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Shrub layer dynamics of Turkey-oak forest between 2002 and 2007 in North-Hungary. Síkfőkút LTER

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Abstract

At the Síkfőkút Project Long Term Ecological Research (LTER) area covered by a sessile oak – Turkey-oak forest (*Quercetum petraeae-cerris*). Similarly to other European countries an oak decline occurred in Hungary at the end of 1970's. The oak decline resulted in an opening of the canopy; the canopy cover decreased from 80% (1972) to 36% (2007). The sparse canopy led to structural change of the understory resulting from changes in light and thermal regime. The aim of our study was to analyse the structural changes in the forest interior during 5 years period. Our hypotheses were the followings: (i) the density of low shrub species showed significantly changes. (ii) The high shrub specimens showed clustered distribution. The dominant species was *Euonymus verrucosus* in the low shrub layer and *E. verrucosus* and *Acer campestre* recorded as dominant species in the high shrub layer. According to the mean height the *A. campestre* and *Acer tataricum* were the biggest high shrub species. The low- and high shrub specimens showed clustered distribution in the plot. The forest responded to the serious tree decline by significant structural changes in the understory shrub layer.

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Introduction

Shrub species represent the largest component of temperate forest diversity amont the woody plant species and may provide important indications of site quality, tree regeneration patterns and conservation status (Hutchinson *et al.*, 1999; Small and McCarthy, 2002). Shrub dynamics can be used as an indicator of forest health and it is also linked to the ecological functioning of forest ecosystems (Augusto *et al.*, 2003; Brosofske *et al.*, 2001; McKenzie *et al.*, 2000). The tree layer affects in temperate forests the understorey, so the shrub layer in various ways notably by modifying the environment. This may differ among tree species (Canham *et al.*, 1994; Pelletier *et al.*, 1999). The goal of this study was to determine the consequences of oak decline for the shrub layer with special respect to forest community structure.

Several factors have been considered in forest health studies, such as extreme weather conditions, drought, storms, heat (Bolte *et al.*, 2010; Drobyshev *et al.*, 2008), and insect fluctuations (Moraal and Hilszczanski, 2000), diseases or human influences such as climate change, air pollution and fires (Kabrick *et al.*, 2008; Signell *et al.*, 2005). These factors lead to a modified functioning of the whole forest ecosystem and may lead to tree decline events. The tree declines heavily affected oak species and especially *Quercus petraea* Matt. L. trees in European countries and naturally in Central Europe (Freer-Smith and Read, 1995; Führer, 1998; Thomas and Büttner, 1998).

Many papers are reported that an increased oak mortality is leading to changes in forest dynamics (Drobyshev *et al.*, 2007; Moraal and Hilszczanski, 2000; Woodall *et al.*, 2005). In contrast to tree decline, relatively few studies deal with the dependence of shrub layer on tree layer characteristics (Brosofske *et al.*, 2001; Gilliam, 2007; McKenzie *et al.*, 2000) and relationship between tree layer and shrub layer. This relationship is complex (Légaré *et al.*, 2002). The tree layer structure strongly influences shrub species cover by altering microsites, resources and environmental conditions (Oliver and Larson, 1996; Stone and Wolfe, 1996). The shrub layer is strongly limited by light availability when the canopy is closed (Légaré *et al.*, 2002), leading to negative correlations of shrub layer species richness and/or cover with tree basal area (Hutchinson *et al.*, 1999). Shrub species richness and diversity were inversely but weakly affected by foliage cover of trees (Gracia *et al.*, 2007). Moreover, the foliage cover of trees is one of the best predictors of total shrub cover (McKenzie *et al.*, 2000). Shrubs can play an important role in the functioning of forests (Augusto *et al.*, 2003), in cycles of some essential nutrients dynamics (Gilliam, 2007) contribute substantially to compositional and structural diversity, help protect watersheds from erosion and enhance the aesthetics of forest ecosystems (Halpern and Spies, 1995). The successful regeneration of oak and also the growth of seedlings are related to the competition that the young plants experience (Johnson *et al.*, 2002). It also has important implications for the regeneration of trees, because it can influence the seedling and sapling dynamics of tree species (Gilliam, 2007).

