



Size condition of shrub species in a Hungarian oak forest in 2022

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Abstract. The oak decline experienced in recent decades resulted in structural changes of the shrub community. The goal of this research was to determine the size condition on high shrubs (> 1.0 m in height) and to compare the average parameters of species in each sample site in 2022. The following measurements were performed in four plots: height, shoot diameter, and foliage cover. 6–9 native high shrub species were observed in the understory plots. The mean height and shoot diameter distribution of high shrubs varied between 1.22 and 10.18 m and between 0.84 and 11.88 cm respectively. The mean foliage cover of high shrub species changed between 0.11 and 15.26 m² in the vegetation period. One-way ANOVA indicated a non-significant difference ($p > 0.05$) among high shrub species' size conditions on sample plots. Our results suggest that the size characteristics of the shrubs were similar on the plots, and it is worth investigating the relationship between shoot height and shoot diameter in more detail.

Keywords: shrub layer, high shrubs, mean height, shoot diameter, foliage cover

1. Introduction

Temperate deciduous oak forests (*Quercetum petraeae-cerridis*, Soó 1963) are the largest zonal forest communities in Hungary, accounting for about 15.0% of the Hungarian forests [1]. Oak decay has been described as a widespread and complex ecological phenomenon in many countries [2–3]. In 1979–80, a severe oak decline started in the study area, heavily affecting sessile oak trees (*Quercus petraea* Matt. L.), and the resulting changes in forest vegetation layers have been described in several scientific papers [4–8].

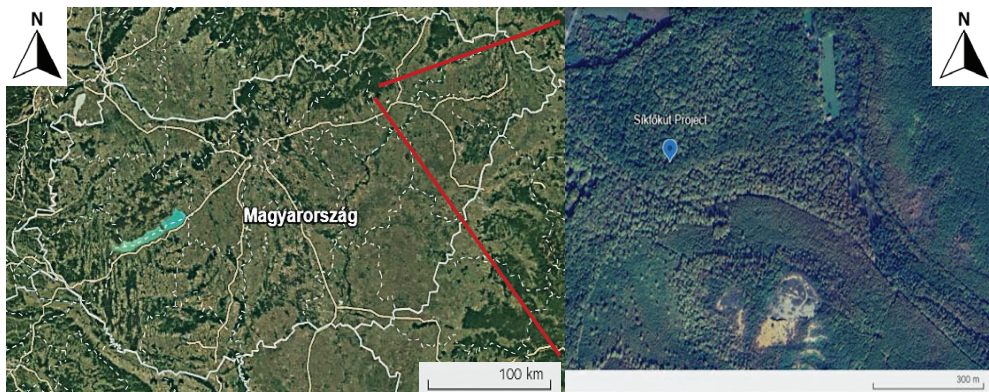
Understory composition is often correlated with site conditions and microclimate, and it provides important indications of ecosystem health and canopy regeneration patterns [9–10]. Despite the fact that shrubs also play important ecological roles in the forest community functioning and structure [11–12], relatively few papers have addressed their complex role. Shrub community dynamics are closely related to forest ecological functions [13–14]. Shrubs can change dynamically and relatively rapidly and respond to changes in their environmental condition [15–16]. They are also closely related to the species composition and structural characteristics of the overstory [17–18]. They play an important role in the cycles of some essential nutrients, including N, K, and C dynamics [19]. Shrub cover contributes essentially to forest biodiversity, including both species and structural diversity indices, and enhances the aesthetics of forest ecosystems [20–21]. Shrubs can improve the water balance of forest ecosystems and protect against severe soil erosion [22–24]. Shrub foliage cover and wood material provide food and habitat for songbirds, large herbivores, and arthropods, among others [25–26]. The shrub community can mitigate forest decline and influence forest-regeneration ability by affecting the quantity and quality of the available light [27–28].

In this paper, we present the results of the latest shrub survey in the lowland forest with a focus on high shrub size conditions in the Síkfőkút Project monitoring site. We discuss the structural characteristics of all four sample plots, shrub height, shoot diameter, and canopy size; we analysed how statistically each parameter differs across plots.

2. Materials and methods

2.1. Sample area

The Síkfőkút forest stand, a 27.0 ha nature reserve with national importance, is located at the foot of the Bükk Mountains in northeastern Hungary (the exact GPS coordinates are N47°55' and E20°46') (*Figure 1*). The forest is characterized by zonal climatic conditions, luvisols soil type, and an altitude of 320–340 m a.s.l. The climate of the forest has become warmer and drier since the establishment of the Síkfőkút Project in 1972 [29–30], which belongs to the ILTER research sites (International Long-Term Ecological Research). A detailed description of the study area can be found in several publications [31–33]. The vegetation stand under study is 110 years old with evenly aged temperate, mixed species deciduous forest, which has not been harvested with forest management in the last 60 years.



