

Martać N., Kanjevac B., Račić M., Lazarević N., Curovic, M., Petrović N., Popović A. (2025) The influence of tree species on microhabitat value in mixed European beech (*Fagus sylvatica*) and silver fir (*Abies alba*) stands on goč. *Agriculture and Forestry*, 71 (3): 113-121. <https://doi:10.17707/AgricultForest.71.3.07>

DOI: 10.17707/AgricultForest.71.3.07

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## **THE INFLUENCE OF TREE SPECIES ON MICROHABITAT VALUE IN MIXED EUROPEAN BEECH (*FAGUS SYLVATICA* L.) AND SILVER FIR (*ABIES ALBA* MILL.) STANDS ON GOČ**

### **SUMMARY**

Habitat trees play a key role in preserving biodiversity of forest ecosystems because they provide microhabitats necessary for the survival of numerous endangered species. The objective of this research was to examine the difference in microhabitat values between beech (*Fagus sylvatica* L.) and fir (*Abies alba* Mill.) in mixed forests of Mount Goč in central Serbia. The basis for this research was three experimental fields of 0.5 ha each. On experimental fields all trees were numbered, their diameter at breast height (dbh) was measured and their microhabitat value was determined. The analysis showed that beech has significantly larger microhabitat values compared to fir on all experimental fields, which was confirmed by applying non-parametric statistical tests. The significant differences in microhabitat values between the researched areas are also determined by statistical analysis, primarily due to different representation of fir. Larger microhabitat values in beech can partially be explained by larger diameters of its trees, since previous studies indicate a significant influence of dimensions of trees on forming of microhabitats. The results obtained emphasize the importance of tree species and its structure for biodiversity preservation and indicate the need of inclusion of habitat trees in strategies of sustainable forest management.

**Keywords:** biodiversity, microhabitat values, mixed forests of Mount Goč

### **INTRODUCTION**

Forests provide key ecosystem products and services, such as food, water, shelter, and nutrient cycling, among others, and play a fundamental role in

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Notes: The authors declare that they have no conflicts of interest. Authorship Form signed online.

Received: 12/05/2025

Accepted: 25/07/2025

preservation of biodiversity. According to recent research, forests cover almost 30% of the Earth's land surface (Keenan *et al.*, 2015), contain 80% of land biomass and provide habitat for more than half of the world's known terrestrial plant and animal species (Shvidenko *et al.*, 2005; Aerts and Honnay, 2011).

Mixed forests of beech (*Fagus sylvatica* L.) and fir (*Abies alba* Mill.) are floristically rich and high number of species makes them unique from a biodiversity perspective (Bledý *et al.*, 2024), especially when it comes to these mixed forests of the Dinaric belt in Southeast Europe (Gazdić *et al.*, 2018; Motta *et al.*, 2024).

Habitat trees are very large, very old and dead or alive trees that carry microhabitats. Depending on their characteristics, habitat trees have different names. Veteran, ancient or monumental trees are specimens of exceptional age or size, while trees suitable for wild animals or trees with cavities serve as a habitat for animals like woodpeckers and other species that nest in cavities (Bütler *et al.*, 2015). Habitat trees, i.e. trees of special importance for habitat diversity, have a key role in preserving biological diversity of forest ecosystems. They represent vital microhabitats for numerous rare, endangered, and stenotopic (specialized) species of flora and fauna. Habitat trees are living or dead upright trees, which enable forming of diverse ecological niches. The niches include cavities (pits), spaces under separated bark, massive dead branches, presence of epiphytic plants, cracks in the trunk, seeping of resinous substances and processes of rotting of woody mass (Großmann *et al.*, 2018; Asbeck *et al.*, 2022; Hämäläinen *et al.*, 2023).

Microhabitat connected with a tree is usually defined as recognizable, clearly delimited structure found on living trees, as well as on dead trees in an upright position. This structure represents a key substrate or place of living for certain species or associations, supporting important phases of their life cycle, such as development, nutrition, shelter or reproduction (Larrieu *et al.*, 2018). At least 25% of forest species are thought to depend on or benefit from dead and habitat trees (Bütler *et al.*, 2013). The most significant factors for which it is determined that they affect on the occurrence of microhabitats are diameter at breast height (dbh), tree species, bark thickness, vitality, tree age and stand structure (Bütler and Lachat 2009; Larrieu and Cabanettes, 2012; Regnery *et al.*, 2013; Sever *et al.*, 2019; Asbeck *et al.*, 2022; Višnjić *et al.*, 2025). Coniferous tree species were found to have a lower microhabitat value compared to deciduous tree species (Vuidot *et al.*, 2011; Winter, 2014; Großmann *et al.*, 2018).