The studies of shrub species performed have mostly focused on static population structure (age and size structures). Some studies have focused on cover and diversity condition of shrubs (e.g. Gracia *et al.*, 2007; Kerns and Ohmann, 2004). In the present study, we are focusing on the structural changes of understory in the forest interior during 5 years. We investigate the species composition, density, mean sizes (height and diameter) and cover of shrub layer. Our hypotheses were the followings. (i) It was recorded a significantly changes in the density of low shrub species. (ii) The high shrub specimens showed clustered distribution. (iii) The mean size parameters of high shrub species did not increased significantly during 5 years.

Materials and methods

Study site

The research area ("The Síkfőkút Project") is located in the Bükk Mountains (N 47° 90’, E 20° 46’) of the north-eastern part of Hungary at a distance of 6 km from the city of Eger at 320 – 340 m a.s.l. The mean annual temperature was 9.7°C (1973 – 1978) which increased during 1979-1994 to 10.0°C. The mean annual precipitation was 682 mm (1973 – 1978), which decreased to 510 mm year-1 (1979 – 1996). See Jakucs (1985, 1988) for more detailed descriptions of geographic, climatic, soil conditions and vegetation of forest. The typical climax forest association in this region is *Quercetum petraeae-cerris* with *Q. petraea* (sessile oak) and *Q. cerris* (Turkey oak) dominant tree species in the canopy layer. Both oak species are important deciduous tree species of the Hungarian natural woodlands. Other tree species also present with some specimens in the area are: *Carpinus betulus*, *Cerasus avium* and *Tilia cordata*. There were 20 shrub species in the study area from 1972. The following 16 species were continuously present at the site ordered by the Raunkiaer's life forms: i. Mega- and Meso-phanerophyta (MM) species: *A. campestre*, *C. avium*, *Juglans regia*, *Q. cerris*, *Q. petraea*, *T. cordata*; ii. Micro-phanerophyta (M) species: *A. tataricum*, *Cornus mas*, *C. sanguinea*, *Crataegus monogyna*, *Euonymus europaeus*, *E. verrucosus*, *Ligustrum vulgare*, *Lonicera xylosteum*, *Rhamnus catharticus*, *Rosa canina*. The studied near-natural, sprout forest is at least 95 years old and has not been disturbed by forest management for more than 50 years.

Sampling and data analysis

The necessary field data of the shrub layer condition has been collected at a definite period on a 48 m × 48 m intensive monitoring plot since 1972, which was subdivided with nylon cords into 144 4 m × 4 m subplots. The permanent subplots were established in 1972. Repeated shrub inventories took place in 1972, 1982, 1988, 1993, 1997, 2002 and 2007. In this paper were used the data from 2002 and 2007. We regarded as trees individuals of sessile oak and Turkey-oak species, whose trunk diameter achieved or exceeded 10.0 cm diameter at 1.3 meters above ground (dbh). Shoot height and shoot diameter of the shrub individuals were the two main variables recorded. Specimens which were higher than 1.0 m were categorized as high shrub. The lower specimens were categorized as low shrub. First, we registered the species richness and density of shrub layer in a plot and the distribution of low- and high shrub specimens in every subplot. Location and cover of all high shrub specimens were mapped in each subplot. Many various studies are included the method of cover map drawing (e.g. Jakucs, 1985). Foliage maps were digitized in ArcView (ESRI 1999). Based on the digitized map we estimated the foliage area of shrub individuals with the Spatial Analysis Tools - Calculate Area function of ArcView. Shrub cover by species was estimated into cover classes (0-5%, 6-25%, 26-50%, 51-75%, 76-95%, and 96-100%) in the plot. We counted the low and the high shrub specimens and finally measured the total shrub density in every subplot and were created a distribution maps. The analysis of variance (ANOVA) and linear regression were used to determine and quantify the connection between oak decline and shrub layer condition. Significance of statistic tests were noted as follow: $p \le 0.05$ or $p \le 0.01$.