Source: GoogleEarth 2025; self-edited

Figure 1. Location of the studied forest community in Hungary

2.2. Methods

The shrub survey was carried out in four randomly selected 24×24 m quadrats in the study area during the growing season of the year 2022. Each sample plot was divided into 36 smaller quadrats, each in size 4×4 m, to facilitate field recording. The shrub community was subdivided into a low and high shrub layer. Specimens higher than 1.0 metres were categorized as high shrubs. Lower specimens were automatically assigned to the low shrub layer. In the monitoring quadrats, the following measurements were taken for each high shrub individual: height (m), shoot diameter (cm), and foliage canopy area (m^2). The height of the shrubs was measured using a 3.0 m scaled wooden pole, while the shoot diameter (at 5.0 cm above ground level) was measured using a digital calliper; the measurement results were averaged for species. Canopy size was determined by two perpendicular measurements with the scaled wooden pole.

A one-way ANOVA (analysis of variance) was used to compare the means of four studied plots for the dependent size condition variable. Statistical analysis was performed using the PAST statistical software, and significant differences for all statistical tests were evaluated at the following levels: $*P < 0.05$; $**P \leq 0.01$; $***P \leq 0.001$. No significant correlation was found between the test variables at n.s. $P \geq 0.05$.

3. Results and discussions

The average height of woody shrub species forming the high shrub layer varied between 1.04 m and 10.09 m in the 4 sample plots. Field maples in quadrat A3

had the biggest shoot height. For all sample plots, field maple (*Acer campestre* L.) individuals were the biggest; they were followed by European cornel (*Cornus mas* L.) and Tatar maple (*Acer tataricum* L.). The average height of the other species typically remained below 3.0 m. Single small-leaved linden (*Tilia cordata* Mill.) and single wild cherry (*Prunus avium* L.) were also present in each sample. However, these species typically reach tree size and appear in the canopy, so we did not take them into account during size comparison. The average shoot diameter of shrubs forming the high shrub layer ranged from 0.75 cm to 14.51 cm in 2022. Field maples in the A3 quadrat also had the largest shoot diameter. The thickest shoots in the studied plots were measured in the field maples, followed by the European cornel and Tatar maples. Detailed data are presented in *Table 1*.

Table 1. Mean height (H) and diameter (D) ($\pm$ standard deviation) of high shrub species on Síkfőkút Project plots in 2022

species	A1		A2		A3		A4	
	H (m)	D (cm)	H (m)	D (cm)	H (m)	D (cm)	H (m)	D (cm)
<i>A. campestre</i>	8.22	11.88	8.26	11.22	10.19	14.51	7.64	9.97
<i>A. tataricum</i>	3.54	5.73	6.33	8.56	4.05	5.26	3.87	5.61
<i>C. mas</i>	5.04	7.02	4.35	6.01	6.28	9.69	5.59	8.08
<i>C. sanguinea</i>	1.41	1.27	2.16	1.41	4.05	3.19	1.06	0.82
<i>Cr. monogyna</i>	2.47	3.76	3.30	3.69	2.43	3.15	2.41	3.41
<i>E. europaeus</i>	2.38	4.02	-	-	1.97	2.49	-	-
<i>E. verrucosus</i>	1.70	1.73	1.98	2.26	1.79	1.62	2.37	2.84
<i>J. regia</i>	-	-	-	-	-	-	1.41	1.00
<i>L. vulgare</i>	1.04	0.75	-	-	-	-	1.39	0.92
<i>P. avium</i> *	21.90	27.87	-	-	-	-	-	-
<i>T. cordata</i> *	-	-	-	-	9.30	11.82	-	-
mean $\pm$ S.D	3.23$\pm$2.4	4.52$\pm$3.7	4.40$\pm$2.5	5.52$\pm$3.8	4.39$\pm$3.0	5.70$\pm$4.7	3.22$\pm$2.3	4.08$\pm$3.5

Note: * The two species were present in plots with a single individual of each tree size, so they were not included in the mean value calculations.

The order of the height and diameter values for the interlocking was determined. Shrub canopy cover values fluctuated between 9.0 and 18.2 m² in 2022 in the four sample plots. Field maple individuals had the highest mean; they were followed by European cornel and Tatar maple. Field maples in the A2 plot had the largest canopy area with 17.6 m². The canopy area of several shrub species was found to be an order of magnitude smaller in all sample plots. Detailed data are presented in *Table 2*.

