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INTERNATIONAL SCIENTIFIC JOURNAL

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Original scientific article

FLORISTIC-VEGETATIONAL VARIABILITY OF THE ASSOCIATION *EPIMEDIO-CARPINETUM BETULI* (HORVAT 1938) BORHIDI 1963 IN THE NORTH OF CROATIA

VUKELIĆ J., ŠAPIĆ I., BARIČEVIĆ D.
University of Zagreb, Faculty of Forestry, Zagreb, Croatia
Corresponding author e-mail address: dario.baricevic@zg.htnet.hr

ABSTRACT: The paper analyzes 246 phytocoenological relevés of the association *Epimedio-Carpinetum betuli* (I. Horvat 1938) Borhidi 1963 in northern Croatia using the standard principles of the Central European Phytocoenological School [5] and applying recent statistical methods [10, 6, 30]. The association is divided into six subassociations with sociologically closely affiliated differential species. The first part of the research implies formalized classification to analyze and correct the selection of diagnostic and differential species in traditional subassociations formed on the basis of previous studies. The second part uses a statistical method to form three clusters, determine their differential species and compare them with the earlier classification of the association. The results of the analysis have revealed a relatively low floristic variability, whereas structural classification has confirmed a smaller number of the described associations. In addition to providing an objective classification of the community *Epimedio-Carpinetum,* the study will also contribute to future analyses of Illyrian oak-hornbeam forests in their distribution range, as well as to the synthesis of the *Carpinetum* communities of Europe.
Keywords: *Epimedio-Carpinetum betuli*, northern Croatia, statistical analysis, differential species.

1 INTRODUCTION

The forests of sessile oak and common hornbeam in the north of Croatia belong to the earliest descriptions of forest communities of south-eastern Europe [11]. The most distinctive features of the association *Querco-Carpinetumcroaticum*I. Horvat 1938 are its wealth of flora and diagnostic value of the species of the Illyrian floristic element. On these bases Horvat [12] establishes a separate alliance of oak-hornbeam forests of the Illyrian region (*Carpinion betuli illyrico-podolicum* Horvat 1958), thus delineating them from the Central European forests. His attitude provoked a number of discussions [3, 4, 8, 14, 34], but phytocoenologists of south-eastern Europe retained this alliance in their later works. They pointed out the absence of their characteristic species, but attributed diagnostic importance to the present species from the Illyrian beech forests of the alliance *Fagion illyricum* (=*Aremonio-Fagion* /Horvat 1938/ Borhidi in Török, Podani et Borhidi 1989). Particularly active in the study of the *Carpinion* communities of south-eastern Europe were Slavic phytocoenologists, so Marinček [in 33], in line with the then valid code of phytocoenological nomenclature, named the alliance *Carpinion illyrico-podolicum* as *Erythronio-Carpinion betuli* (Horvat 1938)Marinček 1993 inWallnöfer et al. 1993; however, this alliance was soon afterwards divided into three sub-alliances [16, 17]. The alliance *Erythronio-Carpinion* is currently recognized in the majority of the surveys of forest vegetation of Europe [25, 1 et al.].

Following research by Horvat, the Illyrian oak-hornbeam forests were nomenclaturally defined by Borhidi [3], who named the association *Epimedio-Carpinetum betuli*. Research into this association has continued in Croatia, resulting in about five hundred relevés to date [23, 24, 29, 15, 27, 21, 31, 2, 18, 28, 26 et al.]. In addition to the association *Epimedio-Carpinetum betuli,* the relevés also describe the association *Festuco drymeiae-Carpinetum betuli*, but it is not analyzed in this paper.

In the cited works, the association *Epimedio-Carpinetum betuli* is divided into six subassociations: ***erythronietosum*** Horvat 1938, on moderately acidophilic podzolic soils of north-western Croatia, ***staphyletosum*** Horvat 1938,on neutrophil-alkaline carbonate soils of the same area**,** thetypical and most common subassociation *caricetosum pilosae* Horvat 1963, mesophilic *asperuletosum* Wraber 1961 and two acidophilic *castanetosum* Wraber 1958 and *luzuletosum albidae*Wraber 1961 with a more pronounced anthropogenic impact. A comparative analysis of the differences and justifiability of the subassociations was not made, while the criteria used to describe them frequently relied on a small number of differential species determined by the first authors of the subassociations I. Horvat and M. Wraber. Since such research activities are supported by new statistical techniques, the goal of our paper was to, with the help of these techniques, analyze the variability and distribution of the association *Epimedio-Carpinetum* in nothern Croatia. The results should critically question the justifiability of the traditional classification from previous studies (1), assess the value of diagnostic species (2), possibly define a new statistically justified classification (3), but also answer other important questions concerning the composition and structure of this well known association. A statistical analysis of the overall phytocoenological material of a larger area has an advantage, since it eliminates the narrowly distributed local syntaxa which were developed under the impact of some local factors. On the other hand, it provides a more comprehensive picture of the impact of the macro-climate, other regional factors and naturally, the biogeographic area. Finally, the present European classifications, Natura 2000 in the first place, are based on such regional types.

