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LONG-TERM EFFECTS OF OAK DECLINE ON SHRUB INDIVIDUAL'S OCCURRENCES IN AN HUNGARIAN OAK FOREST

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ABSTRACT

Information about the occurrence of shrubby individual's relation with oak decline is fundamental to developing knowledge from forest stand. This paper focuses on the following questions: (1) how are the shrub's occurrences changed after oak decline? (2) Which shrubs have the highest occurring in the subplots? The mixed oak stand is located in the Bükk Mountains of Hungary. The monitoring plot (48 m × 48 m) was subdivided into 144 permanent subplots; the measured parameter was observed in the period 1972-2017. The shrub layer was divided into low (< 1.0 m in height) and high (≥ 1.0 m) layer. High shrub specimens were randomly distributed and had become more homogeneous by 2017; there was no subplot with 10 or more specimens in the last decade. In the subplots the policormon forming shrubs were present with a higher occurrence. Correlation analysis showed that occurrence of *Acer tataricum*, *Cornus mas* and *Euonymus verrucosus* in the high and *Cornus sanguinea* and *Ligustrum vulgare* in the low shrub layer changed significantly after the oak decline. High shrubs with the highest occurrence were *E. verrucosus* and *C. mas*. The most occurrent low shrub species were *E. verrucosus* and *L. vulgare*. Our results suggest that after the oak decline the most shrubs' occurrence decreased considerably and the distribution was more homogeneous.

Keywords: S*hrub community, oak decline, occurrence, subplots*.

INTRODUCTION

Oak decline has been described as a widespread and complex phenomenon in many countries (Tomiczek, 1993; Sonesson and Drobyshev, 2010). An increase in the death of oak trees has been observed in many regions of Hungary since 1978 (Igmándy, 1987). In the Síkfőkút forest stand species composition of the canopy was stable until 1979 and the healthy *Quercus petraea* Matt. L. (sessile oak) and *Quercus cerris* L. (Turkey oak) also remained constant. Oak decline was first reported in 1979–80 and by 2017, 62.9% of the oaks had died.

Relatively few studies deal with shrub layer dynamics after oak death and the possible relation between trees and shrubs (Légaré *et al.*, 2002). Understory and overstory relationships are complex and mutual but are dominated by the canopy structure and condition (Burrascano *et al*., 2011; Burton *et al*., 2011; Cutini *et al*., 2015). Shrub layers of forest ecosystems change dynamically and respond sensitively to the environmental changes (Chipman and Johnson, 2002; Rees and Juday, 2002). They are strongly related to the composition and structure of the overstory (Klinka *et al.,* 1996; Palik and Engstrom, 1999). Shrub species play a major role in the cycles of some essential nutrients, including the dynamics of nitrogen, potassium and carbon (Gilliam, 2007). The shrub layers are directly contributes to forest biodiversity (Kerns and Ohmann, 2004; Čermá *et al.,* 2009), including compositional and structural diversity, enhancing the aesthetics of forest ecosystems and helping to protect watersheds from erosion (Alaback and Herman, 1988; Halpern and Spies, 1995; Muir *et al.,* 2002). The distribution of shrubs is strongly influenced by environmental conditions, such as climate (Pedley, 1979; Westman, 1991; Kienast *et al.,* 1998). Chemical and physical soil properties and biotic interactions play a major role in influence the distribution of shrub species (Pedley, 1979). Importance of shrub patch characteristics against other abiotic factors driving the occurrence of shrub species is also poorly studied (Gavilán *et al.,* 2002).

Misik *et al*. (2013) described the possible responses of understory shrub layer's cover, basal area and diversity to the remarkable changes in stand density. Misik *et al*. (2014) reported the dynamics behind the increase in the sizes of woody species and the structure of the new subcanopy layer below the canopy. This paper focuses on the following questions: (1) how are the shrub's occurrences changed after oak decline? (2) Which shrubs have the highest occurring in the subplots? (3) Finally, is a strong relation between occurrences and densities of shrub species?

MATERIAL AND METHODS

Study area The reserve research site (Síkfõkút Project) was established in 1972 by Jakucs (1985) and is located in the Bükk Mountains (47°552 N, 20°462 E) in the north-eastern part of Hungary at an altitude of 320-340 m a.s.l. (Figure 1A). Mean annual temperature is 9.9 °C and mean annual precipitation typically ranges from 500 to 600 mm. Descriptions of the geographic, climatic, soil conditions and vegetation of the forest were reported in detail by Jakucs (1985, 1988). The common forest association in this region is *Quercetum petraeae-cerridis* (Soó, 1963) (sessile oak-Turkey oak) with a dominant canopy of *Q. petraea* and *Q. cerris*; the long-term dynamics of understory shrub layer dynamics are described among others in works of Misik *et al*. (2013, 2014, 2017, 2020). The plots under study were made up of evenly aged temperate, mixed species deciduous forest that was at least 110 years old and had not been harvested for more than 55 years.