Results and Discussion

Species richness and density

We recorded 16 and 17 shrub species in 2002 and in 2007 in the study site. It was not changed significantly ($p > 0.05$) between 2002 and 2007. Stand density of the shrub layer was 23879 and 44018 specimens per hectare. The rate of low and high shrub specimen's density was 83.5% - 16.5% and 93.6% - 6.4%. The most common shrub species was *E. verrucosus* in both years. Moreover, the high shrub layer was dominated by *E. verrucosus*, averaging 1088 individuals/ha. The most frequent high shrub species were *A. campestre*, *C. mas* and *E. verrucosus*; the density of *A. campestre* and *A. tataricum* were decreased to 2007. The density of *C. mas* was relatively stable during this period. The most frequent low shrub species was *E. verrucosus* with 57.7 %, following that were *L. vulgare* and *Q. petraea* in year 2002. On the following measurement

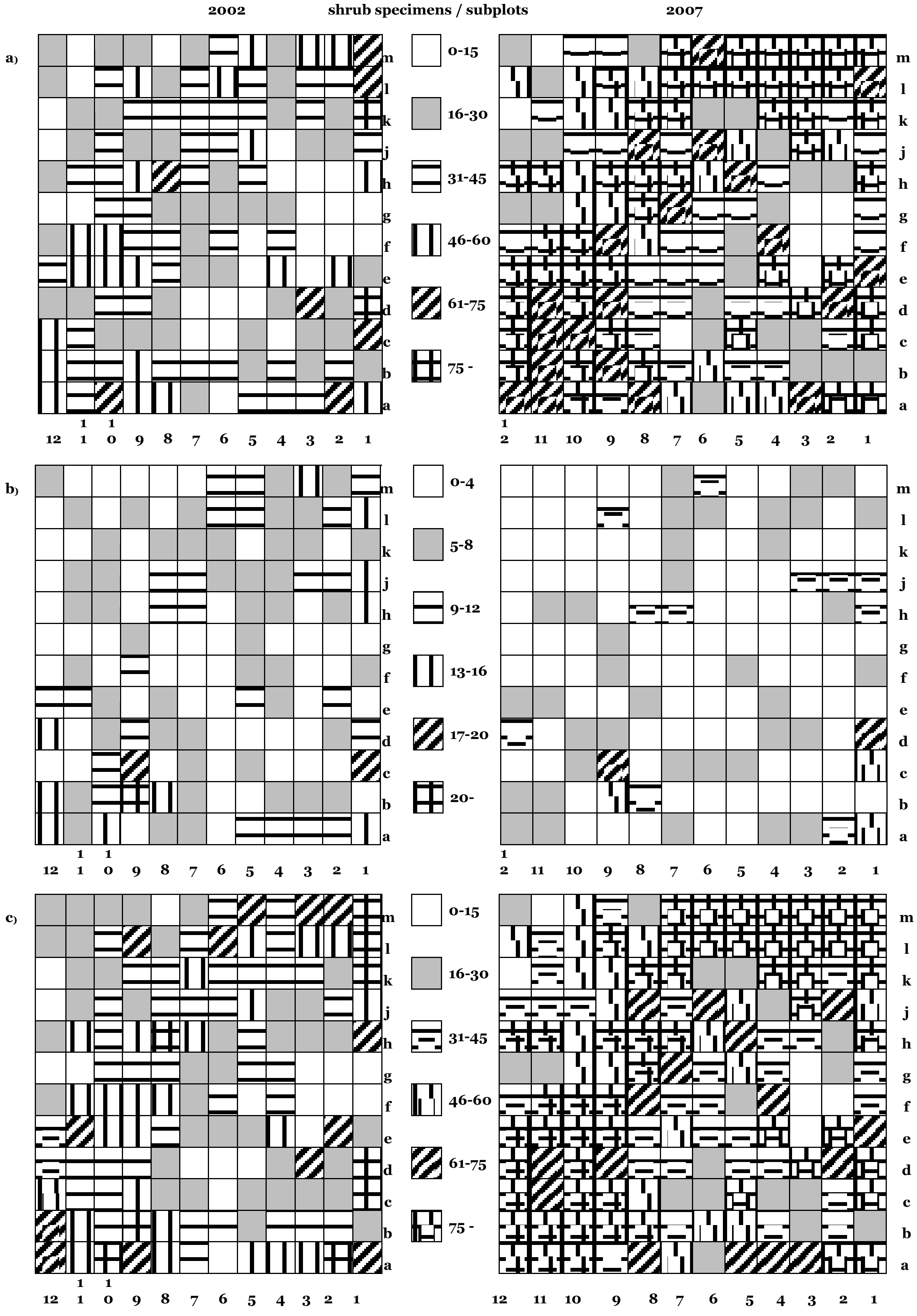

Fig. 1. Density proportion of the low-, high- and understory shrub specimens of subplots in 2002 and in 2007 on the Síkfőkút Forest. (**a**) low- **b**) high- **c**) all shrub specimens).

Table 1. Shrub species density in 2002 and in 2007 (l= low shrub layer, h= high shrub layer) on Síkfőkút Forest.

latin name	Density (specimens ha^{-1})						Changes (specimens ha^{-1})		