2 RESEARCH AREA

The association *Epimedio-Carpinetum betuli* is a zonal association of the colline belt of a larger part of continental Croatia. The most important areas are located in the mountains between the rivers Sava and Drava in Croatia, then on the northern boundary part of the Dinaric mountain range south of Karlovac, and on the slopes of karst fields in the Dinaric region. It occurs between 150 and 450 m above sea level, most frequently on slope pseudogley, eutric cambisol and luvisol above different parent bedrock. The average annual temperature in the eastern part of the distribution range is 10.5 °C, in the

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central part it is 10.3°C, and in the southern part it amounts to 10.0°C. Precipitation also ranges in the same direction from 700 mm annually, to 1,100 mm (central part), to 1,500 mm at Ogulin. Generally, the climate is moderately warm and humid, while in the eastern part of the distribution range it is semi-humid. Precipitation distribution is favourable (over 50 % in the vegetation period), making the climate conducive to the development of forest vegetation. Apart from climate, there are other ecological factors that are suitable for the life of man, and therefore sessile oak - hornbeam forests were massively cut down very early in history. In northern Croatia (Fig. 1) they inhabit the lower slopes of higher mountains in Pannonia and surround them in a ring-like fashion. In the lower hills (up to 350 m), they occupy comprehensive complexes which are interrupted by colline-submontane beech forests on the northern sides.

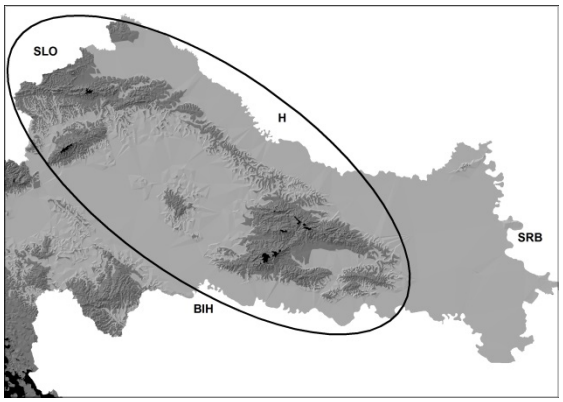

Figure 1: Map ofthe research area

3 MATERIAL AND METHODS

A phytocoenological analysis of the association *Epimedio-Carpinetum betuli* is based on the principles of the Zurich-Montpellier or the standard Central European School [5]. All the cited research was conducted in accordance with the mentioned School. The most important feature is the unique methodology of field phytocoenological sampling as a prerequisite for comparison and analysis of the results. Two basic analyses were conducted in the project: the first analyzes and evaluates the past (traditional) phytocoenological classification of the association *Epimedio-Carpinetum betuli*, and the second divides the same relevés into clusters formed by means of statistical classification.

A total of 246 phytocoenological relevés were used to analyze previous phytocoenological classification. In all the original papers they were classified into the association *Epimedio-Carpinetum betuli*, or into some of its subassociations:

- *erythronietosum* – 33 relevés, [11, 23, 15, 31]
- *staphyletosum* – 41 relevés, [11, 23, 29, 15, 31]
- *caricetosum pilosae* – 107 relevés, [23, 15, 31, 2, 28]
- *asperuletosum* – 23 relevés,[27, 28]
- *castanetosum sativae* – 25 relevés, [18]
- *luzuletosum albidae* – 17 relevés.[29, 27, 15]

Vegetation relevés were entered into TURBOVEG database [10]. Cluster analysis was performed in PRIMER 6 software [6], with Euclidian distance as a measure of similarity. Diagnostic species were determined by means of JUICE 7.0 software package [30] on the basis of the analysis of Fidelity measure. The plant covers that occur in more layers were combined. Each plant species was considered with total cover, regardless of the number of structural layers in which it occurred in a particular relevé. Mosses were not evidenced in the majority of studies and were therefore not taken into consideration.