The results of the one-way ANOVA analysis indicated that the mean values of height in metres, shoot diameter in centimetres, and foliage cover in quadrat metres of the shrub species on the studied 24 $\times$ 24 m quadrat plots differ non-

significantly (^{u.s.} $P > 0.05$) in the different sample plots. The results of the analysis are shown in Table 3.

Table 2. Mean foliage cover (FC) ($\pm$ standard deviation) of high shrub species on Síkfőkút Project plots in 2022

Species	A1	A2	A3	A4
	FC (m ²)	FC (m ²)	FC (m ²)	FC (m ²)
<i>A. campestre</i>	14.97	17.60	16.99	11.47
<i>A. tataricum</i>	7.63	11.80	14.91	12.97
<i>C. mas</i>	12.05	8.68	16.93	15.32
<i>C. sanguinea</i>	0.55	0.80	5.22	8.67 ⁻²
<i>Cr. monogyna</i>	1.70	3.29	2.37	2.80
<i>E. europaeus</i>	3.02	-	3.67	-
<i>E. verrucosus</i>	0.86	1.77	1.10	2.86
<i>J. regia</i>	-	-	-	0.24
<i>L. vulgare</i>	5.92 ⁻²	-	-	0.16
<i>Lo. xylosteum</i>	-	-	-	-
<i>P. avium</i> *	28.18	-	-	-
<i>T. cordata</i> *	-	-	15.05	-
mean $\pm$ S.D.	5.10 $\pm$ 5.76	7.32 $\pm$ 6.59	8.74 $\pm$ 7.19	5.74 $\pm$ 6.40

Note: * The two species were present in plots with a single individual of each tree size, so they were not included in the mean value calculations.

Table 3. One-way ANOVA test of significance in some growth variables among the Síkfőkút Project studied plots in 2022 (between/within groups)

Variables	Sum of squares	df	Mean square	F	P-value
Height	4.55/140.20	3/20	1.52/7.01	0.217	0.88
Diameter	3.85/327.09	3/20	1.28/16.35	0.078	0.97
Cover	34.07/896.98	3/20	11.36/44.85	0.253	0.86

Maple species and European cornel responded positively to the serious oak decline in the last five decades. In the studied forest association, oak decline resulted in remarkably decreasing canopy cover size and led to significant height, shoot diameter, and cover growth of the three woody species (two maples and European cornel) from the shrub layer. Some species in forest communities only wait for certain relatively rapid ecological changes to occur before they can grow considerably; this phenomenon is called the “Oskar” strategy [34]. Maple species typically belong to a genus that displays this characteristic in such circumstances. Therefore, late-seral species, including maples, are well tolerant of disturbance,

even sudden ecological changes in the forest, and can adapt quickly to them, including responding positively to different sizes of foliage gaps in the canopy [35].

Another scientific paper [36] observed that field maple was better adapted to drought than European beech and, in part, even recovered better than oak trees. Combining the aspects of rapid growth ability and drought tolerance, we conclude that rare native tree species (for example, maples in Hungary) are suited as admixed species in future forest stands. Field maple trees are a sensible complement for the climate-stable oak on drier sites. We support this statement because more and more maple specimens will grow into the canopy, which will lead to the eventual formation of a mixed oak forest in the future. On the other hand, maples tolerate drought relatively well [37]. Oak species cannot compete with maples and have been declining at a variable pace to the present day [38–40].

4. Conclusions

Our study suggests that two maples and a significant number of European cornel individuals have also reached great sizes in plots. European cornel has retained its original shrubby form; this species develops multiple stems above the ground and has a large foliage canopy. It is clear from the data (*tables 1–2*) that the other shrubs play a much smaller role in the functioning of the shrub community, in terms of mean height, shoot diameter, and cover alike, and their ecological importance in the forest community is more limited. There were no significant differences between shrub height ($^{n.s.}P > 0.05$), shoot diameter ($^{n.s.}P > 0.05$), and canopy cover ($^{n.s.}P > 0.05$) data for shrubs in each sample plot using one-way ANOVA analysis. Individual field maple was the tallest growing species in the sample plots during the 2022 field recruitment. Field maples also had the highest mean shoot diameter and cover values.

As a result, individuals of both maple species have become higher and thicker, with many individuals reaching typical tree size after the onset of oak decline in the Síkfőkút Project area in the last decades. The 2022 data also supports this.

