BIOLOGICA NYSSANA

DOI: 10.5281/zenodo.964117

8 (1) • September 2017: 73-81

Original Article

Received: 22 July 2017
Revised: 17 August 2017
Accepted: 30 August 2017

Chasmophytic forests of *Ostrya carpinifolia* in west-Serbian canyons

Branko Karadžić

Institute for Biological Research of Belgrade University, Bul. Despota Stefana 142, 11000 Belgrade, Serbia

** E-mail: branko@ibiss.bg.ac.yu*

***Abstract*:**

Karadžić, B.: *Chasmophytic forests of Ostrya carpinifolia in west-Serbian canyons. Biologica Nyssana, 8 (1), September 2017: 73-81.*

Variability patterns and biodiversity components of chasmophytic forests of *Ostrya carpinifolia* in west-Serbian ravine habitats were analyzed in this article. Investigations were performed in four gorges along Gornja Trešnjica, Gradac, Ljutina and Lim rivers. Chasmophytic hop hornbeam forests occur on steep slopes (25° to 50°) at elevations ranging from 260 m to 1200 m, on all aspects. These forests grow on screes, rocky clifs, colluvial gravel, on shallow soils on dolomites, limestone and serpentine. Canonical correspondence analysis indicates that moisture, light and temperature gradients are the main factors affecting diversification of investigated forests. The greatest alpha diversity was detected in Brodarevo and Gostun gorges, along the Lim River.

Key words: Alpha diversity, Beta diversity, *Ostrya carpinifolia,* Chasmophytes, Canonical correspondence analysis

***Apstrakt*:**

Karadžić, B.: *Hazmofitske šume sa Ostrya carpinifolia u zapadnoj Srbiji. Biologica Nyssana, 8 (1), Septembar 2017: 73-81.*

U ovom radu ispitivani su obrasci varijabilnosti i komponente biodiverziteta hazmofitskih šuma *Ostrya carpinifolia* u klisurskim habitatima zapadne Srbije. Istraživanja su sprovedena u četiri klisure duž reka Gornja Trešnjica, Gradac, Ljutina i Lim. Hazmofitske šume crnog graba se javljaju na strmim padinama (25° do 50°) i visinama od 260 m do 1200 m. Ove šume rastu na siparima, kamenitim liticama, koluvijalnom šljunku, plitkim zemljištima na dolomitu, krečnjaku i serpentinima. Kanonska korespodentna analiza ukazala je da gradijenti vlage, svetlosti i temperature predstavljaju glavne faktore koji utiču na diverzifikaciju ispitivanih šuma. Najveći alfa diverzitet uočen je u klisurama Brodareva i Gostuna duž reke Lim.

Ključne reči: alfa diverzitet, beta diverzitet, *Ostrya carpinifolia,* hazmofite, kanonijska korespodentna analiza

Introduction

The chasmophitic vegetation is very complex, since it involves communities on calcareous, serpentine and silicate rocks, at different altitudes, from colline (usually ravine) habitats to nival regions (Lakušić & Karadžić, 2010). These communities are intra-zonal, since they occur in all vegetation zones.

Chasmophytes in ravine habitats usually belong to the group of (paleo) endemic rare species. In ravine habitats, these species found a refuge from unfavourable climatic conditions, stronger competitors from neighbouring non-ravine communities, grazing and human-induced disturbances.

This article is focused on the chasmophytic forests, dominated by European hop hornbeam (*Ostrya carpinifolia* Scop.). The forests are located in ravine habitats along the Gradac, Gornja Trešnjica, Ljutina and Lim rivers. *Ostrya carpinifolia* Scop. is a species adapted to warm to moderate climate. This species has a wide tolerance limits with respect to both, the light and moisture gradients (Popović, et al., 1996). Therefore it (co)dominates in a wide spectrum of communities that belong to ecologically different alliances (Trinajstić & Cerovečki, 1978, Puncer & Zupančič, 1982, Tomić, 1994, 2000).

Distribution of *Ostrya carpinifolia* comprises Apennines, Tyrol, western parts of the Balkan Peninsula, Asia Minor and Lebanon (Meusel et al., 1965). The closest aliens of this species occur in East Asia and North as well as Central America (Trinajstić & Cerovečki, 1978). Such distribution clearly indicates a Tertiary disjunction of the genus *Ostrya* Scop.

European hop hornbeam codominates with other (sub)Mediterranean xeric trees (*Carpinus orientalis* Mill., *Quercus pubescens* Willd., *Paliurus spina-christi* Mill.) in xeric communities of the alliance *Carpinion orientalis* Horvat 1954, along the Adriatic Sea and in regions where the maritime influence extends deep into the continent, along the rivers Una, Neretva, Drim and Vardar. In more humid habitats, these forests are replaced by the amphiadriatic mesic calcareous climte-zonal alliance *Fraxino orni-Ostryion carpinifoliae* Tomažič 1940 = *Ostryo-Carpinion orientalis* Horvat 1959 (Horvat et al., 1974, Čarni et al., 2009, Mucina et al., 2016). Hop hornbeam also occurs on relict *Pinus nigra* forests on dolomite and ultramafic substrates of the Dinarides (alliance *Erico carneae-Fraxinion orni* Horvat 1959). Due to a broad ecological amplitude with respect to moisture, *Ostrya carpinifolia* forms mesic intrazonal forests in inland ravine habitats. These forests are included into the alliance *Tilio platyphylli - Acerion pseudoplatani* Klika 1955 (Borhidi et al., 1999, Košir et al., 2008, Dakskobler et al., 2013). Broad-leaved ravine *Tilio-Acerion* forests specify an EU priority type of ecosystems (Rodwell et al., 1998). Compared with *Tilio platyphylli - Acerion pseudoplatani* forests, the hop hornbeam forests in ravine habitats of inland Balkan aea are more diverse (Karadžić et al., 2001, 2015).