In the first analysis the relevés were classified into six groups (Table I) according to the original subassociations described by the previous authors of research. Species participating with over 30% and fidelity index above 30 were taken as their differential species.

The second analysis was performed on the basis of statistical classification of the same relevés using cluster analysis, which resulted in their grouping within 3 clusters.

Research results (Tables I and II) show only differential, constant, dominant and Illyrian floral element species. Constant species were defined as those with a frequency ≥ 50% inside the vegetation unit (cluster), whereas dominant species were those with a cover value > 25% in at least 20% of the relevés belonging to a particular vegetation unit. Differential species were listed separately. The analysis of ecological conditions using Ellenberg's ecoindicator coefficients [7] was performed in JUICE 7.0 programme [30]. The plant nomenclature was adjusted to the *Flora Croatica* database [19]. The nomenclature of plant communities was adjusted to the survey of forest vegetation of Croatia [32] andsubassociation as determined by Croatian phytosociologies in the cited papers [11,13,18, 27, 28].

4 RESULTS AND DISCUSSION

A total of 276 species of higher plants were recorded in 246 relevés of the association *Epimedio-Carpinetum betuli.* The most important species of the Illyrian floral element distributed in all the six subassociations include *Lonicera caprifolium*, *Epimedium alpinum*, *Ruscus hypoglossum*, *Cyclamen purpurascens*, *Aposeris foetida*, *Knautia drymeia* ssp. *drymeia* and *Primula vulgaris*. A major part of the subassociations also contain *Lamium orvala*, *Erythronium dens-canis*, *Aremonia agrimonoides* and *Vicia oroboides.* The species *Omphalodes verna, Cardamine trifolia, Helleborus purpurascens* and *Crocus vernus* ssp. *vernus* occur in only one subassociation. In two subassociations in the eastern part of the study area there is an abundance of the species *Helleborus odorus*. It is the presence of these species in oak-hornbeam forests of the Illyrian floral province that constitutes the main reason for the establishment of the alliance *Erythronio-Carpinion betuli*.

From a relatively large number of the species, 55 species were observed in all the subassociations. Constant species of the association are *Carpinus betulus*, *Quercus petraea*, *Prunus avium*, *Fagus sylvatica*,*Crataegus monogyna*, *Corylus avellana*, *Ligustrum vulgare*, *Cornus sanguinea*,*Acer campestre, Fraxinus ornus, Viola reichenbachiana*, *Pulmonaria officinalis*, *Galium odoratum*, *Asarum europaeum*, *Stellaria holostea*, *Hedera helix*, *Carex sylvatica*, *Rubus hirtus, Epimedium alpinum* and *Galium sylvaticum.* They are generally not differential for particular subassociations. The dominant species are *Carpinus betulus* and *Quercus petraea.*

Table I: Schortened synoptic table with percentage frequency and modified fidelity phi coefficient based on the traditional division of associations *Epimedio-Carpinetum betuli*