The study of microhabitat values in forests of different compositions, especially the comparison between deciduous and coniferous trees, is essential for efficient biodiversity conservation. Since a significant part of forest fauna and flora relies on specific microhabitats provided by habitat trees, understanding differences in quality and quantity of microhabitats between these two groups of trees can help in optimization of forest management and protection of endangered species.

Current research indicates that coniferous species generally support smaller number and diversity of microhabitats compared to deciduous species, which has important implications for planning protection measures and sustainable use of forests. Therefore, more detailed analysis of these differences is crucial for shaping target strategies of preservation of forest biodiversity in different ecosystems.

## MATERIAL AND METHODS

The research was conducted in central Serbia in the territory of the Mount Goč in mixed stands of silver fir and beech. The studied stands are part of the large mountain massif Goč - Željina, which stretches between the Ibar and the Western Morava. To the north this massif is connected to the mountain Stolovi, and to the south it abuts the striking massif of Kopaonik (Figure 1).

The studied stands are located on a bedrock which predominantly consists of granodiorite, the soil is acidic brown, 80-120 cm deep and fresh. Regional climate is classified as continental with pronounced mountain influence, the average annual temperature is 11.5°C, and the annual precipitation is 740 mm. The altitude of the part of the mountain massif where the experimental fields are located ranges from 1100 to 1180 m.

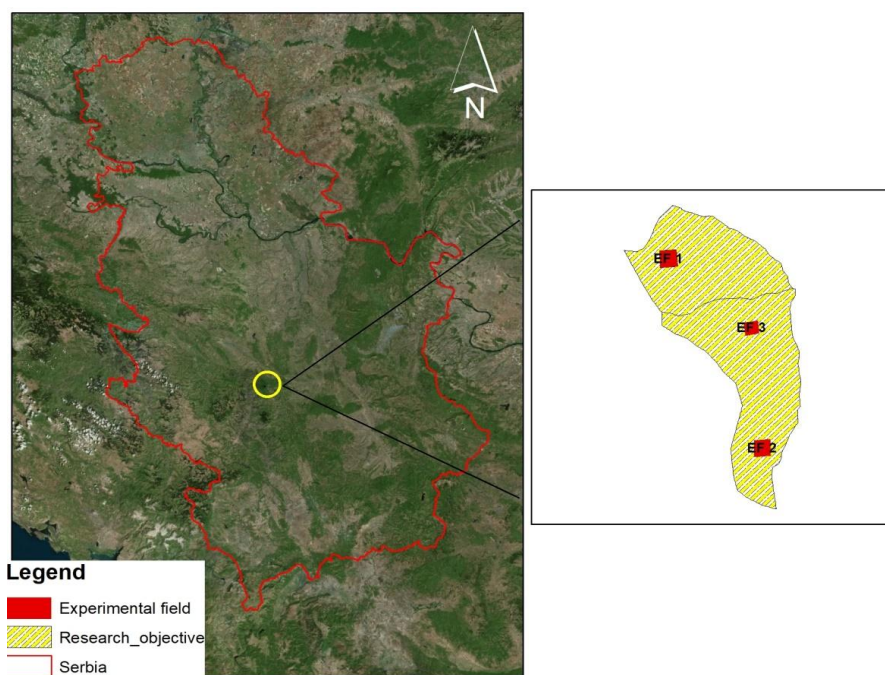


Figure 1. The object of research

Monitoring and data collection was carried out on square-shaped sample plots with an area of 0.5 ha (Figures 2-4). On experimental fields all trees were

numbered, their diameter at breast height (dbh) and height were measured. Microhabitat value of each tree was determined using the methodology defined by the researchers of European Forest Institute which is integrated within the software “Integrate+” and described through “Catalogue of tree microhabitats” (Kraus *et al.*, 2016). In order to decrease the possibility of partiality of the observer (Paillet *et al.*, 2015), the inventory was carried out by same team during autumn. This period was chosen because the foliage had already fallen, by which the microhabitats in the crown became more visible. Subsequent to field data collection, the recorded information was entered into an Excel database, where systematic and logical checks were performed to ensure data integrity. Taxation data processing was performed by standard dendrometry methods.



