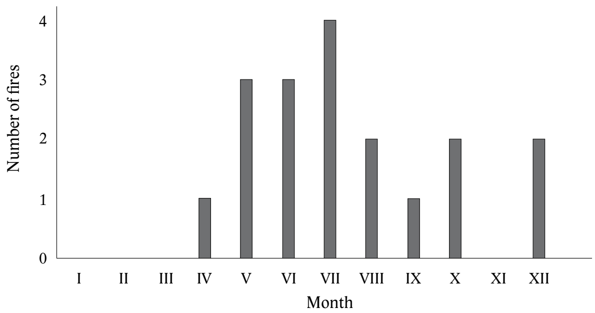

Fig. 2. Number of hollow tree fires in the Czech forests from 2006–2015 as affected by month of year.

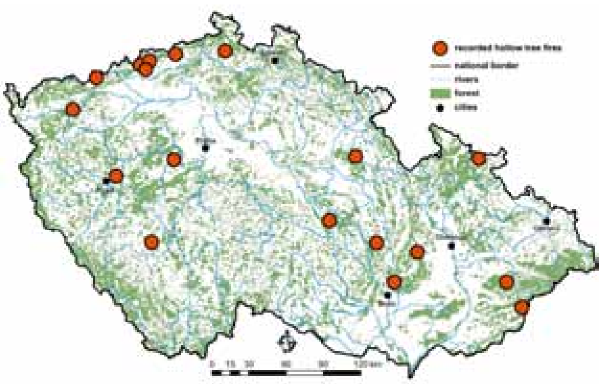

Fig. 3. Locations of hollow tree fires in the Czech Republic from 2006–2015.

4. Causes of a hollow fire occurence

We consider tree damage and rot and their relationship to fire in the following paragraphs.

When rocks impact trees, different types of tree failure can occur, including uprooting and trunk breakage (Berger et al. 2002). Certain species, particularly angiosperms, appear to be more resistant to failure than others and often sustain minor rather than severe wounds (Dorren & Berger 2005). The larger the tree, the smaller the percentage of cambial damage that will occur. Some broadleaf species are able to produce scar tissue faster than fir or spruce. This scar tissue will form around the wound and protect it from pathogen attack (Shigo 1986). Wounds on silver fir (*Abies alba* Mill.) and Norway spruce are relatively susceptible to pathogens, leading to internal stem rot and decay and then to reduced mechanical resistance to rockfall. Thick bark can protect the living cambium from wounding (Guyette & Stambaugh 2004). Damage from rockfall is not a widespread problem; it tends to occur only in the isolated cirques in high mountains with steep rocky slopes, as in the Giant Mts. and Bohemian Forest Mts. in the Czech Republic (Hrádek et al. 1997).

As amended under Section 20 (1) N) of Act No. 289/1995 Coll., On Forests and on Amendment and Supplementation of Certain Acts (Forestry Act), it is forbidden to graze cattle in forests or to allow cattle to move through forests in the Czech Republic.

Grazing of cattle has a long history in the Czech Republic (Svoboda 1952), but precise information on its occurrence is lacking. Although peeling, the rubbing of trunks by horns, and the trampling of roots by hooves have recently occurred in the Carpathians (Křístek 2008), quantitative data are lacking, and this kind of damage is rarely reported in scientific publications (e.g., Lutz 1980; Okada et al. 2007). There is also evidence of bark-stripping by horses in neighboring Poland (Kuiters et al. 2006; Klich 2017).

Bark-stripping and bark-peeling in European conifers by deer (*Cervus elaphus* L.) (Pfeffer et al. 1961; McIntyre 1972; Homolka 1995; Welsch et al. 1997) is an increasing problem in many European countries and elsewhere (e.g., see Mitchell et al. 1977; Mayer & Ott 1991; Donaubauer 1994; Reimoser 2003; Mansson & Jarnemo 2013). Some tree species, such as fir and ash (*Fraxinus* sp.), have been debarked by European bison (Klich 2015).