Group No.	1		2		3		4		5		6	
No. of relevés	107		23		33		25		17		41	
Subassociations	caric		aspe		eryt		casta		luzu		staph	
Differential species												
Tilia tomentosa	28	49.5	.	---	.	---	.	---	.	---	.	---
Melica uniflora	52	45.5	13	---	6	---	.	---	12	---	10	---
Carex pilosa	60	40.1	13	---	9	---	32	10.3	6	---	15	---
Viola hirta	41	37.4	26	17.4	.	---	.	---	6	---	5	---
Glechoma hirsuta	44	36.6	22	8.7	3	---	12	---	6	---	2	---
Acer tataricum	45	40.9	30	22.0	6	---	.	---	.	---	.	---
Helleborus odorus	37	39.0	26	22.6	.	---	.	---	.	---	.	---
Galeobdolon luteum	42	17.3	65	41.1	12	---	12	---	18	---	2	---
Prunella vulgaris	5	---	35	35.6	3	---	.	---	18	10.6	2	---
Galium odoratum	65	6.9	91	30.3	61	2.5	44	---	29	---	56	---
Asarum europaeum	41	---	96	30.1	67	3.2	48	---	47	---	80	16.1
Sanicula europaea	30	---	87	29.8	52	---	60	5.6	35	---	59	4.3
Erythronium dens-canis	2	---	.	---	64	60.2	20	5.9	6	---	.	---
Crocus vernus agg.	3	---	.	---	58	50.8	16	---	.	---	20	4.3
Anemone nemorosa	24	---	.	---	82	41.1	56	17.2	6	---	56	17.3
Milium effusum	11	---	35	7.3	58	30.1	.	---	18	---	44	16.4
Doronicum austriacum	3	---	.	---	52	41.8	36	23.2	.	---	10	---
Convallaria majalis	12	---	.	---	64	37.9	48	22.0	.	---	34	7.9
Luzula pilosa	4	---	.	---	58	34.7	52	28.9	18	---	15	---
Fragaria vesca	20	---	30	---	82	33.7	20	---	41	---	73	25.9
Frangula alnus	1	---	.	---	33	29.7	8	---	12	---	17	7.2
Cephalanthera longifolia	11	---	.	---	.	---	60	66.6	.	---	.	---
Castanea sativa	10	---	9	---	24	---	100	55.2	53	12.2	41	1.7
Melampyrum pratense	10	---	22	---	33	---	88	50.9	41	6.7	10	---
Euonymus latifolius	1	---	.	---	.	---	32	47.3	.	---	5	---
Prenanthes purpurea	2	---	.	---	9	1.4	36	45.2	.	---	2	---
Potentilla micrantha	47	19.3	26	---	6	---	68	40.6	6	---	12	---
Lamium orvala	6	---	.	---	42	12.8	68	37.9	12	---	49	19.0
Fraxinus ornus	64	19.1	9	---	21	---	80	34.0	18	---	63	19.0
Hedera helix	46	---	48	---	52	---	96	31.4	47	---	83	19.4
Acer platanoides	7	---	4	---	6	---	36	30.1	6	---	20	8.3
Gentiana asclepiadea	6	---	9	---	61	22.6	76	36.9	35	---	32	---
Hieracium murorum	9	---	.	---	33	22.4	36	25.7	6	---	7	---
Luzula luzuloides	11	---	.	---	48	8.8	64	23.0	100	56.0	10	---
Hieracium racemosum	19	---	13	---	15	---	40	16.8	47	24.2	10	---
Staphylea pinnata	3	---	.	---	.	---	.	---	.	---	66	76.4
Hacquetia epipactis	.	---	.	---	9	---	28	13.5	.	---	63	55.9
Scilla bifolia agg.	.	---	.	---	6	---	.	---	.	---	34	49.1
Helleborus atrorubens	4	---	.	---	9	---	.	---	6	---	44	49.0
Melampyrum nemorosum	9	---	.	---	21	5.8	.	---	12	---	56	47.9
Campanula trachelium	3	---	4	---	24	8.8	8	---	6	---	56	46.8
Vicia oroboides	12	4.9	.	---	3	---	.	---	.	---	39	46.8
Tamus communis	36	10.6	.	---	21	---	28	2.0	.	---	71	45.5
Solidago virgaurea	6	---	9	---	15	---	.	---	12	---	49	42.3
Mercurialis perennis	7	---	.	---	9	1.0	.	---	.	---	34	41.3
Salvia glutinosa	7	---	13	---	.	---	24	10.4	.	---	49	41.0
Viburnum lantana	20	5.3	.	---	6	---	20	5.8	.	---	46	38.5
Acer pseudoplatanus	19	---	9	---	52	10.9	56	15.0	29	---	73	30.7
Senecio nemorensis agg.	2	---	.	---	9	---	40	31.3	.	---	39	30.1
Dominant species												
Carpinus betulus	100	6.4	100	6.4	100	6.4	88	---	100	6.4	100	6.4
Quercus petraea	100	14.6	83	---	100	14.6	68	---	94	5.7	98	10.9
Constant species												
Fagus sylvatica	90	5.6	87	2.1	70	---	92	8.5	100	18.6	73	---
Corylus avellana	48	---	83	---	91	10.1	88	6.7	94	13.9	90	9.3
Carex sylvatica	65	---	91	18.5	70	---	52	---	76	3.5	83	10.0
Prunus avium	79	8.4	65	---	82	11.6	72	2.1	41	---	80	10.4