	l		h		sum		l	h	sum
year	2002	2007	2002	2007	2002	2007	2002-2007		
Acer campestre	746	2361	727	595	1473	2956	+1615	-132	+1483
Acer tataricum	1289	1215	195	130	1484	1345	-74	-65	-139
Cerasus avium	4	746	9	13	13	759	+742	+4	+746
Cornus mas	529	508	511	529	1040	1037	-21	+18	-3
Cornus sanguinea	655	1684	173	208	828	1892	+1029	+35	+1064
Crataegus monogyna	586	673	290	234	876	907	+87	-56	+31
Euonymus europaeus	104	4366	95	48	199	4414	+4262	-47	+4215
Euonymus verrucosus	11505	22967	1256	920	12761	23887	+11462	-336	+11126
Juglans regia	4	65	4	9	8	74	+61	+5	+66
Ligustrum vulgare	2973	4136	290	91	3263	4227	+1163	-199	+964
Lonicera xylosteum	13	95	30	26	43	121	+82	-4	+78
Quercus cerris	130	182	4	4	134	186	+52	0	+52
*Quercus petraea**	1397	1606	-	-	1397	1606	+209	-	+209
Quercus pubescens	-	473	-	-		473	+473	-	+473
Rhamnus catharticus	-	61	4	-	4	61	+61	-4	+57
Rosa canina	4	52	22	-	26	52	+48	-22	+26
Tilia cordata	-	17	4	4	4	21	+17	0	+17
sum	19939	41207	3614	2811	23553	44018	21268	-803	20465

*the density with *Q. pubescens* seedlings in 2002

E. verrucosus was the dominant species with 55.7%, *E. europeus* and *L. vulgare* followed them. The rate of *Quercus* seedlings (*Q. petraea Q. cerris* and *Q. pubescens*) were a quite small, referring to hectare it was 6.4% and 5.1% proportion of all shrubs (Table 1).