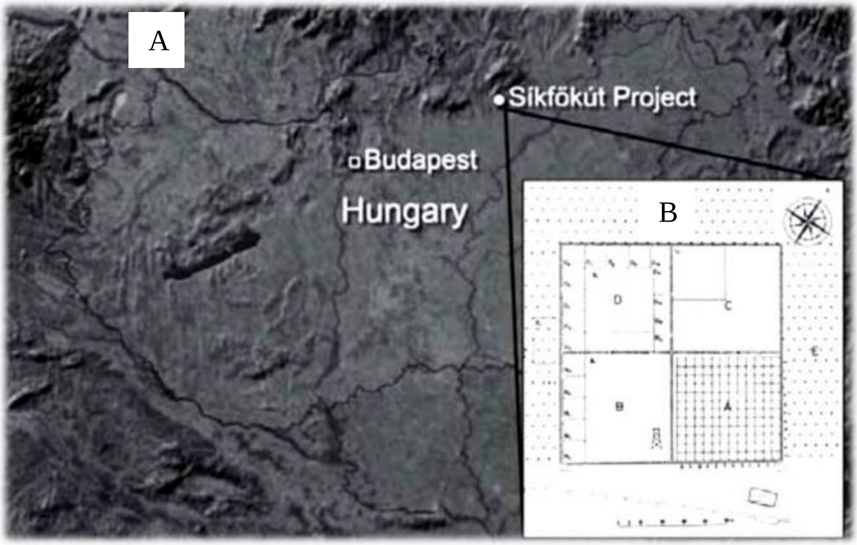

Figure 1.A. Location of the study area in Hungary. B. Study site location with plots.

Sampling and data analysis The structural condition of the shrub layer was monitored on an "A" plot at the research site, 48 m × 48 m in size; the plot was subdivided into 144 4 m × 4 m permanent subplots (Figure 1B).
The subplots were established in 1972; the understory occurrences data collected at subplots measured in the period of 1972-2017 vegetation season on site. Repeated shrub inventories took place in every 4-5 years period. The shrub layer was divided into low (< 1.0 m in height) and high (≥ 1.0 m) layer. Shrub specimens of the vegetation lower than 1.0 m in height were categorized as low understory; higher specimens were categorized as high understory. The occurrence of specimens of each shrub species (occurrence % in subplots of the monitoring plot) was determined as a number expressing in what percentage of the 144 subplots they occurred. Presented frequency values in this paper represent the occurrence of the species (in percentage) in the shrub layer.
Linear regression was used to analyse the relationship between shrub densities and shrub occurrences. The experimental data were analysed by correlation analysis to investigate the possible effects by the occurrences of shrubs on oak tree density (SPSS Statistics 19, Tulsa, USA). Statistical analysis was performed using the PAST statistical software and significant differences for all statistical tests were evaluated at the level of $^{*}P < 0.05$; $^{**}P \leq 0.01$; $^{***}P \leq 0.001$. There was no significant correlation found between the test variables at $^{n.s.}P \geq 0.05$.

RESULTS AND DISCUSSION

Most species were less occurring in 2017 compared with 1972. The occurrence of shrub species change between 0.7 - 98.6% in the period of 1972-2017. Mean values of occurrence changed between 22.4% and 57.6% in the high and between 42.0%

and 94.6% in the low shrub layer. High shrubs with the highest mean occurrence were *Acer campestre* L. (field maple) (57.6%) and *Cornus mas* L. (European cornel) (52.1%) in the last decades. The most occurring low shrub species with the highest mean values were *Euonymus verrucosus* Scop. (spindle tree) (94.6%) and *Ligustrum vulgare* L. (wild privet) (70.8%). The distribution of *Q. petraea* seedlings and saplings occurrence fluctuated between 16.7% and 81.9% on the 144 subplots in the past 45 years. The most frequent species of the shrub community was *E. verrucosus*; followed them *Q. petraea* and *A. campestre* (Table 1).

Table 1. Frequency of occurrence (%) of most common species in shrubs between 1972 and 2017.

species	high shrub layer							
	1972	**1982**	**1988**	**1993**	**2002**	**2007**	**2012**	**2017**
A. campestre	61.8	66.7	58.3	59.0	56.9	52.8	52.1	50.0
A. tataricum	31.9	27.8	26.4	22.2	24.3	19.4	14.6	12.5
C. mas	70.8	57.6	59.7	47.9	46.5	46.5	43.8	40.3
E. verrucosus	0.7	36.1	50.7	39.6	61.8	54.2	47.2	54.9
species	**low shrub layer**							
	1972	**1982**	**1988**	**1993**	**2002**	**2007**	**2012**	**2017**
C. sanguinea	93.1	67.4	72.2	25.7	13.9	37.5	18.1	16.0
E. verrucosus	95.1	94.4	96.5	89.6	91.7	98.6	91.7	95.8
L. vulgare	97.9	91.0	88.9	74.3	52.1	63.9	43.1	45.8
Q. petraea	98.6	16.7	63.2	19.4	41.0	41.7	81.9	78.5

Correlation analysis showed a significantly positive relationship between oak tree density and the occurrence frequency of Acer tataricum L. (Tatar maple) (r = 0.82*), C. mas (r = 0.84**) and E. verrucosus (r = 0.91**) high shrub species and the Cornus sanguinea L. (common dogwood) (r = 0.84*) and L. vulgare (r = 0.73*) low shrub species in the subplots. There was a statistically non-significant interaction ($p > 0.05$) between occurrence values on A. campestre high and E. verrucosus, Q. petraea low shrub species and long-term trend of the canopy oaks density (Table 2).