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Pulmonaria officinalis	55 ---	65 2.7	79 15.2	68 5.3	24 ---	83 19.1
Ligustrum vulgare	50 ---	48 ---	58 4.7	44 ---	41 ---	73 18.6
Crataegus monogyna	54 ---	48 ---	61 1.8	64 4.9	47 ---	78 17.6
Viola reichenbachiana	58 6.0	43 ---	73 19.2	32 ---	35 ---	66 13.1
Acer campestre	79 16.4	74 12.2	55 ---	72 10.5	24 ---	61 ---
Epimedium alpinum	66 14.1	65 13.0	61 8.9	28 ---	47 ---	37 ---
Cornus sanguinea	62 2.9	57 ---	55 ---	72 12.2	24 ---	83 22.1
Rubus hirtus s.lat.	86 35.4	30 ---	24 ---	64 15.7	35 ---	39 ---
Stellaria holostea	60 ---	74 13.5	88 26.2	24 ---	53 ---	56 ---
Galium sylvaticum	40 ---	13 ---	82 26.5	60 7.0	35 ---	83 27.5
Illirian floral element						
Lonicera caprifolium	14 ---	65 13.8	61 9.7	52 2.0	53 2.9	54 3.5
Ruscus hypoglossum	14 ---	22 4.2	3 ---	20 2.2	35 19.9	15 ---
Primula vulgaris	22 ---	39 ---	73 29.5	28 ---	24 ---	56 14.4
Aposeris foetida	11 ---	52 ---	91 27.5	76 13.9	47 ---	88 24.7
Knautia drymeia	24 ---	43 6.5	42 5.5	16 ---	29 ---	63 25.0
Cyclamen purpurascens	10 ---	17 ---	33 ---	48 14.3	35 2.2	54 19.7

Differential species of the subassociations are decisive for the classification of the association. According to the studies of the cited authors, the differential species of the compared subassociations are:

- *erythronietosum: Erythronium dens-canis, Lathyrus montanus,*
- *staphyletosum: Staphylea pinnata, Hacquetia epipactis, Craex digitata, Salvia glutinosa, Viciaoroboides, Aconitum vulparia, Rhamnus cathartica;*
- *caricetosum pilosae: Carex pilosa, Potentilla micrantha, Hepatica nobilis;*
- *asperuletosum: Galium odoratum, Asarum europaeum, Sanicula europaea;*
- *castanetosum: Castanea sativa, Melampyrum pratense, Gentiana asclepiadea, Pteridium aquilinum, Luzula luzuloides, Serratula tinctoria;*
- *luzuletosum: Luzula luzuloides.*

In the first statistical analysis the subassociations were distributed into six groups (subassociations), according to the standpoints of the phytocoenologists in the cited works. The goal of our analysis was to re-examine their standpoints and use a statistical method to determine differential species. Our subjective criterion guiding the selection was the following: participation in more than 30% of the relevés of a particular subassociation and the fidelity index above 30. The results of the analysis are given in Table I. Of 21 differential species determined by the original researchers, our analysis confirmed 14 and grouped as many as 37 new ones. Since the majority of the species had broader distribution, the previous phytocoenologists did not consider them sociologically significant for discriminating the subassociations. These are, for example, *Tilia tomentosa*, *Melica uniflora*, *Viola hirta*, *Hedera helix*, *Prenanthes purpurea, Fraxinus ornus*, *Senetio ovatus*, *Convallaria majalis* etc. On the other hand, a differential status was not confirmed for a smaller number of species (e.g. *Lathyrus montanus*, *Carex digitata*, *Hepatica nobilis, Serratula tinctoria*). In the primary research, these species had received this status on the basis of their higher participation, but in a small number of relevés.

In the second analysis we wanted to highlight some new possibilities of classifying the association *Epimedio-Carpinetum betuli* on the basis of the same phytocoenological relevés. Cluster analysis was employed to group the relevés into three clusters, which were then used for further analysis.

Cluster I: comprises 36 relevés formed for the most part of the former groups 3 and 6, i.e. of the subassociations *erythronietosum* (13 relevés) and *staphyletosum* (21 relevés). The differential species of the new cluster include all the differential species of the former subassociation *staphyletosum* and the majority of the differential species of the former subassociations *erythronietosum* and *asperuletosum.* This cluster is the richest in the species of the Illyrian floral geoelement. A total of 11 species occur with over 30% in all the relevés in the cluster.

