

SYNTAXONOMY AND ECOLOGY OF FOREST VEGETATION IN THE ŠTIAVNICKÉ VRCHY MTS (CENTRAL SLOVAKIA)

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ABSTRACT

Vegetation of deciduous forests in the Štiavnické vrchy Mts (Central Slovakia) was studied using the standard Zürich-Montpellier approach. The numerical classification and ordination technique were applied to determine the main forest vegetation types and to find the responsible environmental drivers related to their distribution patterns, respectively. The data set including 198 relevés collected by authors in 1997-2009 and 185 relevés excerpted from literature was used to analysis. Numerical classification resulted in delimitation of fourteen vegetation types representing eleven associations with two variants and two communities within the Quercetea roboretetiae and Querceto-Fagetetea classes. The major environmental gradients in variation of forest species composition were associated with moisture and nutrient content following the average Ellenberg indicator values. Along the moisture gradient, vegetation types were ordered from subxerophilous oak forests turn mesophilous mixed oak-hornbeam, beech and ravine forests to hygrophilous riparian alder forest. The results confirmed important role of soil nutrients and moisture by determination of forest vegetation in subcontinental part of Central Europe. Special attention was given to the discussion of floristical characteristics, site conditions and syntaxonomy.

KEY WORDS: classification, Quercetea roboretetiae, Querceto-Fagetetea, numerical methods, Ellenberg indicator values, vegetation survey, Western Carpathians.

INTRODUCTION

Forest ecosystems are the most important functional component of the Central European landscape, and they are essential for maintaining biological diversity. Spatial distribution and horizontal structure of forest vegetation are simultaneously influenced by a number of ecological and anthropogenic factors and their interactions. The different geology and soil properties, long-term development of vegetation, land-use history and the biogeographical position resulted in a mosaic of plant species and forest communities (e.g. Roo-Zielinska and Solon 1997; Aude and Lawesson 1998; Kolb and Diekmann 2004; Dambrine et al. 2007). Environmental and geographical gradients are therefore the main drivers of variation in floristic composition of temperate deciduous forests. In the last decade, this issue has been discussed in a number of botanical studies, especially those dealing with vegetation classification (e.g. Matuszkiewicz 2000; Willner 2002; Knollová and Chytrý 2004; Boublík et al. 2007; Douda 2008; Towpasz and

Stachurska-Swakoń 2008), evaluation of vegetation-environmental relationships (e.g. Härdtle et al. 2005; Leuschner and Lenzion 2009) and also vegetation dynamics (e.g. Šamonil and Vrška 2008). Because of the increasing threats to forests by a range of human activities, special attention was given to the impact of forest management and air pollution on the herbaceous layer (e.g. von Oheimb and Härdtle 2009). The above-mentioned works have enhanced our understanding of vegetation patterns in these ecological systems. The obtained knowledge should provide initial data for justifying suitable conservation management, integrated ecological landscape planning and also for the establishment of national vegetation surveys or checklists of plant communities (Pott 1992; Borhidi 2003; Matuszkiewicz 2007; Willner and Grabherr 2007; Jarolímek et al. 2008; Onyshchenko 2010). In the territory of Slovakia, studies of these features are relatively limited, and focusing on selected vegetation types, i.e. alder- (Šomšák 2000), beech- (Ujházy et al. 2004; Ujházyová 2007) or dry-mesic oak forests (Roleček 2005).

Štiavnické vrchy Mts are generally considered as a very interesting Slovakian vegetation-landscape type with respect to their location in the transition zone between the Western Carpathian and Pannonian region. This forest vegetation consists of thermophilous as well as submontane (dealpine or praealpine) vascular plants, many of which belong to rare and endangered species (Hlavaček 1985). Deciduous forests are among the most widespread vegetation types of region and their investigation according to the Braun-Blanquet approach has a long history in the Štiavnické vrchy Mts (Mikyška 1929, 1933, 1939; Neuhäusl and Neuhäuslová-Novotná 1964). Although some papers have been recently published (Balkovič 2002; Ciriaková and Hegedúšová-Kučerová 2003; Slezák and Kukla 2009; Slezák and Petrášová 2010), syntaxonomy, ecology and vegetation diversity of these forests have been remained poorly known. Aim of this paper was: (i) to prepare a complex syntaxonomical revision of deciduous forest vegetation in the Štiavnické vrchy Mts as a result of numerical classification, and (ii) to find the major environmental gradients responsible for variation in their floristic composition.