Our results supported the first hypothesis. The shoots density of low shrub layer increased more than 100.0% between 2002 and 2007. The density of policormon type shrub species (*Euonymus* species, *C. sanguinea* and *L. vulgare*) increased the biggest rate. Most shrub species respond postiviely to gaps, but some species are predestined to be obligate shade plants (Collins *et al.*, 1985). Therefore, only three species responded positively to gaps, especially the maples in Síkfőkút. The other shrub species of the site responded differently ecological mechanisms to the oak decline. For example, the density of *E. verrucosus* increased remarkably, however, the specimens of this species never grew up from the high shrub layer into the midcanopy layer. The species richness and diversity of shrub layer were inversely but weakly affected by trees cover (Gracia *et al.*, 2007). In our site athe significant part of sessile oak trunks disappeared from the site and foliage cover of tree layer decreased. Despite of this process new and/or invasive species could not appear in this forest ecosystem, because some shrub species could be respond successfully to the oak decline and therefore to the changing of light and thermal condition of the forest.

Table 2. Mean height, mean shoot diameter and mean foliage cover of the high shrub species in 2002 and in 2007 on Síkfőkút Forest.

latin name	Height (m)		Shoot diameter (cm)		Cover (m^2)	
	2002	2007	2002	2007	2002	2007
Acer campestre	5.88	8.23	8.61	11.03	6.22	11.54
Acer tataricum	4.22	4.92	5.36	6.45	5.58	9.71
Cerasus avium	5.10	8.62	9.45	17.28	13.24	24.02
Cornus mas	4.66	4.85	6.43	7.82	7.18	12.44
Cornus sanguinea	2.48	2.58	2.09	2.18	1.27	2.35
Crataegus monogyna	2.54	2.66	3.04	3.10	1.69	2.87
Euonymus europaeus	2.28	2.11	2.01	2.40	0.51	1.60
Euonymus verrucosus	1.71	1.75	1.68	1.64	0.61	1.04
Juglans regia	3.10	1.56	2.93	1.65	2.43	0.21
Ligustrum vulgare	1.59	1.53	1.40	0.94	0.53	0.51
Lonicera xylosteum	1.51	1.35	1.20	1.07	0.37	0.33
Quercus cerris	1.97	2.15	6.02	4.54	1.28	1.79
Rhamnus catharticus	2.10	-	1.32	-	0.69	-
Rosa canina	2.17	-	1.41	-	1.44	-
Tilia cordata	6.54	7.50	5.16	8.12	3.73	12.05
mean	3.03	3.83	3.87	5.25	3.12	6.19

Distribution

The maximum low shrub specimens developed in 2002 in "d1" and "k1" subplot with 79 and 82 pieces. We were not found low shrubs only in one quadrat ("f2"). In this quadrat was lived only single high shrub individual. The density of high shrubs was the highest in "b9" subplot with 26 specimens. We did not found so small quadrats where did not grown high shrub individuals. The total density of shrub species was the highest in the "c1" and the "d1" subplot with 89-89 specimens and they exceeded the limit of 80 species only in 6 subplots. In 2007 the highest shrubs developed in 2 small quadrats ("m5" and "d1") with 284-263 specimens and the low shrubs exceeded the 100 pieces limit in 20 small subplots. The minimum low shrubs were found in 2 subplots with 4-4 specimens ("f2" and "k12"). The high shrub density was the highest with 19 trunks in the "d1". We found 2 subplots ("c11" and "l8") where did not found high shrub specimens (Fig. 1).

Our results supported the second hypothesis. The distribution of low- and especially of high shrub individuals in the site showed clustered distribution. It was changed significantly ($p \leq 0.05$) from 2002 to 2007 in the low shrub layer. The relationship was significant ($p \leq 0.05$) between the 2002 and 2007 distribution condition in the high shrubs. The influence of competition among forest trees on their spatial arrangement is obscured by other factors, which are not closely related to the distribution of individuals (Szwagrzyk, 1990). Skov (2000) investigated the importance of neighbourhood structure on the distribution of plant functional attributes. This research was found that the best predictors were neighbourhood scores for open areas, road-side habitat, and neighbourhood diversity. The interactions among factors such as light, soil nutrient availability, and understory vegetation are associated with variation in gap size and that can affect regeneration success (Bartemucci, 2006; Raymond, 2006). In our site the gaps may determining the distribution of higher shrub specimens after the oak decline. In Síkfőkút the correlation between foliage gaps and distribution of the shrub specimens will be demonstrate in other paper.