Each logging system can cause a different kind of damage to remaining trees. Because it potentially reduces tree vigour and increases attack by insects or diseases, logging injury to the remaining trees may lead to serious economic losses (Ohman 1970; Vasiliauskas 2001). Skinned bark and exposed sapwood, damaged roots, and broken branches are the most common forms of damage (Vasiliauskas & Stenlid 2007). Damage may decrease the quality of residual trees and increase stand mortality through insect and disease infestation (Han & Kellogg 2000; Kiser 2011). Wounding can cause stem deformity and decay and significantly reduce final crop volume and value (Meadows 1993). Stem wounds and root damage are also potential means of entry for organisms causing decay and pitch rings (Shigo 1986).

When fungi invade a wound caused by mechanical damage, the reduce wood hardness, texture, and color. Rot arises because fungi secrete a wide range of extracellular enzymes that degrade host tissues (Eriksson & Pettersson 1968; Nord & Hata 1969; Hüttermann 1980; Johansson 1988; Karlsson & Stenlid 1991; Maijala et al. 1995; Asiegbu et al. 1998; Korhonen & Stenlid 1998; Maijala et al. 2003; Asiegbu et al. 2004).

Stereum sanquinolentum (Alb. & Schwein.) Fr. is the most common decay fungus of Norway spruce. This fungus is able to infect open wounds of live trees (Isomäki & Kallio 1974; Atta & Hayes 1987; Mäkinen et al. 2007). The spread and extent of the attack depend on the frequency of damage, wound age, and tree diameter at breast height (Vlad & Sidor 2013; Vlad 2014). Other important fungal pathogens include *Heterobasidon* species, which cause destructive diseases of conifers in the northern temperate regions of the world, especially in Europe (Asiagbu et al. 2005). *Heterobasidon* spp. also attack wounds, especially those caused by logging (Rönnberg et al. 2013).

Fungal pathogens can grow rapidly through infected trees. *S. sanguinolentum*, for example, can spread up to 70 cm per year in tree trunks (Čermák et al. 2004a, b, c; Čermák & Strejček 2007), and *Heterobasidion* spp. can spread up to 1 m yr^{-1} in tree trunks and can grow into the trunk from infected roots (Huse & Venn 1994). The rot caused by these pathogens spreads upward through the mature, middle part of the trunk (Černý 1989; Čermák et al. 2004b).

Rotted wood is 2.0- to 2.5-times lighter in weight than healthy wood. In addition to reducing the mechanical strength of wood, rot also changes wood color and appearance (Zeidler 2012). The rotting of wood by fungi increases its ability to burn. That fire is usually initiated by lightning or arson (Hendrych 1956; Krakovský 2004) is confirmed by our records for hollow tree fires.

When lightning strikes a healty tree, it causes mechanical damage, but when lightning strikes a tree with rot in the trunk, it causes fire. The natural occurrence of forest fires resulting from lightning sticking a dry or hollow tree is rare in the Czech Republic (Nechleba 1927; Kula 1985a). Only 2% of the forest fires were caused by lightning in 2015 (Zpráva o stavu lesa a lesního hospodářství České republiky v roce 2015 2016). This is consistent with past records. From 1992–2004, for example, Kula & Jankovská (2013) reported that lightning caused only 1.39% of forest fires in the Czech Republic.

In 1970, 70,000 ha of spruce stands in the Czech Republic had significant levels of game damage (Černý 2001). The area of such damaged stands had increased to 106,000 ha by 1994 and to 220,000 ha by 1999. At the beginning of the 21st century in the Czech Republic, it was estimated that more than 20% of the total volume of harvested timber (Půlpán 2001) was damaged by rotting. The losses due to rot have continued to increase (Malík & Karnet 2007).

According to the National Forest Inventory for the period 2014–2016, more than 13% of the trees between 41 to 60 years old in the Czech Republic had been damaged by browsing, peeling, or rubbing, and 8% of all trees in the country were damaged, regardless of age (Table 3). The damage increases with altitude (Table 4) Kučera et al. 2016.

Table 3. Percentage of trees damaged by browsing, peeling, or rubbing as affected by age class in the territory of the Czech Republic (2014–2016).