Table 2. Long-term relationship between canopy oak trees density and occurrences of dominant low and high shrub species on the Síkfőkút mixed oak forest (*N*=81).

high shrub layer species	**oak trees density ind. ha^{-1}**									**correlation**	
	1972	**1982**	**1988**	**1993**	**1997**	**2002**	**2007**	**2012**	**2017**	***p***	***F***
A. campestre										$0.057^{n.s.}$	5.50
A. tataricum	816	651	408	372	304	324	323	305	303	0.012*	12.41
C. mas										0.009**	14.17
E. verrucosus										0.002**	27.01
low shrub layer species	**oak trees density ind. ha^{-1}**									**correlation**	
										p	***F***
C. sanguinea										0.018*	12.16
E. verrucosus	816	651	408	372	304	324	323	305	303	$0.930^{n.s.}$	0.008
L. vulgare										0.039*	6.91
Q. petraea										$0.244^{n.s.}$	1.74

Regression analysis resulted a highly significant relation (p < 0.001) between density and frequency of occurrence by *A. tataricum* and *C. mas* high and *C. sanguinea* and *L. vulgare* low shrub species. This association is lower (p < 0.05) by *A. campestre* and *E. verrucosus* high shrub species. This relationship was not significant ($p \geq 0.05$) in the cases of *E. verrucosus* and *Q. petraea* in the low shrub layer (Table 3).

The effect of competition between trees was examined by Szwagrzyk (1990) in terms of the spatial distribution of tree individuals. It was found that competition did not affect the distribution of trees. Skov (2000) investigated the effect of neighbouring individuals on tree distribution in forest communities. In his research, he found that the main influencing factor of the distribution is the size and density of open areas, open lanes along roads and the species diversity of neighbouring stocks. Maestre and Cortina (2005) paper resulted than relative importance of shrub size, species identity and abiotic factors as determinants of shrub species occurrence.

Table 3. Long-term relationship between densities and occurrences of dominant shrub species on the Síkfőkút mixed oak forest (N=144) (SD=standard deviation).

high layer shrub species	**min. density ind. ha^{-1}**	**max. density ind. ha^{-1}**	**mean density ind. ha^{-1}±SD**	**linear regression**		
				r	***p***	***t***
A. campestre	543	1905	932±360	0.77	0.016*	3.16
A. tataricum	87	430	226±93	0.94	0.15^{-3}***	7.40
C. mas	373	2335	857±453	0.95	8.89^{-5}***	8.03
E. verrucosus	4	1263	663±314	0.87	0.002**	4.73
low layer shrub species	**min. density ind. ha^{-1}**	**max. density ind. ha^{-1}**	**mean density ind. ha^{-1}±SD**	**linear regression**		
				r	***p***	***t***
C. sanguinea	655	13673	3762±3561	0.92	4.38^{-4}***	6.22
E. verrucosus	8098	22967	13471±2761	0.46	$0.218^{n.s.}$	1.35
L. vulgare	1432	21059	8124±5353	0.93	2.62^{-4}***	6.76
Q. petraea	417	47354	9791±10710	-0.18	$0.651^{n.s.}$	-0.47

CONCLUSIONS

The consequences of serious oak decline cause notable changes in the light and stand thermal conditions of forest community which led to structural changes of the shrub layer (Chapman *et al.*, 2006). Our results confirm that the decreasing canopy density led to the occurrence condition changes of the shrubs. The most occurring low shrub species were *E. verrucosus* and *Q. petraea*; the highest frequency of occurrence values have got *A. campestre* and *E. verrucosus* shrub species in the high shrub layer. The mean occurring values changed between 22.37% and 94.60% in the shrub community on the basis of the 45-years long dataset. Our results from 1972 suggest that some dominant shrub species in the understory responded very differently and counter to the oak decline; the occurrence of *A. tataricum* and *C. mas* high shrubs decreased considerably after the oak decline. In parallel in this layer the occurrence of *E. verrucosus* increased many times in a short time. We found highly significant interaction between occurrence of *C. mas* and *E. verrucosus* high shrubs and oak trees density. This relationship is lower or non-significantly by other shrub species. Our results suggest that were a highly significant impact of shrub density on shrub occurrence by *A. tataricum*, *C. mas* high and *C. sanguinea*, *L. vulgare* low shrub species. A better understanding of forest structure and shrub species occurrence in temperate ecosystems may provide useful further information on the shrub layer dynamics of the community.

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