Figure 2. Experimental field 1



Figure 3. Experimental field 2

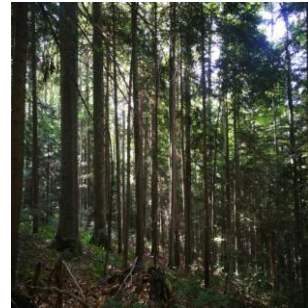


Figure 4. Experimental field 3

It was tested the differences in microhabitat values between experimental fields and among tree species within experimental fields. Considering the violated assumptions of normality and homogeneity of variances (verified by Levene’s test and visual inspection of distributions), the Kruskal–Wallis test was applied to analyze differences in microhabitat values among the three experimental fields as a suitable nonparametric alternative to one-way analysis of variance (ANOVA). Statistical significance of differences between groups was assessed at the 0.05 significance level. In the case of significant differences, Dunn’s post hoc test with Bonferroni correction was performed.

Due to violated assumptions of normality and homogeneity of variances, the Mann–Whitney U test was applied to analyze differences in microhabitat values between beech and fir trees, as an appropriate non-parametric alternative to the independent samples t-test. Statistical significance was assessed at the 0.05 level. The results are presented in terms of the U statistic, Z value, and corresponding p-values, whereby lower mean rank values indicated groups with lower overall microhabitat scores. The analyses were conducted separately for each experimental field. Statistical analysis was conducted using the statistical software SPSS and JASP.

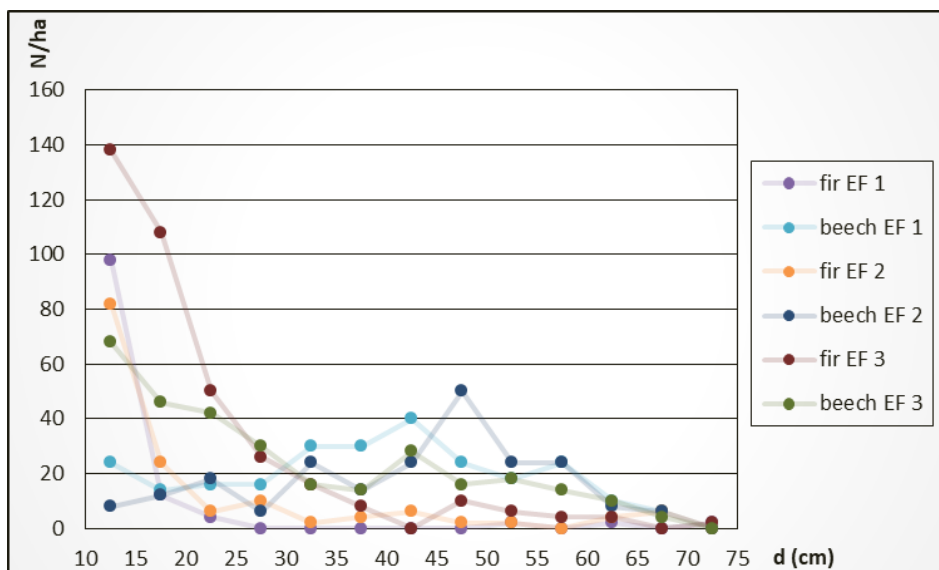
## RESULTS AND DISCUSSION

The number of living trees with a diameter larger than or equal to 10.1 cm ranges between 366 and 678 trees per hectare, basal area and volume range from

36.96 to 43.7 m<sup>2</sup>/ha, and from 553.0 to 743.4 m<sup>3</sup>/ha, respectively (Table 1). These parameters indicate high productivity of the researched stands and they are located within the range of previous research of beech (*Fagus sylvatica* L.) and fir (*Abies alba* Mill.) in mixed forests carried out in Serbia (Obradović *et al.*, 2018; Martać *et al.*, 2021) and in Montenegro (Čurović *et al.*, 2020). In the mixed beech-fir forest of Southern Carpathian average volume is 893.1 m<sup>3</sup>/ha (Braga *et al.*, 2023), while in Bosnia and Herzegovina, show volumes ranging from 747–1201 m<sup>3</sup>/ha (Motta *et al.*, 2024).

Table 1. Value of taxation indicators and microhabitats

Species	EF1				EF2				EF3			
	N/ha	Basal area m <sup>2</sup> /ha	Volume m <sup>3</sup> /ha	Microhabitat	N/ha	Basal area m <sup>2</sup> /ha	Volume m <sup>3</sup> /ha	Microhabitat	N/ha	Basal area m <sup>2</sup> /ha	Volume m <sup>3</sup> /ha	Microhabitat
Beech	252	33.6	615.4	5858	148	33.98	629.2	5928	306	27.38	370.6	5096
Fir	120	3.36	39.2	918	218	8.06	114.2	640	372	16.32	182.4	1496
Total	372	36.96	654.6	6776	366	42.04	743.4	6568	678	43.7	553	6592



Graph 1. Diameter-class structure

Research findings indicate that the studied stands are quite similar in both structure and productivity. The diameter-class structure analysis reveals that these are selection stands. However, when we examine fir and beech separately (Graph 1), it becomes clear that fir exhibits a selection structure, while beech does not show a typical selection structure. Namely, in the case of beech share of the trees with diameter at breast height above 40 cm is significantly larger than the trees of smaller dimensions. Therefore, the reason for higher microhabitat values in beech trees (Table 3) is likely to be found in thickness structure of the trees since beech has significantly higher representation of trees of larger dimensions which affect

positively the occurrence of microhabitats, as indicated by earlier research (Asbeck *et al.*, 2022; Larrieu & Cabanettes, 2012; Vuidot *et al.*, 2011).