Cluster II: comprises 99 relevés, of which 90% belonged to the subassociation *caricetosum pilosae* in the previous analysis, and the rest mainly to the subassociation *asperuletosum*. The subassociation *caricetosum pilosae* had 7 differential species and they all regained their differential status. Along with these, the following species were also determined as differential: *Quercus cerris*, *Euphorbia amygdaloides, Lathyrus vernus, Lamium galeobdolon* and *Potentilla micrantha*. In the previous analysis, the first three did not prove to be differential species, *Potentilla micrantha* was found in the subassociation *castanetosum*, while *Lamium galeobdolon* was found in the subassociation *asperuletosum*.

Cluster III: comprises 111 phytocoenological relevés grouped from all the subassociations. This heterogeneous cluster contains all the relevés of the subassociations *castanetosum* and *luzuletosum*, while of other subassociations, the relevés lacking differential species determined in the two remaining clusters. It was also found that relevés with acidothermophilic species were more fully present, where *Castanea sativa* and *Luzula luzuloides* feature as differential species. Acidophytes *Melampyrum pratense*, *Hieracium racemosum*, *Hieracium murorum*, *Gentiana asclepidea*, *Aposeris foetida* and other species have distinctly high participation. The backbone of this cluster is formed by the subassociations *castanetosum* and *luzuletosum,* and six species of the Illyrian floral geoelement are present in more than 30% of all the relevés.

According to the results of the analysis, the former subassociations *caricetosum pilosae* in Cluster II and *castanetosum* and *luzuletosum* in Cluster III manifest the highest degree of homogeneity.

The differential species of the subassociation *asperuletosum* are widely distributed and had a lower fi -

Table II: Schortened synoptic table with percentage frequency and modified fidelity phi coefficient identifiend by cluster analysis

Group No.	**1**		**2**		**3**	
No. of relevés	**36**		**99**		**111**	
Differential species						
Heracleum sphondylium	**81**	65.1	**12**	---	**16**	---
Ranunculus lanuginosus	**67**	64.4	**1**	---	**12**	---
Euonymus europaeus	**83**	60.7	**27**	---	**13**	---
Milium effusum	**75**	58.5	**14**	---	**17**	---
Crocus vernus agg.	**58**	58.4	**1**	---	**11**	---
Campanula trachelium	**61**	58.4	**2**	---	**13**	---
Lamium orvala	**72**	57.0	**1**	---	**29**	---
Aegopodium podagraria	**61**	55.5	**3**	---	**15**	---
Melampyrum nemorosum	**58**	52.4	**3**	---	**16**	---
Staphylea pinnata	**50**	52.1	**2**	---	**9**	---
Scilla bifolia agg.	**39**	52.0	**2**	---	**.**	---
Hacquetia epipactis	**53**	50.8	**.**	---	**15**	---
Daphne mezereum	**64**	49.2	**1**	---	**30**	---
Helleborus atrorubens	**44**	48.4	**8**	---	**2**	---
Galanthus nivalis	**31**	46.3	**.**	---	**1**	---
Ranunculus ficaria	**44**	44.0	**10**	---	**5**	---
Frangula alnus	**36**	41.5	**2**	---	**7**	---
Arum maculatum	**39**	41.4	**10**	---	**2**	---
Convallaria majalis	**58**	41.1	**6**	---	**30**	---
Paris quadrifolia	**31**	39.9	**4**	---	**2**	---
Glechoma hederacea	**36**	37.3	**8**	---	**5**	---
Malus sylvestris	**39**	37.1	**4**	---	**13**	---
Carex digitata	**36**	36.7	**5**	---	**9**	---
Mercurialis perennis	**33**	35.8	**4**	---	**8**	---
Ulmus glabra	**39**	35.7	**3**	---	**15**	---
Vicia oroboides	**36**	35.0	**6**	---	**10**	---
Prunus spinosa	**31**	34.5	**7**	---	**4**	---
Scrophularia nodosa	**44**	33.5	**9**	---	**19**	---
Moehringia trinervia	**33**	33.5	**10**	---	**5**	---
Geranium phaeum	**33**	32.9	**8**	---	**7**	---
Serratula tinctoria	**39**	30.2	**.**	---	**25**	6.6
Helleborus odorus	**.**	---	**45**	58.7	**1**	---
Rubus hirtus s.lat.	**6**	---	**87**	55.1	**51**	4.8
Acer tataricum	**6**	---	**52**	55.1	**4**	---
Melica uniflora	**.**	---	**53**	52.1	**14**	---
Viola hirta	**3**	---	**46**	51.8	**5**	---
Glechoma hirsuta	**3**	---	**46**	47.5	**10**	---
Carex pilosa	**17**	---	**56**	37.0	**22**	---
Quercus cerris	**6**	---	**38**	36.1	**12**	---
Tilia tomentosa	**3**	---	**26**	36.0	**3**	---
Galeobdolon luteum	**11**	---	**47**	35.6	**18**	---
Potentilla micrantha	**8**	---	**49**	33.9	**26**	---
Euphorbia amygdaloides	**.**	---	**30**	30.6	**14**	---
Lathyrus vernus	**22**	---	**60**	30.4	**34**	---
Castanea sativa	**19**	---	**2**	---	**57**	49.4
Luzula luzuloides	**25**	---	**6**	---	**45**	32.0
Sanicula europaea	**47**	2.2	**23**	---	**67**	29.8
Dominant species						
Carpinus betulus	**100**	6.7	**100**	6.7	**97**	---
Quercus petraea	**100**	15.1	**96**	1.1	**91**	---
Constant species						
Fagus sylvatica	**58**	---	**89**	17.0	**90**	19.1
Galium odoratum	**58**	---	**69**	11.6	**55**	---
Carex sylvatica	**83**	15.7	**70**	---	**68**	---
Prunus avium	**94**	26.3	**79**	---	**65**	---
Hedera helix	**78**	23.0	**41**	---	**67**	6.9
Asarum europaeum	**100**	50.3	**42**	---	**57**	---
Pulmonaria officinalis	**100**	45.1	**57**	---	**57**	---
Ligustrum vulgare	**92**	42.8	**57**	---	**39**	---