The aim of present study is to describe structure of the mixed black hornbeam forests that are located in West-Serbian canyons, to relate their floristic composition with environmental factors and to detect patterns of α- and β-diversity.

Material and methods

The study area is located in western parts of the Central Serbia. Investigations were performed in four ravine habitats along the Gradac, Gornja Trešnjica, Ljutina and Lim rivers. The altitudinal range and geographic coordinates of investigated localities are presented in **Table 1**.

The eastermost and northernmost locality is the gorge of the Gradac River. This gorge is exposed to the influence of Panonnian Plane.

The vegetation samples (relevés) were collected seasonally, from early spring to late autumn. Combined cover-abundance values of Braun-Blanquet's (1965) alphanumeric scale were replaced by a nine-degree numeric values (Westhoff & van der Maarel, 1973). The taxonomic nomenclature was harmonized with the Plant List database that involves accepted Latin name for vascular plants and Bryophytes (http://www.theplantlist.org).

Differentiation of communities with respect to environmental variables was assessed using the

Table 1. Geographic position and altitudinal range of investigated localities

Rivers	Locality	Altitudinal range	Angular coordinates	
Gornja Trešnjica	Trešnjica	315-855	44.08447 N	19.32165 E
Lim	Brodarevo, Gostun	500-1080	43.10567 N	19.46642 E
Ljutina	Ljutina	619-1200	43.28807 N	19.24945 E
Gradac (Sušaja)	Lastva	261-819	44.11722 N	19.51642 E

canonical correspondence analysis (ter Braak, 1986). Environmental variables within analyzed communities were assessed using the weighted average of ecological indicator values (Kojić et al., 1997).

Alpha diversity was calculated using the Shanon function

$$H = -\sum_{i=1}^{n} p_i \log p_i ,$$

where p_i is the proportion for species within community. According to Hill (1973) and Pielou (1974), the Shanon's function is a special case of Renyi's general entropy function. Beta diversity was detected according to the Routledge (1977) method:

$$\beta = \frac{s^2}{2r+s} - 1,$$

where s is the total number of species, and r is the number of species pairs whose distributions overlap. Above equation specifies the changing rates of compositional turnover along an environmental gradient (Wilson & Shmida, 1984).

All statistical analyses were performed using "FLORA" software package (Karadžić, 2013).

Results and discussion

Floristic differences among analyzed canyons

Ravine forests in Serbian gorges and canyons occur on screes, rocky clifs, colluvial gravel and also on developed soils, mainly shallow rankers, rendzinas and brown calcareous soils (Pavlović et al., 2017). Screes were recorded in all investigated ravines. They are covered by sparsely distributed individuals of *Ostrya carpinifolia* Scop., *Fraxinus ornus* L., *Frangula rupestris* (Scop.) Schur. and *Cotinus coggygria* Scop. On more favourable soils, the hop hornbeam occurs in combination with *Carpinus orientalis* L., *Rhamnus saxatilis* Jacq., *R. cathartica* L., *R. Alpina* subsp. *fallax* (Boiss.) Maire & Petitm., *Tilia platyphyllos* Scop., *Acer campestre* L., *Juglans regia* L., *Carpinus betulus* L., *Viburnum lantana* L., *Quercus cerris* L., *Q. petraea* (Matt.) Liebl., *Q. pubescens* Willd., *Fagus sylvatica* L. etc, forming complex polydominant communities.

In order to detect patterns of floristic variability of analyzed forests a set of multivariate statistical methods was performed. Correspondence analysis (CA) and principal components analysis (PCA) with their canonical forms are the most frequently used ordination methods in ecology (Jongman et al., 1987; Legendre & Legendre, 2003; Greenacre, 2010). Principal axes obtained by either CA or PCA are mutually uncorrelated, but not necessarily independent. A