References

- [1] Bartha, D. (ed.) (2001), *A természetszerű erdők kezelése*. A KöM Természetvédelmi Hivatalának tanulmánykötetei 7. Budapest: Természetbúvár Alapítvány Kiadó.
- [2] Tomiczek, C. (1993), Oak decline in Austria and Europe. *J. Arboricult.* 19, 71–73.
- [3] Sonesson, K., Drobyshev, I. (2010), Recent advances on oak decline in southern Sweden. *Ecol. Bull.* 53, 197–207.

-
- [4] Mészáros, I., Módy, I., Marschall, M. (1993), Effects of air pollution on the condition of sessile oak forests in Hungary. *Studies Environ. Sci.* 55, 23–33.
- [5] Kotroczó, Zs., Krakomperger, Zs., Papp, M., Bowden, R. D., Tóth, J. A. (2005), Thirty-one years of change in vegetation composition of a Central European oak forest at the Síkfőkkút ILTER. In: *INTECOL ESA Joint Meeting in Montreal, Quebec, Canada*.
- [6] Misik, T., Kárász, I. (2020), Long-term relationship between oak decline and shrub growth dynamics in a Hungarian oak forest, 1972–2017. *AGROFOR Inter. J.* 5, 47–54.
- [7] Misik, T., Kárász, I. (2022), Long-term effects of oak decline on shrub individuals' occurrences in a Hungarian oak forest. *AGROFOR Inter. J.* 7, 24–31.
- [8] Misik, T., Kárász, I., Tóthmérész, B. (2014), Understory development in an oak forest in Northern Hungary: The subcanopy layer. *Acta Silv. Lign. Hung.* 10, 9–21.
- [9] Jhariya, M. K., Oraon, P. R. (2012), Regeneration status and species diversity along the fire gradients in tropical deciduous forest of Chhattisgarh. *J. Plant Develop. Sci.* 4(1), 49–54.
- [10] Oraon, P. R., Singh, L., Jhariya, M. K. (2015), Shrub species diversity in relation to anthropogenic disturbance of Bhoramdeo Wildlife Sanctuary, Chhattisgarh. *Environ. Ecol.* 33(2A), 996–1002.
- [11] Balandier, P., Gobin, R., Prévosto, B., Korboulewsky, N. (2022), The contribution of understorey vegetation to ecosystem evapotranspiration in boreal and temperate forests: A literature review and analysis. *Eur. J. For. Res.* 141, 979–997.
- [12] Landuyt, D., De Lombaerde, E., Perring, M. P., Hertzog, L. R., Ampoorter, E. et al. (2019), The functional role of temperate forest understorey vegetation in a changing world. *Global Change Biol.* 25, 3625–3641.
- [13] Augusto, L., Dupouey, J. L., Ranger, J. (2003), Effects of tree species on understory vegetation and environmental conditions in temperate forests. *Annals For. Sci.* 60, 823–831.
- [14] Royo, A. A., Carson, W. P. (2006), On the formation of dense understory layers in forests worldwide: Consequences and implications for forest dynamics, biodiversity, and succession. *Can. J. Forest Res.* 36, 1345–1362.
- [15] Chipman, S. J., Johnson, E. A. (2002), Understory vascular plant species diversity in the mixedwood boreal forest of western Canada. *Ecol. Appl.* 12, 588–601.
- [16] Rees, D. C., Juday, G. P. (2002), Plant species diversity on logged versus burned sites in central Alaska. *For. Ecol. Manag.* 155, 291–302.