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Galium sylvaticum	89 41.9	37 ---	53 ---
Corylus avellana	100 39.0	43 ---	86 16.5
Cornus sanguinea	94 38.3	64 ---	50 ---
Acer campestre	97 36.9	76 2.1	50 ---
Stellaria holostea	89 33.2	64 ---	48 ---
Crataegus monogyna	86 31.3	57 ---	52 ---
Viola reichenbachiana	83 31.1	58 ---	45 ---
Illyrian floral elemente			
Ruscus hypoglossum	3 ---	17 9.6	18 11.4
Erythronium dens-canis	14 4.0	6 ---	16 9.0
Epimedium alpinum	50 ---	71 22.8	43 ---
Knautia drymeia	58 27.6	16 ---	43 5.8
Lonicera caprifolium	86 54.0	9 ---	49 1.0
Cyclamen purpurascens	56 34.6	8 ---	34 2.4
Primula vulgaris	81 48.8	18 ---	40 ---
Aposeris foetida	100 60.4	4 ---	69 16.6

delity index than all the differential species of other subassociations. As it turned out, this subassociation does not show individuality in northern Croatia. It was primarily established because the sampled plots lacked the favoured differential Illyrian species from other subassociations (*staphyletosum* and *erythronietosum* in the first place), while species of beech forests listed in Table Idominated. It should be mentioned that the association *Asperulo-Carpinetum* Wraber 1969 was described in Slovenia.

The subassociation *luzuletosum* follows a similar pattern. In the first analysis it had only two differential species (*Luzula luzuloides* and *Hieracium racemosum*) which occur in the new Cluster III with a high percentage of participation. Since chestnut was singled out as the differential species, the subassociation *castanetosum* should be given priority.

In relation to the previous insights, what is most surprising is the absence of the subassociation *erythronietosum*. Its 33 relevés were for the most part grouped into Cluster I and III. Of its differential species, *Erythronium dens-canis* and *Luzula pilosa* do not have diagnostic importance, whereas all the other species have differential importance for Cluster I, i.e. for the subassociation *staphyletosum*. Evidently, the diagnostic species from the previous studiesy could not accentuate the identity of the subassociation *erythronietosum* clearly enough to form its own cluster. However, it may have local importance, because the difference between the subassociations *staphyletosum* and *erythronietosum* was also confirmed by pedological research [9]. Undoubtedly, in the process of merging the majority of the relevés of these two subassociations into Cluster I, an important role was played by the biogeographic position of the sampled forest stands. Namely, the study area in the north-western Croatia is the richest in the species of the Illyrian floral geoelement, and so these relevés were grouped into Cluster I.