MATERIAL AND METHODS

Study area

The research was carried out in the Štiavnické vrchy Mts ($48^{\circ}12' - 48^{\circ}35' \text{N}$; $18^{\circ}32' - 19^{\circ}05' \text{E}$), which represent a clearly defined and homogenous geomorphologic unit in

the central part of Slovakia (Fig. 1). They occupy a geographic territory of approximately 800 km², extending from the colline to the submontane belt. The studied area belongs to the typical volcanic mountains with a quite uniform geological substrate. The bedrock consists mainly of andesites and rhyolites with scattered occurrence of conglomerates and shales. A substantial part of the area has a moderately warm climate. The values of the long-term (1961-1990) mean annual precipitation and air temperature are 771 mm and 7.7°C respectively, the mean air temperature in April-September is 14.0°C (climatic station Banská Štiavnica; Slovak Hydrometeorological Institute).

Vegetation sampling and phytosociological analysis

The base for the study and evaluation of forest communities in the Štiavnické vrchy Mts were the phytosociological data collected during the field research and the ones excerpted from Central Phytosociological Database of Slovakia (CDF, <http://ibot.sav.sk/cdf/index.html>; Hegedúšová 2007). All the phytosociological relevés were recorded according to the principles of the Zürich-Montpellier approach (Braun-Blanquet 1964), frequently using the modified 9-degree Braun-Banquet's sampling scale (Barkman et al. 1964) and stored in a TURBOVEG database (Hennekens and Schaminée 2001). The CDF relevés with size smaller than 250 m² have been deleted before the analysis. For numerical analysis, some taxonomically problematic species, which were not distinguished in several relevés, were classified within higher or broadly defined taxa and marked with abbreviation 'agg.': *Achillea mille-*