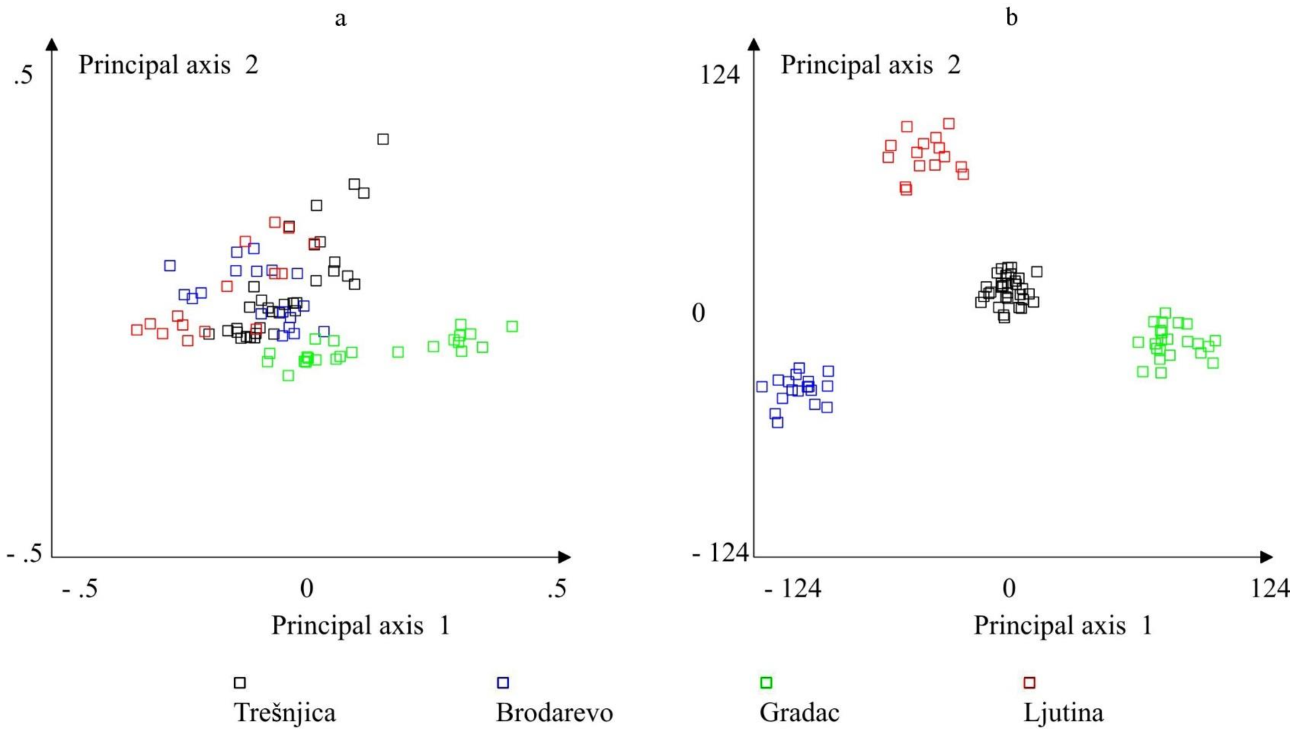

Fig 1. Correspondence analysis (a) and discriminant correspondence analysis (b) of analyzed forests. Analyses were performed on a hypercorrelated matrix, in order to avoid undesirable Guttman effect

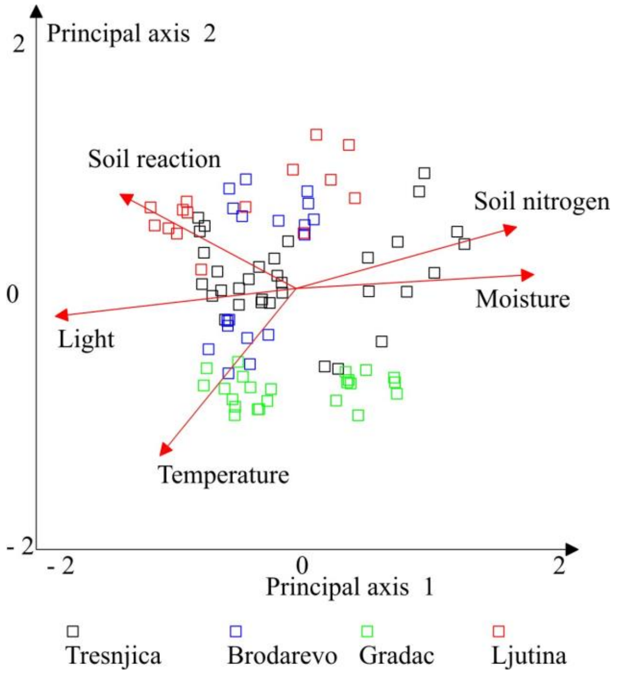

Fig 2. Canonical correspondence analysis of chasmophytic hop hornbeam forests in investigated gorges

spurious polynomial relation between ordination axes (the arch effect or Guttman effect) is a well-known drawback of CA and PCA. Compared to CA, PCA is more sensitive to the arch effect, especially in the case when beta diversity (species turnover) along spatial or environmental gradients is high (Jongman et al., 1987, Karadžić & Popović, 1994, Karadžić et al., 1999). Karadžić et al. (2014) revealed that the hypercorrelated matrices significantly reduce the Guttman effect. Therefore, all multivariate analyses were performed on hypercorrelated matrices. The results of Correspondence Analysis (**Fig. 1**) clearly indicate that the forests continuously intergrade. This is a consequence of polydominant structure and a great number of species with overlapping distribution.

Contrary to ordinary correspondence analysis, the discriminant correspondence analysis (Greenacre, 2000), clearly separates chasmophytic forests of *Ostrya carpinifolia* in different gorges. First principal axis separates analyzed forests according to the altitudinal gradient (from the lowermost gorges along the Gradac and Gornja Trešnjica to mountainous communities in Ljutina and Brodarevo gorges).