The former subassociation *staphyletosum* is represented by 41 relevés. Of this, 21 relevés was placed in Cluster I, which gathered all the differential species of the subassociation, including *Staphylea pinnata*. The remaining relevés were grouped into Cluster III. These relevés are characterized by a poorer floristic composition, lessened participation of Illyrian species, absence of diagnostic species of the subassociation *staphyletosum* and higher participation of the species *Castanea sativa*, *Solidago virgaurea*, *Sanicula europaea* and others. This can well be illustrated with a concrete example of the percentage ratio of some particular species of the former subassociation *staphyletosum* after it was grouped into two clusters. The participation ratio of the species *Staphylea pinnata* in Cluster I in relation to Cluster III is 86:45 %, that of the species *Heracleum sphondylium* is 90:25 %,of *Ranunculus lanuginosus* it is 81:20 %, of *Hacquetia epipactis* it is 90:35 %, etc. All the relevés from the SamoborMountains were grouped into Cluster III [29].

The subassociation *caricetosum pilosae* underwent the least changes in relation to the traditional standpoints. All the differential species remained the same in the new analysis as well, but some new ones were also added. The number of Illyrian species decreases from the west towards east, while some, such as *Lamium orvala* and *Hacquetia epipactis,* are completely absent. However, it is in this subassdociation that important Illyrian species *Epimedium alpinum* and *Helleborus odorus* are the best represented, despite being the only ones that occur in more than 30% of the relevés in Cluster II. Important differential species in the central and eastern distribution range of the community are *Tilia tomentosa*, *Heleborus odorus*, *Acer tataricum* and *Quercus cerris*. It will be interesting to compare the relationship of these 99 relevés towards the related associations *Festuco drymeiae-Carpinetum* Vukelić ex Marinček 1994, and *Caricipilosae-Carpinetum betuli* Neuhäusl et Neuhäuslova-Novotna 1964. They are characterized by the smaller number and cover of Illyrian species and high participation of the species *Carex pilosa* and *Festuca drymeia*.

The analysis of ecological conditions conducted with Ellenberg's ecoindicator coefficients [7] did not show significant differences between individual clusters. According to these conditions, the association *Epimedio-Carpinetum betuli* occurs in semi-light (4.58 to 4.81), moderately warm (5.54 to 5.73) and fresh (4.81 to 5.04) habitats. They are moderately acidophilic to moderately basophilic (6.41 to 6.80) and moderately rich in nutrients (4.88 to 5.21).

By summarizing the problem of differential species in this manner, it is evident that they were determined primarily by means of numerical methods. In these methods all the species are put on the same level, regardless of their sociological affiliation. In this sense, it is possible to combine research methodologies for the purpose of achieving the best possible results. By analyzing as many relevés or syntaxa as possible, the fidelity value of more widely distributed ("common")

species is lessened, while the sociologically more closely affiliated species gain increasing importance. Moreover, an unbalanced number of relevés of a particular taxon may give a distorted image, which is also the problem of this analysis. This is the reason that we recommend our results primarily as guidelines for future research.

5 CONCLUSIONS

Based on the analysis of 246 relevés and participation of 276 species of higher plants of the association *Epimedio-Carpinetumbetuli*, we re-examined its classification into traditional subassociations and proposed a possible new classification. The analysis is based first and foremost on differential species, for which of decisive importance was their participation and fidelity index in a particular syntaxon, i.e. cluster. A small number of differential species which were sociologically closely affiliated to a particular subassociation was frequently the reason for describing a larger number of subassociations, but this often did not correspond to the real field condition. In our study, the fund of differential species in traditionally formed subassociations was significantly increased, which facilitates field research and mapping.

In the second statistical analysis all the relevés were grouped into three clusters. In these clusters, the subassociations *caricetosum pilosae* and *staphyletosum* retained their basic identity, regardless of the fact that a part of the relevés was grouped into other clusters. The subassociation *asperuletosum* does not have distinct differential species and does not show an independent character. Its species are relatively abundantly present in other subassociations. The subassociation *luzuletosum* coincides with the subassociation *castanetosum* in terms differential species and character, but the latter should be given priority. The relevés of the subassociation *erythronietosum* on deeper, more humid and shadier soils can be added to the subassociation *staphyletosum*, while those on steeper, drier and moderately acidophilic to neutrophilic soils with the species *Erythronium dens-canis* require more detailed study and analysis within the stands grouped in Cluster III.

The results of research suggest the need for further studies and a new syntaxonomic classification of the association *Epimedio-Carpinetum betuli* on the northern boundary of the Illyrian floral province. The results will also be useful for future research into the Illyrian oak-hornbeam forests in their overall distribution range, but also the *Carpinetum* communities in a wider European space.

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