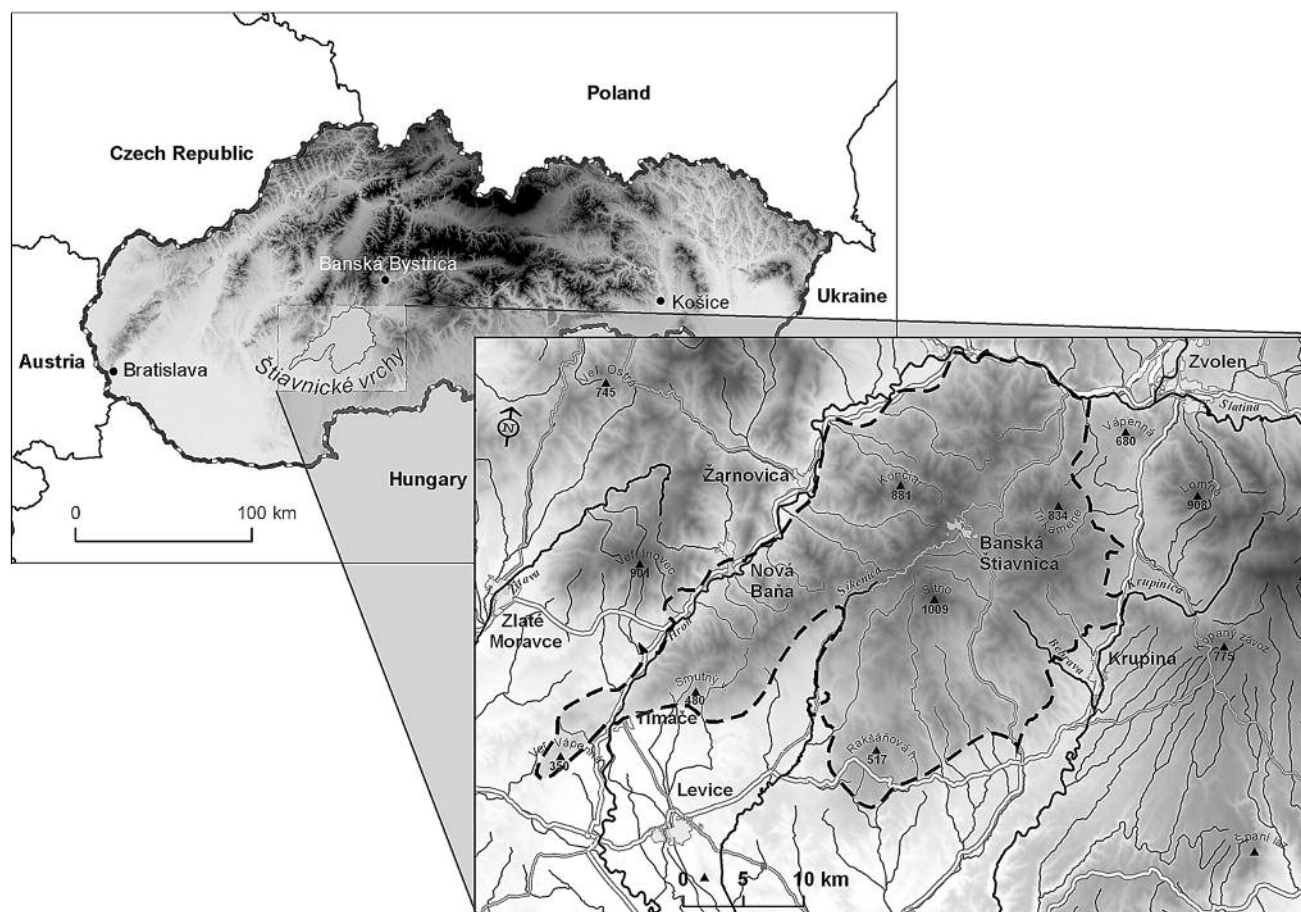


Fig. 1. Location of the study area.

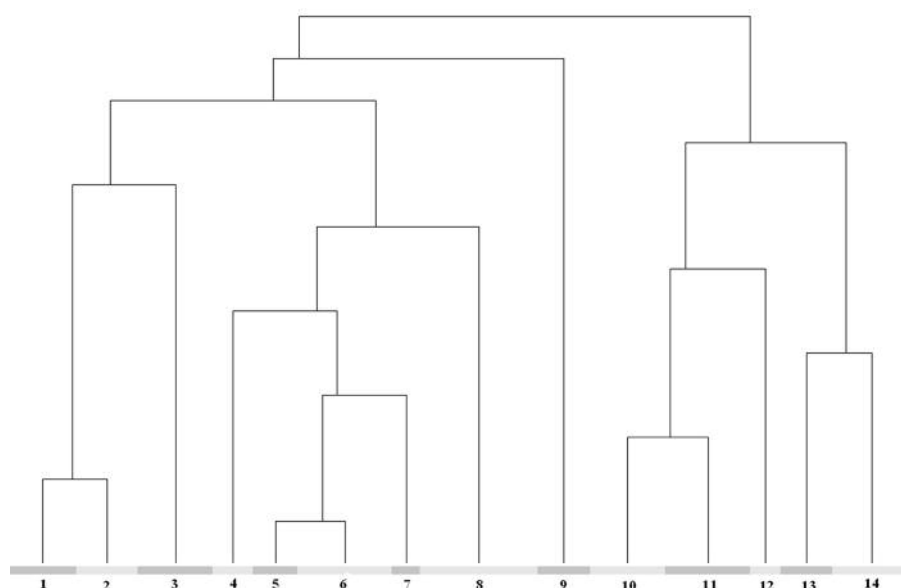


Fig. 2. Dendrogram of numerical classification of the study relevés (for explanation of cluster numbers see Table 1).

folium agg. (incl. *A. collina*, *A. millefolium*, *A. setacea*), *Festuca ovina* agg. (*F. ovina*, *F. valesiaca*), *Festuca rubra* agg. (*F. nigrescens*, *F. rubra*), *Galium mollugo* agg. (*G. album* subsp. *album*, *G. mollugo*, *G. pycnotrichum*), *Poa pratensis* agg. (*P. angustifolia*, *P. pratensis*), *Pulmonaria officinalis* agg. (*P. obscura*, *P. officinalis*), *Pyrus communis* agg. (*P. communis*, *P. pyraeaster*), *Quercus petraea* agg. (*Q. dalechampii*, *Q. petraea*, *Q. polycarpa*), *Senecio nemorensis* agg. (*S. germanicus*, *S. ovatus*), *Verbascum thapsus* agg. (*V. densiflorum*, *V. thapsus*), *Vicia cracca* agg. (*V. cracca*, *V. tenuifolia*). The resulting set of 383 relevés was compiled; 198 unpublished relevés were taken by the authors in the period 1997–2009 and 185 relevés were obtained from CDF (including all relevés assigned to the classes *Quercetea robori-petraeae* and *Querco-Fagetea* by their authors). Numerical classification of the data set was performed by the PC-ORD 5 program (McCune and Mefford 1999) with relative Euclidean distance as a measure of dissimilarity and Ward's linkage method. Species percentage cover was logarithmically transformed. The optimal number of cluster was estimated by the crispness method (Botta-Dukát et al. 2005) using the JUICE software (Tichý 2002). The diagnostic species of the clusters were determined on the basis of the fidelity concept (Chytrý et al. 2002) and frequency (threshold values: $\Phi \geq 0.25$ and frequency ≥ 30) in the JUICE software. The size of all clusters was standardized to an equal size (Tichý and Chytrý 2006). Fisher's exact test ($P < 0.001$) was used to eliminate the fidelity value of species with a non-significant pattern of occurrence.