Environmental conditions

Specific topography of gorges and canyons significantly modifies microclimate conditions. Solar rays hit the opposite slopes of canyons at different angles. Amount of solar energy per unit surface is much greater on southern than on northern slopes. Moreover, the evaporation is much greater on southern than on northern slopes. Such conditions form strong environmental gradients.

Effects of environmental variables on floristic differentiation of analyzed forests were detected using Canonical Correspondence Analysis (CCA). The canonical ordination axes maximize floristic variability of a data set that can be explained by a set of environmental variables. The results of CCA (**Fig. 2**) clearly indicate that the forests continuously intergrade. This is a consequence of polydominant structure and a great number of species with overlapping distribution. The main factors that affected floristic differentiation of analyzed forests are moisture, light and temperature. Thermophylous communities covering the gorge of the Gradac River are clearly separated from other communities.

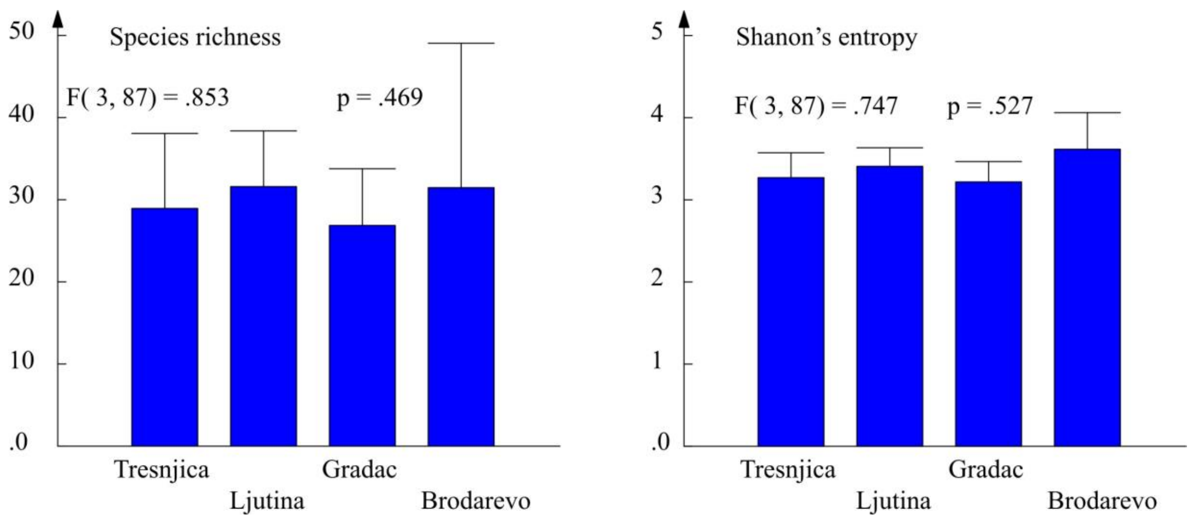

Fig. 3. Components of alpha diversity in chasmophytic hop hornbeam communities

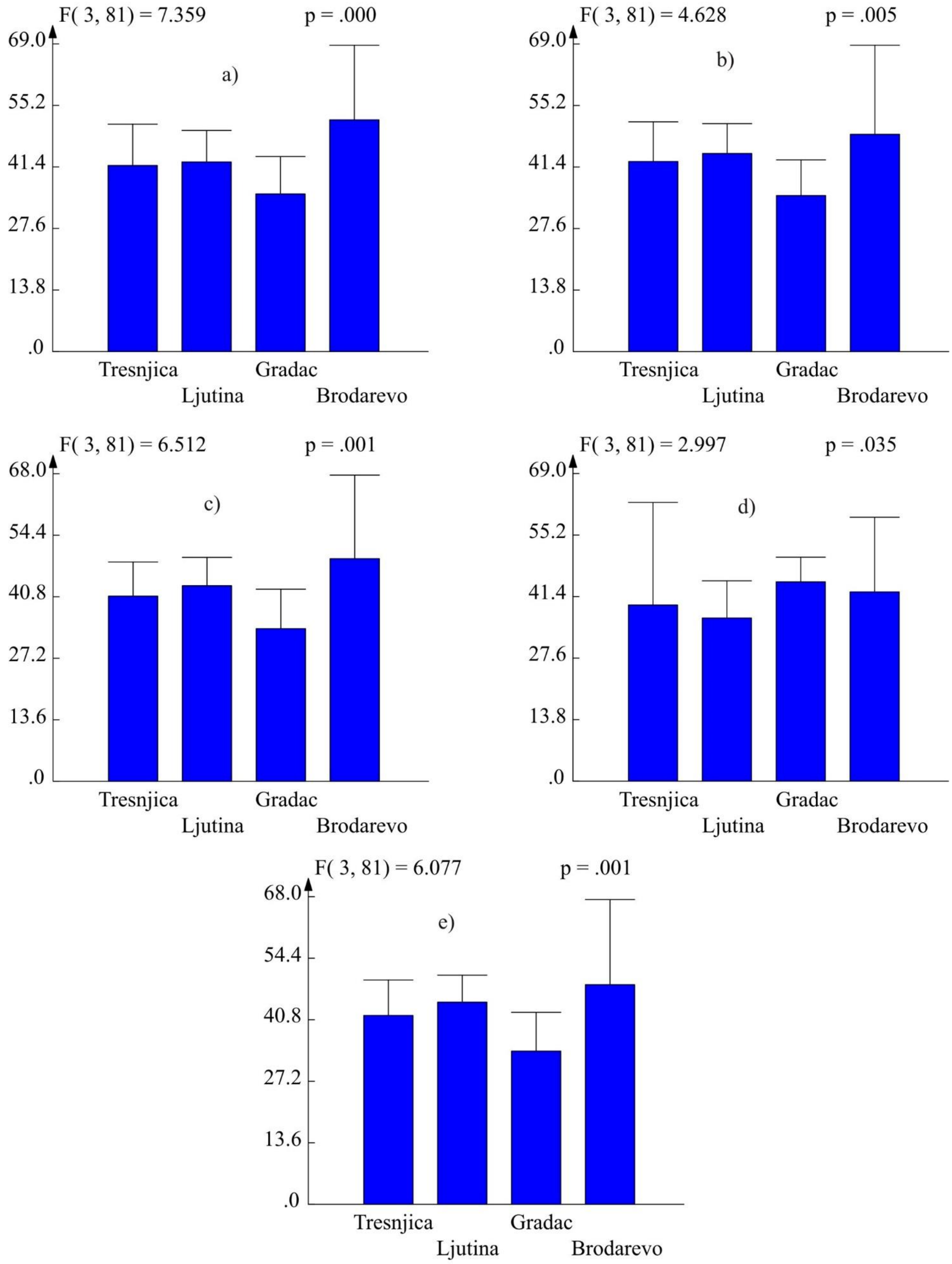

Fig 4. Beta diversity of hop hornbeam forests along the gradients of moisture (a), temperature (b), light (c), soil acidity (d) and soil nitrogen (e)

Diversity components of analyzed forests

Biological diversity is the term, which in its broadest sense means *variability of the living world*. Such general definition needs further elaboration, since biological variability is a multi-component, complex parameter that involves intraspecies (*population*) and interspecies (*cenotic*) variety (Whittaker, 1972; Karadžić & Marinković, 2009). Intraspecies or population variability is the result of genetic variability, the