Age of forest	Browsing, peeling, or rubbing [%]
1–20	7.2
21–40	11.0
41–60	13.9
61–80	8.9
81–100	5.3
>100	1.7
Total	8.2

Table 4. Percentage of trees damaged by browsing, peeling, or rubbing as affected by altitude in the Czech Republic (2014–2016).

Altitude [m]	Browsing, peeling, or rubbing [%]
less than 400	3.5
400 – 700	7.6
> 700	17.2

In the case of forest fires in stands with rotting trees, flames can spread over the surface of the forest litter and ignite trees at the base of the trunk. The ideal condition for spread occurs when an ignited tree has a hole in the upper part of its trunk, creating a so-called „chimney effect" (Pfeffer et al. 1961; Forst et al. 1970).

Although extinguishing a single, burning hollow tree is not complicated, some precautions should be followed. The trees must be felled (Fig. 4a) and, for safety, guided blasting charges (Fig. 4b) are used [see Staré Hory 2007 (enclosed pictures - Forests of the Slovak Republic, (Fig. 4c)]. Burned and felled trees must also be repeatedly inspected to ensure that they are extinguished (Fig. 4d). Even after the front of a forest fire passes through these trees, rotten trees may continue to burn and may activate the forest fire (Fig. 4e).

For reasons of safety, pyrotechnics is necessary (Fig. 4b). In such cases - directed burst charges, lightning bolts are also used for the destruction of such trees.

It is often safer to use explosive charges (for every 10 cm of stem thickness, single spin, thread) rather than axes and saws to fell rotten trees that have burned or are still burning.

Even when they are felled, however, the cavities of burning hollow trees may contain fire. The hidden fires in such trees create a so-called "cigarette effect" (Fig. 4c), and the felled trunks must be repeatedly checked and

Fig. 4. Extinguishing burning trees with rot near the village of Staré Hory (Velká Fatra) on 15 April 2007 (48.8587644N, 19.1457272E) (Masica 2007) (photo I. Chromek). (A) Preparation cuts in the burning tree; (B) The use of explosive charges on a hollow tree with an inner fire at the top; (C) A tree with rot continues to burn even after it has been felled; (D) A hollow tree fire that has been extinguished; (E) A rotten tree that is still burning after the forest fire has moved through the area; and (F) A rotten tree in which the fire has been extinguished.

sprayed with water. This problem is especially important after the front of a forest fire has passed through an area (Fig. 4d) because, as noted earlier, the hidden fire in the rotten trees (Fig. 4e) can continue to burn even after it has been assumed to be extinguished. The hidden fire can then help reactivate the forest fire.

Therefore, both the standing and lying trunks must be checked. The above-mentioned method of fire forest destruction is time-consuming but also demanding for personnel and water (up to 200 l of water per m^2 is required). An area with such trees must be repeatedly inspected. Rotten trees that have burned but are still standing are also dangerous because they are unstable and can fall on firefighters (Fig. 4f). Another risk involves rotten roots, which can burn and spread the fire ground (Pfeffer et al. 1961).

5. Discussion

The number of hollow tree fires was very small in the Czech Republic (and is probably also very small in other countries of Central Europe), suggesting that this type of fire should not be considered as a separate category of forest fire. Rather than being recognized as a separate category, perhaps hollow tree fires should be considered as a part of other types of forest fires.

Hollow trees fires occur on trees with damage and rot. Tree injury results from mechanical damage to the trunk due to falling stones; peeling caused by sheep, goats, beef cattle, or game; or poor handling by foresters during cleaning, thinning, and logging[2].

From 2006–2015, only three cases of hollow tree fires caused by lightning were documented in the FRS CR database, representing only 0.04% of all forest fires. Among all of the forest fires in the database, lightning caused a total of 96 fires, i.e., 1.32% of all fires.