Mean height, shoot diameter and foliage cover

Among high shrubs was detected the maximum mean height of shoots by *A. campestre* (5.9 m in 2002 and 8.2 m in 2007) individuals, *C. mas* and *A. tataricum* followed them in the first survey. In 2007 the individuals of *A. tataricum* and *C. mas* followed them. The considerably part of specimens of 3 species (*A. campestre*, *A. tataricum* and *C. mas*) grew up from the high shrub layer in the last decade and they reached the tree-stratum. In the site were lived 22 specimens of *A. campestre* over 10.0 meters in 2002 and this density was 29 specimens 5 years later. Some individuals of *C. mas* and *A. tataricum* reached or exceeded a 7.0-8.0 m height in the surveys. The mean height of all high shrub species was 3.0 m and 3.8 m. The biggest mean shoot diameter was recorded by *A. campestre*, the individuals of *C. mas* and *A. tataricum* followed them. Five years later the condition was similar, only the mean values increased (Table 2). Among the high shrubs *C. mas* individuals reached the maximum mean foliage cover, A. *campestre* and *A. tataricum* followed them. *E. europaeus* species reached the minimum mean foliage cover with 0.5 m^2, the individuals of *L. vulgare* and *E. verrucosus* followed them with 0.5-0.6 m^2 mean cover (Table 2). On the basis of shrub cover classes the most shrubs belong to the 0-5% class. Only by *A. tataricum* and *E. verrucosus* were recorded 6-25% and by *A. campestre* and *C. mas* 26-50% covers percentage. Five years later *Cr. monogyna* also belong to the 6-25% cover class and by *A. campestre* and *C. mas* were detected 51-75% cover.

Our results was not supported the third hypothesis. The mean sizes of some high shrub species (two maples species and *C. mas*) increased significantly ($p \leq 0.05$) in the 5 years period. The tree layer cover is one of the best predictors of total shrub cover (McKenzie *et al.*, 2000). It was detected the highest increasing by mean cover of some shrubs among the structural parameters in the shrub community. After the oak decline the mean cover of shrub species and total cover of understory were increased remarkably. Results from different forest types show that canopy openings modify light, thermal and moisture conditions (Holeksa, 2003; Nakashizuka, 1985; Wayne and Bazzaz, 1993). After the serious oak decline different sizes gaps were formed in the foliage of tree layer in the site and the shrub species could be increased considerably in these gaps by higher light level. Therefore, some specimens of 3 dominant high shrub species (especially *A. campestre*) reached the tree-size. The decreasing tree cover led to changes of the forest structural condition, but the species composition did not changed considerably. The dense tree layers can inhibit regeneration of trees and high shrubs (Knowe *et al.*, 1997; Stein, 1995; Tappeiner *et al.*, 1991).

Conclusions

Our results suggest some considerably changes in the shrub layer in a 5 year term. The species composition did not change between 2002 and 2007, but the density and the rate of low- and high shrub specimens in the forest community showed remarkably changes. A total of 16 and 17 shrub species recorded as dominant or codominant species on the site, because since 2007 we have been separated the *Q. pubescens* seedling from *Q. petraea* seedling on the basis of typical leaf morphological characters. We represented that the size parameters of dominant high shrub species were changed considerably after the oak decline. Among high shrubs the trunks of *A. campestre* reached the maximum mean height. The maximum mean shoot-diameter was detected by *A. campestre*. It seems that the increasing of the mean size condition of dominant shrub species continued onwards in last year.

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