variability induced by influence of environmental factors and the variability which arises from the interaction of genetic background and environmental conditions. Interspecies or coenotic variability can be divided into within-community variability (*alpha diversity*), variability between communities (*beta diversity*) and the total variability in a given region (*gamma diversity*).

Alpha diversity (within-community diversity) depends on species richness and equitability of species abundances in a community. Both, species richness and entropy are the greatest in Brodarevo (and nearby Gostun) gorges along the Lim River. A high species richness and Shanon's entropy were recorded also in communities that inhabit the Ljutina River gorge. The lowermost values of alpha diversity components were recorded in communities covering the gorge of the Gradac River (**Fig. 3**).

Anderson et al. (2015) distinguish two types of beta diversity: directional turnover along a gradient and nondirectional between-community variation.

Directional beta-diversity (or extent of species replacement along environmental gradients) indicates the degree to which habitats have been partitioned by species. Replacement of species (species turnover) is a function of the habitat heterogeneity and ecological tolerance of species (Whittaker, 1972; Karadžić et al., 2003).

Beta diversity was calculated for each adjacent pairs of sites that are ordered along an environmental gradient (**Fig. 4**). Irrespective on environmental gradient, the greatest values of beta diversity were observed in communities that inhabit gorges along the Lim River.

Endemism of hasmophytic taxa

According to Velčev et al. (1992), the Balkan endemics may be divided into two main categories: *paleo-endemics* and *neo-endemics*. The first group involves Tertiary relics, with low-genetic variability, diploid or low-ploid chromosome number and