Detrended correspondence analysis (DCA) from the CANOCO 4.5 for Windows package (ter Braak and Šmilauer 2002) was applied for the ecological interpretation of the main gradients in the studied forest vegetation units. Average Ellenberg indicator values (Ellenberg et al. 1992) and Shannon-Wiener diversity index for relevés were plotted onto a DCA ordination diagram as supplementary variables. The significance of differences in Ellenberg indicator values among the clusters was tested with one-way ANOVA and post-hoc Duncan test. The STATISTICA software (STATSOFT INC. 2006) was used for multiple comparisons and construction of Box and Whisker plots. Altitude and aspect of the vegetation plots were measured by

Garmin GPSmap 60 CSx equipment (WGS-84 system). The environmental characteristics of individual vegetation types (clusters) are in accordance with methodological and result parts of earlier studies (Slezák and Kukla 2009; Slezák and Petrášová 2010). The nomenclature follows Marhold and Hindák (1998) for vascular plants. The names of syntaxa have been unified according to Jarolímek et al. (2008).

RESULTS

Phytosociological and ecological characteristics of forest communities

According to the syntaxonomical interpretation and description given below, the fourteen floristically differentiated vegetation units can be assigned to two classes of *Quercetea robori-petraeae* and *Querco-Fagetea* (Fig. 2, Tables 1 and 2).

Cluster 1: *Carici pilosae-Carpinetum* var. *typicum*

The Carpathian oak-hornbeam forests with dominant *Carex pilosa* are developed in the colline belt. The tree layer is mostly uniform; *Carpinus betulus* is absolutely predominant, *Quercus petraea* agg. and *Fagus sylvatica* may be admixed. The species-poor shrub layer has a higher cover degree only in defined spots. Except for the younger individuals of the tree species, *Swida sanguinea*, *Corylus avellana*, *Acer campestre* and *Tilia cordata* alternate as dominants. In addition to *Fragaria vesca*, *Melica nutans*, *Pulmonaria officinalis* agg. and *Viola reichenbachiana*, the herb layer is abundant in mesophilous species (e.g. *Carex digitata*, *Galium odoratum*, *G. schultesii*, *Lathyrus vernus*, *Melica uniflora*, *Stellaria holostea*, *Symphytum tuberosum*, *Tithymalus amygdaloides*). The participation of thermophilous oak species is generally low.

Cluster 2: *Carici pilosae-Carpinetum* var. *Poa nemoralis*

The *Poa nemoralis* variant is more xeric and it occupies the more open sites. The herb layer is richer in thermophilous and heliophilous vascular plants (*Clinopodium vulgare*, *Cruciata glabra*, *Cardaminopsis arenosa*, *Vincetoxicum hirsutinaria* and *Digitalis grandiflora*). It has

TABLE 1. Shortened synoptic table of forest vegetation of the Štiavnické vrchy Mts. Diagnostic species of communities are shaded and ranked by decreasing phi values (phi coefficient \times 100, upper indices); only species with phi values \geq 0.25 and frequency \geq 30 are presented.