Table 2. Results of Kruskal – Wallis test and Dunn’s post hoc comparisons for microhabitat values between EF

Test	Statistic / Z	Df	p – value	p – (Bonferroni)
Kruskal – Wallis test	14.873	2	<0.001	
Dunn post hoc test				
EF1-EF2	0.181	/	0.856	1.000
EF1-EF3	3.279	/	0.001	0.003
EF2-EF3	3.056	/	0.002	0.007

The Kruskal–Wallis test (Table 2) revealed a statistically significant difference in microhabitat values among the three EF ( $\chi^2(2) = 14.873$ ,  $p < 0.001$ ). Subsequent pairwise comparisons using Dunn’s post hoc test with Bonferroni correction showed no significant difference between EF 4 and EF 5 ( $p = 1.000$ ). However, significant differences were found between EF 4 and EF 6 ( $p = 0.003$ ), as well as between EF 5 and EF 6 ( $p = 0.007$ ). These results indicate that microhabitat values in EF 6 are significantly different from those in EF 4 and EF 5, while no significant difference exists between EF 4 and EF 5.

Table 3. Results of the Mann – Whitney U Test for Differences in Microhabitat Values Between European Beech (*Fagus sylvatica*) and Silver Fir (*Abies alba*) Across Experimental fields

Experimental fields	N	Mean Rank ( <i>Fagus sylvatica</i> )	Mean Rank ( <i>Abies alba</i> )	Mann-Whitney U	Z	p-value
4	186	114.54	49.32	1129.00	-7.914	0.000
5	183	119.79	51.06	1003.50	-8.819	0.000
6	339	228.99	121.48	5204.00	-10.511	0.000

The results of the Mann–Whitney U test (Table 2) indicate statistically significant differences in microhabitat values between European beech (*Fagus sylvatica*) and silver fir (*Abies alba*) trees across all analyzed experimental fields, with p-values below the significance level of 0.001 ( $p < 0.001$ ).

In each experimental field, the mean ranks clearly show that microhabitat values are significantly higher for beech compared to fir:

- In EF 4, beech had a mean rank of 114.54, while fir had a considerably lower mean rank of 49.32.
- In EF 5, the mean rank for beech was 119.79, whereas for fir it was 51.06.
- In EF 6, beech exhibited the highest mean rank of 228.99, compared to fir’s rank of 121.48.

These differences in mean ranks indicate that microhabitat values are more frequent and greater for beech than for fir across all sample plots, as further confirmed by the negative Z-values observed in all cases. Considering that the

test is non-parametric and does not require a normal data distribution, these results suggest a robust and reliable difference in microhabitat values between the two species, regardless of potential deviations in data distribution. Further knowledge of multiple structural characteristics differences between the actual and the theoretically balanced structure should provide a more complex and reliable data (Govedar *et al.*, 2018).

## CONCLUSION

The results of the research indicate that the tree species has a key effect on microhabitat value in forest ecosystems. Certain species, especially beech and other deciduous species, more often carry a larger number and diversity of microhabitats than conifer species such as silver fir, by which they directly contribute to preservation of habitats for different forest organisms. This is extremely important to keep in mind when designing interventions in mixed forests. Until now, it has been common to force the dominant participation of coniferous species through management measures. Earlier research indicates that, in addition to the species, tree diameter also proved to be an important factor – trees of larger dimensions usually provide more potential for the development of microhabitats.

Therefore, it is necessary that future studies analyze in more detail the mutual influence of the species and dimensions of trees on forming of microhabitats, in order to better understand their role in the preservation of biodiversity and improve sustainable forest management strategies. Such research is of particular importance because it contributes to the creation of realistic and scientifically founded overview of microhabitat value, which further enables to define optimal measures through management plans that simultaneously ensure durability in management, as well as preservation and improvement of biological diversity in forest ecosystems.

## ACKNOWLEDGEMENTS

This research was funded by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (Contract No. 451-03-136/2025-03/ 200027).

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