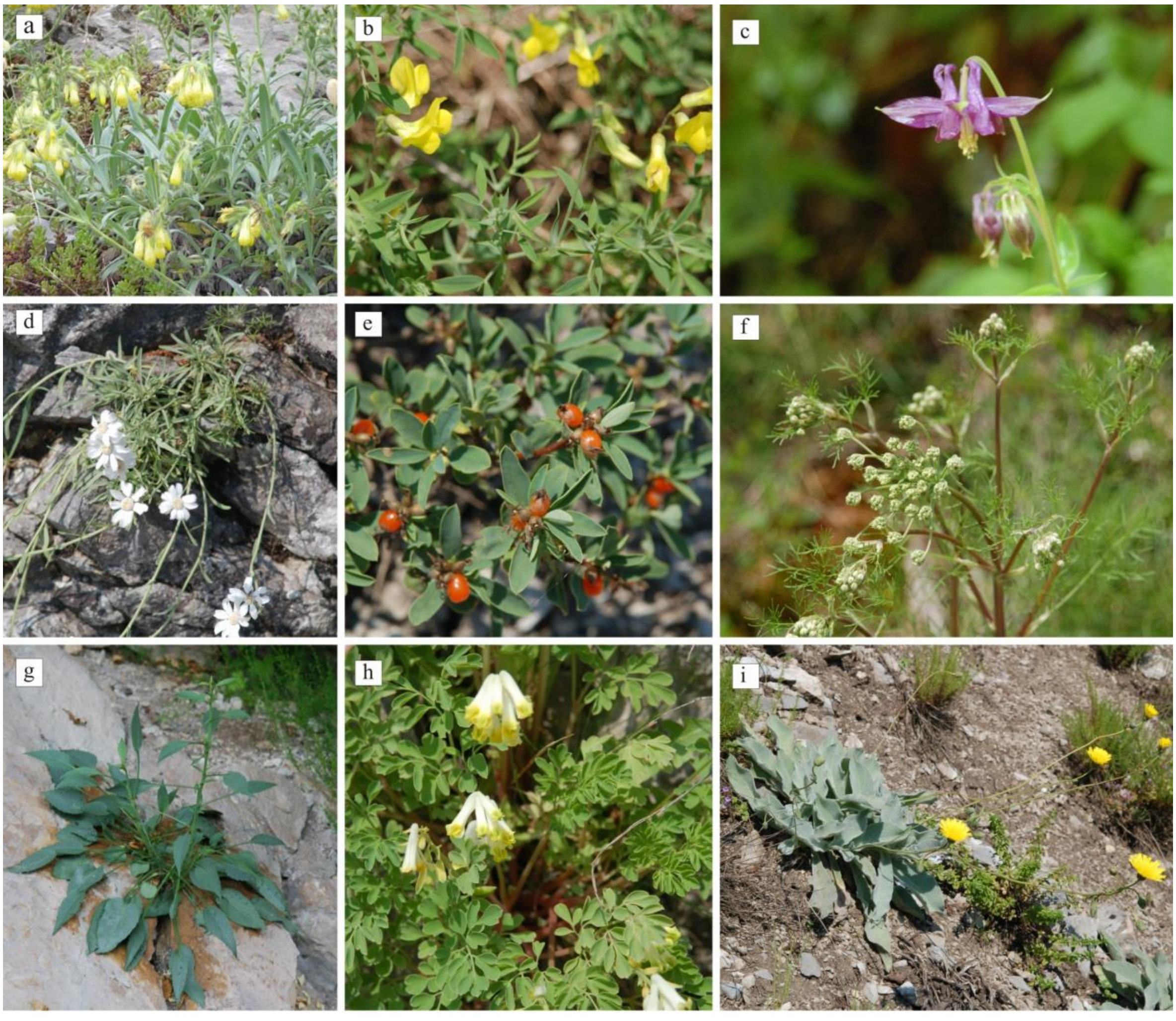

Fig 5. Important endemic chasmophytes in analyzed forests: *Onosma stellulatum* Wald. et Kit (a), *Lathyrus binatus* Pančić (b), *Aquilegia grata* Zimmeter (c), *Achillea ageratifolia* (Sibth. & Sm.) Boiss. (d), *Daphne malyana* Blečić (e), *Athamanta turbith* (L.) Brot. *subsp. haynaldii* (Borbas & Uechtr.) Tutin. (f), *Campanula secundiflora* Vis. & Pančić (g), *Corydalis ochroleuca* Koch. (h) and *Hieracium waldsteinii* Tausch (i).

apparent disjunct distribution with its closest relatives. Due to long time scale isolation and absence of genetic contacts with their relatives, these species formed stable genotypes under particular conditions. Neo-endemics are species that appeared during Quartenary climatic stresses. These species are characterized by polyploidy (tetraploid or high ploid chromosome numbers).

Tertiary relics comprise species that dominated in Europe at the beginning of the so-called Quaternary period. Repeated swings of glacial and interglacial periods affected significant reduction of floristic diversity in Europe. Periodic latitudinal (northward and southward) migrations of flora were obstructed by the mountain barriers. The east–west orientation of European main mountain massifs prevented latitudinal migration of Tertiary relics. Therefore, the remnants of Tertiary flora persisted in three South-European peninsulas (Iberia, Apennines and the Balkans), mostly in ravine habitats, where specific topography attenuated climate oscillations. The most important endemo- relics in analyzed communities are *Onosma stellulatum* Wald. et Kit, *Lathyrus binatus* Pančić, *Aquilegia grata* Zimmeter, *Achillea ageratifolia* (Sibth. & Sm.) Boiss., *Daphne malyana* Blečić, *Athamanta turbith* (L.) Brot. subsp. *haynaldii* (Borbas & Uechtr.) Tutin., *Campanula secundiflora* Vis. & Pančić, *Corydalis ochroleuca* Koch., *Hieracium waldsteinii* Tausch, *Cardamine glauca* Sprengel, *Dianthus petraeus* Waldst. & Kit. *Seseli rigidum* Waldst. & Kit., *Edraianthus graminifolius* (L.) A. subsp. *jugoslavicus* Lakušić. Some (steno)endemic taxa that inhabit investigated forests are presented in **Fig. 5**.