Forests in the Czech Republic are intensively managed, and most forest fires are caused by human activity and not by lightning (Kula & Jankovská 2013). The chances that fire is caused by lightning in the Northern Hemisphere increase with latitude. In areas just south of the Arctic Circle, lightning causes up to 90% of the natural fires (Post 1936). Because there are few people near the Arctic Circle, humans are unlikely cause fires in that region. In addition, that region has conditions that are extremely favorable for forest fires. The polar day in Alaska, for example, has 19 to 24 h of sunshine and temperatures as high as 37.3°C, while the average annual precipitation is < 382 mm (Kunt 1967).

Earlier reports indicate that hollow tree fires in some countries have often been caused by shepherds who intentionally started fires in hollow trees (Pfeffer et al. 1961). We did not find any information in the scientific literature about whether shepherds intentionally started fires in hollow trees in Central Europe. Nechleba (1927) mentions that the careless manipulation of fire by human minors was often a cause of forest fires. In some cases, minors have intentionally started fires in tree cavities (e.g., see https://www.youtube.com/watch?v=XqnHRA-XNGw). This trend is evident today; from years 1974–1983, minors were responsible for approximately 7% of forest fires (Kula 1985a). In the years 1992–2004, the percentage decreased to 4.5% (Kula & Jankovská 2013).

In the case of hollow tree fires, the tree burns to the height of the cavity or rot. If the cavity is at the bottom of the trunk, only this part burns. If the rot occurs higher, the fire can move up the stem and emerge from holes and cracks ((https://www.youtube.com/watch?v=LbxCFIbsKy0) (see Appendix A2)), from wounds (https://www.youtube.com/watch?v=p1dgewYCECU; http://www.wideopencountry.com/insane-footage-tree-fire-inside/; Fig. 4), and from holes formed by woodpeckers (http://vtecostudies.org/blog/spring-wildfire/).

Extinguishing a single burning tree is not a complicated procedure (Krakovský 2004). Some older reports recommend clogging all holes in the hollow trunk with soil, or cutting down the tree and then extinguishing the fire (Hendrych 1956). There is currently no official way of dealing with hollow tree fires in the Czech Republic. In terms of felling, a burning hollow tree is generally felled in the same manner as a non-burning hollow tree (Appendix A3).

In some circumstances, the hollow tree can break apart or burst, such that hot coals fall to the litter and cause a surface fire (Hendrych 1956). If the surface fire spreads to young coniferous stands, a crown fire can develop, and a relatively small problem can become a large one (Pfeffer et al. 1961). In this case, the hollow tree fire becomes the source of a regular forest fire.

Although hollow tree fires are rare, hollow trees in forests commonly burn during forest fires. The occurrence of forest fires with burning rotten trees will increase as a consequence of the increasing area of forest stands with game damage. Game damage leads to rot. Trees damaged by game are more likely to be attacked by *S. sanquinolentum* (Čermák et al. 2004a, b; Čermák & Strejček 2007).

6. Conclusion

Hollow tree fires are rare in the Czech Republic and lack many characteristics common to forest fires such as burnt area, head, flanks, and back of fire (Krakovský 2004). They also have relatively small economic and environmental consequences. We therefore conclude that hollow tree fires should not be considered a category of forest fire.

A stand-alone tree in a meadow would not be considered a forest, and if such a tree is ignited, it could not be called a forest fire. Similarly, if a hollow tree is ignited in a forest and burns without spreading, the event would not be considered a forest fire and would not generally be registered. If the fire spreads, it is by definition a forest fire and is no longer a hollow tree fire. We also note that hollow tree fires are not recognized as a category of forest fire in most of the countries in Central Europe, which only

[2] In the USA, fire can also produce tree damage in the form of basal cavities, which are ubiquitous in coast redwoods. They are common in the humid coastal forests of Del Norte County of California and also in the dry forests of the southernmost extent of the species range. Cavities result from a complex interaction between repeated fires and decay associated with two fungi, *Poria sequoiae* and *Poria albipellucida*. Coast redwood heartwood is remarkably decay- and fire-resistant, but these fungi thrive in sapwood behind newly formed fire scars (https://redwood.forestthreats.org/cavities.htm).

recognize ground, surface, and crown fires as common types of forest fires (e.g., Forest Fires in Europe, Middle East and North Africa 2015)[3].