-
- [17] Klinka, K., Chen, H. Y. H., Wang, Q. L., de Montigny, L. (1996), Forest canopies and their influence on understory vegetation in early-seral stands on west Vancouver Island. *Northwest Sci.* 70, 193–200.
- [18] Gracia, M., Montané, F., Piqué, J., Retana, J. (2007), Overstory structure and topographic gradients determining diversity and abundance of understory shrub species in temperate forests in central Pyrenees (NE Spain). *For. Ecol. Manag.* 242, 391–397.
- [19] Gilliam, F. S. (2007), The ecological significance of the herbaceous layer in temperate forest ecosystems. *BioSci.* 57, 845–858.
- [20] Aubin, I., Ouellette, M. H., Legendre, P., Messier, C., Bouchard, A. (2009), Comparison of two plant functional approaches to evaluate natural restoration along an old-field–deciduous forest chronosequence. *J. Veg. Sci.* 20, 185–198.
- [21] Wang, B., Bu, Y., Li, Y., Li, W., Zhao, P., Yang, Y., Qi, N., Gou, R. (2019), Quantifying the relationship among impact factors of shrub layer diversity in Chinese pine plantation forest ecosystems. *Forests* 10(9), 781–796.
- [22] Halpern, C. B., Spies, T. A. (1995), Plant species diversity in natural and managed forests of the Pacific Northwest. *Ecol. Appl.* 5, 913–934.
- [23] Muir, P. S., Mattingly, R. L., Tappeiner, J. C., Bailey, J. D., Elliott, W. E., Hager, J. C., Miller, J. C., Peterson, E. B., Starkey, E. E. (2002), Managing for biodiversity in young Douglas-fir forests of Western Oregon. *Biological Science Report*. US Geological Survey, Forest and Rangeland Ecosystem Science Center: Corvallis, OR.
- [24] Kreye, M. M., Adams, D. C., Escobedo, F. J. (2014), The value of forest conservation for water quality protection. *Forests* 5(5), 862–884.
- [25] González-Hernández, M. P., Silva-Pando, F. J., Casal Jiménez, M. (1998), Production patterns of understory layers in several Galician (NW Spain) woodlands: Seasonality, net productivity and renewal rates. *For. Ecol. Manag.* 109, 251–259.
- [26] Verschuyt, J., Clark, L., Loehle, C. (2018), Predicting shrub biomass and current annual growth from field measurements in the Oregon coast range. *Northwest Sci.* 92(1), 9–17.
- [27] Kunstler, G., Curt, T., Bouchaud, M., Lepart, J. (2006), Indirect facilitation and competition in tree species colonization of sub-Mediterranean grasslands. *J. Veg. Sci.* 17, 379–388.
- [28] Wagner, S., Fischer, H., Huth, F. (2011), Canopy effects on vegetation caused by harvesting and regeneration treatments. *Eur. J. For. Res.* 130(1), 17–40.
- [29] Antal, E., Berki, I., Justyák, J., Kiss, Gy., Tarr, K., Vig, P. (1997), *A síkfőkúti erdőtársulás hő- és vízháztartási viszonyainak vizsgálata az erdőpusztulás és az éghajlatváltozás tükrében*. Debrecen.

-
- [30] Tóth, J. A., Lajtha, K., Kotroczó, Zs., Krakomperger, Zs., Caldwell, B., Bowden, R. D., Papp, M. (2007), The effect of climate change on soil organic matter decomposition. *Acta Silv. Lign. Hung.* 3, 75–85.
- [31] Jakucs, P. (ed.) (1985), *Ecology of an oak forest in Hungary. Results of "Síkfőkút Project"* I. Budapest: Akadémia Kiadó.
- [32] Koncz, G., Török, P., Papp, M., Matus, G., Tóthmérész, B. (2011), Penetration of weeds into the understory and seed bank of an oak forest in Hungary. *Community Ecol.* 12, 227–233.
- [33] Fekete, I., Lajtha, K., Kotroczó, Zs., Varbiro, G., Varga, Cs, Tóth, J. A., Demeter, I., Veperdi, G., Berki, I. (2017), Long-term effects of climate change on carbon storage and tree species composition in a dry deciduous forest. *Global Change Biol.* 23, 3154–3168.
- [34] Silvertown, J. W. (1982), *Introduction to plant population ecology*. Oxford, UK: Blackwell Scientific.
- [35] Stewart, G. H. (1988), The influence of canopy cover on understory development in forests of the western Cascade Range, Oregon, USA. *Veg.* 76, 79–88.
- [36] Schmucker, J., Uhl, E., Schmied, G., Pretzsch, H. (2023), Growth and drought reaction of European hornbeam, European white elm, field maple and wild service tree. *Trees* 37, 1515–1536.
- [37] Röhrig, E., Ulrich, B. (1991), *Ecosystems of the world 7: Temperate deciduous forests*. London: Elsevier.
- [38] Zaczek, J. J., Groninger, J. W., Van Sambeek, J. W. (2002), Stand dynamics in an old-growth hardwood forest in Southern Illinois, USA. *Nat. Areas J.* 22, 211–219.
- [39] Dey, C. D., Jacobs, D., McNabb, K., Miller, G., Baldwin, V., Foster, G. (2008), Artificial regeneration of major oak (*Quercus*) species in the eastern United States – A review of the literature. *For. Sci.* 54(1), 77–106.
- [40] Misik, T., Kotroczó, Zs., Kárász, I., Tóthmérész, B. (2017), Long-term oak seedling dynamics and regeneration ability in a deciduous forest in Hungary. *Baltic Forestry* 23, 595–602.