Most of endemic species in Serbia belong to the group of paleo-endemics and high-mountain endemics. The third group of the endemics belongs to the serpentinophytes. The serpentine soils are characterized by low levels of the essential plant elements (nitrogen, phosphorus, potassium and calcium), as well as high levels of iron, magnesium, and manganese, and toxic levels of chromium, cobalt and nickel. Due to the "serpentine stress" (toxic effects of heavy metals, nutrient shortages and droughts), most plant species avoid serpentine soils. A small percent of serpentine-tolerant taxa has evolved morpho-anatomical and physiological adaptations that allow them to survive in extremely unfavourable conditions. Strong selective pressures of serpentine soil and spatial isolation of serpentine regions resulted with high percent of endemic serpentinophyte taxa in the Balkans (Jakovljević et al., 2011). The most important serpentinophytes that inhabit analyzed communities are *Euphorbia glabriflora* Vis., *Scrophularia tristis* Maly and *Asplenium cuneifolium* Viv. These species occur on patches of serpentinous soil in gorges along the Lim River.

The chasmophitic vegetation is distributed on rocky habitats of Paleo-Temperate region (Pignatti et al., 1995). Despite the wide distribution, chasmophitic vegetation is fragmented and isolated. Gene flow between population in fragmented and geographically isolated habitats is obstructed. Even within the same saxatile region the effective gene flow between chasmophytic populations may be considerably inhibited through the frequent failure of seed to establish new individuals (Davis, 1951). The first step on the colonization of bare-rock must be the establishment of seedlings. This occurs in microsites with finely divided material, especially crevices, in which root-systems can find anchorage. Most of the holes suitable for ecesis are already occupied in saxatile habitats, so that it is extremely difficult for the individual to produce progeny.

Due to a low effective population size, the effects of genetic drift and inbreeding depression may lead to the accident elimination of alleles and increased proportion of homozygous (often non-adaptive) alleles. Ecological plasticity of rare chasmophytes is narrowed because of reduced genetic variability. Therefore, most of rare chasmophytes belong to the group of critically endangered taxa.

Reduced gene flow, in combination with both, the strong natural selection in adverse saxatile habitats, together with genetic drift due to reduced effective population size, resulted in amazing diversification of chasmophytic flora. Most chasmophytic species are endemics. Strong selective pressures and reduced gene flow due to both, geographical isolation of saxatile areas and ecessis problems resulted in fast speciation of chasmophytic taxa with relatively narrow distribution.

Conclusion

Polydominant forest vegetation in West-Serbian canyons represents a valuable pool of species diversity. A great heterogeneity of environmental conditions and specific history of biota in the canyons resulted with complex communities that represent significant resource of rare taxa.

Additional research of these forests is required, in order to elucidate syntaxonomic status of these communities.

Acknowledgements. This work was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia (Grant. No.173018). I would like to thank two anonymous referees for valuable comments on the chasmophytic endemism.

References

Anderson, M.J., Crist, T.O., Chase, J.M., Vellend, M., Inouye, B.D., Freestone, A.L., Sanders, N.J., Cornell, H.V., Comita, L.S., Davies, K.F., Harrison, S.P., Kraft, N.J.B., Stegen, J.C., Swenson, N.G. 2010: Navigating the multiple meanings of b diversity: a roadmap for the practicing ecologist. *Ecology Letters*, 14: 19–28

Borhidi, A., Kevey, B., Varga, Z. 1999: Checklist of the higher syntaxa of Hungary. *Annali di Botanica*, 57: 159-166.

Dakskobler, I., Košir, P., Kutnar, L. 2013: *Gozdovi plemenitih listavcev v Sloveniji: združbe gorskega javorja, gorskega bresta, velikega jesena, ostrolistnega javorja, lipe in lipovca*. Silva Slovenica, and Zveza gozdarskih društev Slovenije, Ljubljana.

Davis, H.P. 1951: Cliff vegetation in the Eastern Mediterranean. *Journal of Ecology*, 39, 63-93

Čarni, A., Košir, P., Karadžić, B., Matevski, V., Redžić, S., Škvorc, Ž. 2009: Thermophilous deciduous forests in Southeastern Europe. *Plant Biosystems* 143:1–13.

Greenacre, M.J. 1984: *Theory and Applications of Correspondence Analysis*. Academic Press, London.

Greenacre, M.J. 2010: *Biplots in Practice*. Fundación BBVA, Barcelona.

Hill, M.O. 1973: Diversity and evenness: a unifying notation and its consequences. Ecology, 54: 427-432.

Horvat, I., Glavač, V., Ellenberg, H. 1974: *Vegetatin Sudosteuropas*. Gustav Fischer: Jena.

Jakovljević, K., Lakušić, D., Vukojičić, S., Tomović, G., Šinžar-Sekulić, J., Stevanović, V. 2011: Richness and diversity of Pontic flora on serpentine of Serbia. *Cent. Eur. J. Biol.* 6: 260-274.

Jongman, R.H., ter Braak, C.J.F., van Tongeren, O.F.R. 1987: *Data analysis in community and landscape ecology*. Pudoc, Wageningen.

Karadžić, B., Jarić, S., Pavlović, P., Mitrović, M. 2015: Aquatic and Wetland Vegetation Along the Sava River. Pp. 249-316. in: Milačič. R., Ščančar, J., Paunovič, M. (eds), *The Sava River*. Springer Heidelberg.