On the other hand, the presence of rotten trees in forest stands is a serious threat. Such trees can become a long-lasting source of fire, and extinguishing them if they are burning is not straight forward. Because the numbers of trees with rot is increasing in the forests of the Czech Republic, firefighters should be trained in how to deal with such trees and should be advised of areas with stands where rotten trees are abundant.

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[3] In Poland, however, fires are divided into four types: 1) individual tree fires, 2) ground fires (peat, peat-muck), 3) surface fires, and 4) forest stand fires. A fire involving only one tree is extremely rare in Poland and is the result of arson or lightning strikes. In the case of arson, the fire can transform into any other kind of fire. In the case of lightning strikes, the threat of fire spread is small because lightning is usually accompanied by rain in Poland Predecka 2011).

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3. Požár dutého stromu. [online] [2017-07-10]: Avalaible at: http://hasici.stenovice.cz/index.php?option=com_content&view=article&id=147:3-poar-duteho-stromu&catid=39:2008&Itemid=101

Hořel dutý kmen stromu i celý les, 2015: [online] [2017-07-10]. Avalaible at: https://www.regionvalassko.cz/aktuality_zobraz.php?lang=1&id=198&akt=9488&page=33

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Požár dutého stromu 2. 8. 2015, 2015: [online] [2017-07-10]. Avalaible at: http://www.hasicihrusky.cz/news/pozar-duteho-stromu/

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Appendix A2. Case study: Fighting a fire that was intentionally started by humans in lime trees

Fig. A.1. Fighting an intentionally set fire in lime trees on the border of a mixed forest on 3 December 2011 (photo J. Vaněk).

Comment:
On 3 December 2011, a fire that was intentionally started in a hollow lime tree was found on the border of a mixed forest. The burning hollow lime tree was located in the alley leading to the chapel at the top of Zámecký vrch in Stráž pod Ralskem. A stream of water was first used to extinguish the fire in the tree trunk, but this did not eliminate the entire fire. Either because of a branch break or a tree cut, a chimney effect occurred, and the fire moved up the trunk and into the branches. The tree was then felled and sprayed with water. The tree was finally cut into smaller pieces and was again sprayed with water (Fig. A.1).

Appendix A3. Firefighting procedures for hollow trees

In practice, there are two methods to eliminate this type of fire:

1) Fighting the fire in the upright tree

This is clearly the safer and easier of the two methods. It is more likely to be used with coniferous trees. Because such trees have relatively thin branches that are oriented downward at a sharp angle, the fire tends to remain in the trunk. The burning often results in holes in trunk where rotten branches were present. Firefighters will spray water into these holes as a way to get water into the burning, interior trunk. It is also possible to spray water into holes that the firefighters have drilled into the trunk.

2) Fighting the fire by first felling the tree

This method is used with deciduous trees because both the trunk and skeletal branches of such tree are often affected by fire. Tree branches located high in the canopy do not usually burn. Skeletal branches that are oriented upward will help spread the fire. Fires in deciduous trees with many branches can be difficult to extinguish because the branches prevent the sprayed water from contacting smouldering branches. As a result, the risk of fire reactivation is high, and the fire can reactivate even after appearing to be extinguished for several days.

In this method, firefighters must be aware of the risk of falling branches. They must also be aware that during the felling process, the gas exchange conditions can change significantly and may increase the intensity of the fire. The firefighters can be damaged by both flames and radiant heat. Firefighters must also consider that in felling rotten and hollow trees, controlling the direction of the tree's fall may be difficult. Firefighters must further consider that the entire weight of the tree is supported only by the outer circular layer of wood and that such trees may therefore collapse without warning. Wedging of these trunks is usually not recommended because there is not enough wood around the circumference of the trunk to make wedging effective. Rather than cutting the tree, it might be possible to drop the tree with a rope.

Once the tree is felled, the flow of air and combustion gases inside the trunk will decrease, reducing the intensity of the fire. To facilitate the penetration of the extinguishing substance into the trunk, the felled tree can be cut into smaller parts. When cutting, a prepared water stream should be available to prevent the spread of fire to the surrounding trees.