Karadžić, B., Jarić, S., Pavlović, P., Marinković, S., Mitrović, M. 2014: Application of hypercorrelated matrices in ecological research. *Computational Biology and Bioinformatics* 2: 57-62.

Karadžić, B., Marinković, S. 2009: *Kvantitativna ekologija*. IBISS, Beograd, p 489.

Karadžić, B., Marinković, S., Kataranovski, D. 2003: Use of the β-function to estimate the skewness of species responses. *Journal of Vegetation Science*, 14: 799-805.

Karadžić, B., Mijović, A., Popović, R., Perišić, S., Marinković, S. 2001: Forest vegetation in West-Serbian canyons: biodiversity hotspots. In: Ragodlou, K. (ed), *Forest research: a challenge for an integrated European approach*. NAGREF-Forest Research Institute, Thessaloniki, Greece, pp 513–518.

Karadžić, B., Popović, R. 1994: The generalized standardization procedure in ecological ordination: Tests with "metric" ordination methods. *Journal of Vegetation Science*, 5: 259-262.

Karadžić, B., Šašo-Jovanović, V., Jovanović, Z., Karadžić, D. 1999: On detrending in correspondence Analysis and Principal Components Analysis. *Ecoscience*, 6: 110-116.

Karadžić, B. 2013: FLORA: A Software Package for Statistical Analysis of Ecological Data. *Water Research and Management*, 3: 45-54.

Kojić, M., Popović, R., Karadžić, B. 1997: *Vaskularne biljke Srbije kao indikatori staništa*. IBISS: Beograd. 160 p.

Košir, P., Čarni, A., di Pietro, R. 2008: Classification and phytogeographical differentiation of broad-leaved ravine forests in southeastern Europe. *Journal of Vegetation Science*, 19: 331–342.

Lakušić, D., Karadžić, B. 2010: New associations of serpentine chasmophitic vegetation (*Asplenietea trichomanis* Br.-Bl. 1934 corr. Oberd. 1977) on Kopaonik Mt in Serbia. *Botanica Serbica*, 34: 67-79.

Legendre, P., Legendre, L. 2003: *Numerical Ecology*. Elsevier, Amsterdam. 853 p.

Meusel, H., Jager, A., Weinert, A. 1965: *Vergleichende Chorologie der ceatraleuropischea Flora*. Gustav Fisher: Jena.

Pavlović, P., Kostić, N., Karadžić, B., Mitrović, M. 2017: *The Soil of Serbia*. Springer. Heidelberg. 225 p.

Pianka, E. 1984: *Evolutionary ecology*. Harper & Row: New York.

Pielou, E.C. 1974: *Population and community ecology*. Gordon and Breach, New York.

Popović, R., Kojić, M., Karadžić, B. 1996: Ecological characcteristics of six important submediterranean tree species in Serbia. *Bocconea* 5: 431-438.

Puncer, I., Zupančič, M. 1982: Die ökologische und wirtschaftliche Bedeutung der *Ostrya carpinifolia* Scop. in Slowenien. *Studia Geobotanica*, 2: 25-32.

Rodwell, J.S., Schamine´e, J.H.J., Mucina, L., Pignatti, S., Dring, J., Moss, D., 1998: *The scientific basis of the EUNIS Habitat*

Classification. Report to the European Topic Centre on Nature Conservation, Unit of Vegetation Science, Lancaster.

Routledge, R.D. 1977: On Whittaker's components of diversity. *Ecology*, 58, 1120-1127.

Shmida, A., Wilson, M.V. 1983: Biological determinants of species diversity. *Journal of Biogeography*, 12: 1-20.

ter Braak, C.J.F. 1986: Canonical Correspondence Analysis: a new eigenvector technique for multivariate direct gradient analysis. *Ecology*, 67: 1167-1179.

Tomić, Z. 1994: Cenoareal crnog graba (*Ostrya carpinifolia* Scop.) u Srbiji. *Glasnik Instituta za botaniku botaničke bašte Univerziteta u Beogradu,* 28: 173-182.

Tomić, Z. 2000: Zajednica *Orno-Ostryetum* Aich. 1933 u refugijumima zapadne Srbije. *Glasnik šumarskog fakulteta,* Beograd, 82: 177-189.

Trinajstić, I., Cerovečki, Z. 1978: O cenoarealu crnog graba, *Ostrya carpiaifolia* Scop. *(Corylaceae)* u Hrvatskoj. *Biosistematika* 4: 57-65.

Westhoff, V., van der Maarel, E. 1973: The Braun-Blanquet approach. In: *Handbook of vegetation science V, pp* 617-726. Edited by R. H. Whittaker. Junk: The Hague.

Whittaker, R.H. 1970: *Communities and ecosystems*. MacMillan: New York.

Wilson, M., Shmida, A. 1984: Measuring β diversity with presence-absence data. *Journal of Ecology* 72: 1055-1064.

Velčev, V.I., Kožuharov, S.I., Ančev, M.E. 1992: *Atlas of endemic plants in Bulgaria*. Bulgarian Academy of Sciences, Sofia.