Cluster number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Number of relevés	29	29	32	17	19	40	12	50	22	32	36	13	22	33
<i>Polygonatum multiflorum</i>	52 ^{36.8}	8	28 ^{15.6}	.	16 ^{4.6}	5	17 ^{5.3}	10	9	3	3	.	.	.
<i>Carex digitata</i>	69 ^{29.8}	50 ^{17.4}	12	47 ^{15.5}	37 ^{8.8}	22	17	32 ^{5.6}	.	16	17	.	9	.
<i>Ranunculus lanuginosus</i>	38 ^{28.2}	4	.	.	5	2	25 ^{15.6}	2	32 ^{22.2}	3	.	.	14 ^{4.6}	.
<i>Pulmonaria officinalis</i> agg.	86 ^{28.0}	65 ^{16.1}	53 ^{9.0}	53 ^{8.9}	58 ^{11.8}	30	25	54 ^{9.5}	50 ^{7.2}	22	22	.	5	.
<i>Melica nutans</i>	52 ^{27.0}	31 ^{11.1}	3	29 ^{10.1}	37 ^{15.7}	10	8	12	.	16	8	.	18 ^{1.6}	.
<i>Tilia cordata</i> (E ₂)	38 ^{26.2}	15 ^{5.2}	.	35 ^{23.8}	.	5	.	6	.	3	3	.	32 ^{20.5}	.
<i>Ajuga reptans</i>	79 ^{26.0}	54 ^{11.2}	34	53 ^{10.7}	37 ^{1.3}	35	50 ^{8.9}	46 ^{6.6}	18	53 ^{10.8}	3	8	9	6
<i>Heracleum sphondylium</i>	31 ^{25.6}	12 ^{4.7}	9 ^{2.3}	.	11 ^{3.6}	5	.	.	23 ^{16.7}	3	3	.	5	.
<i>Viola reichenbachiana</i>	97 ^{25.2}	81 ^{16.4}	78 ^{14.9}	94 ^{23.8}	74 ^{12.5}	78 ^{14.6}	42	88 ^{20.4}	18	6	36	.	23	3
<i>Melica uniflora</i>	52 ^{9.4}	19	100 ^{37.4}	18	53 ^{9.9}	20	17	38 ^{1.4}	5	72 ^{21.1}	67 ^{18.1}	15	5	18
<i>Moehringia trinervia</i>	17 ^{5.5}	19 ^{7.3}	47 ^{31.8}	12	5	5	.	10	9	3	11	.	9	6
<i>Quercus robur</i> (E ₃)	.	.	.	35 ^{48.9}	.	.	.	.	.	3	.	.	98 ⁷	.
<i>Corylus avellana</i> (E ₂)	24	19	12	82 ^{36.5}	26	18	8	20	55 ^{18.7}	16	17	.	50 ^{15.8}	6
<i>Lonicera xylosteum</i> (E ₂)	.	4	.	35 ^{36.4}	5	5	8 ^{3.5}	2	5	.	.	.	94 ⁴	3
<i>Picea abies</i> (E ₃)	7	4	.	41 ^{34.6}	11 ^{2.8}	2	8	10 ^{2.3}	5	.	.	.	18 ^{10.8}	3
<i>Carex sylvatica</i>	34 ^{20.9}	8	.	47 ^{32.1}	16 ^{4.3}	22 ^{10.3}	.	12	14 ^{2.4}	.	.	.	.	.
<i>Rubus hirtus</i> agg.	76 ^{17.6}	46 ^{1.0}	44	100 ^{31.1}	58 ^{7.6}	68 ^{13.0}	8	66 ^{12.1}	18	44	19	23	32	18
<i>Dryopteris carthusiana</i>	17 ^{1.8}	.	3	53 ^{29.6}	21 ^{4.8}	30 ^{11.7}	8	16	45 ^{23.7}	3	3	.	9	.
<i>Galium odoratum</i>	66 ^{10.3}	46	78 ^{17.3}	100 ^{29.4}	79 ^{17.7}	48	50 ^{1.7}	88 ^{22.8}	18	25	31	.	18	12
<i>Dryopteris filix-mas</i>	76 ^{13.9}	23	44	100 ^{27.3}	84 ^{18.5}	78 ^{14.8}	75 ^{13.4}	74 ^{12.9}	36	3	28	.	73 ^{12.1}	18
<i>Fragaria vesca</i>	69 ^{17.4}	73 ^{19.7}	41 ^{1.2}	82 ^{25.0}	11	22	42 ^{1.8}	36	5	41 ^{1.2}	58 ^{11.3}	.	32	27
<i>Acer pseudoplatanus</i> (E ₃)	.	.	6	6	58 ^{51.1}	10 ^{2.1}	17 ^{8.9}	6	5	.	.	.	5	.
<i>Fraxinus excelsior</i> (E ₃)	3	.	12 ^{7.6}	.	42 ^{42.1}	18 ^{13.4}	.	4	5	.	.	.	.	.
<i>Mercurialis perennis</i>	34 ^{7.8}	12	44 ^{13.9}	18	74 ^{33.7}	35 ^{8.1}	42 ^{12.5}	32 ^{6.1}	9	.	19	.	.	.
<i>Ribes uva-crispa</i>	17 ^{3.7}	4	12	18 ^{4.1}	53 ^{33.2}	18 ^{3.9}	8	10	5	6	8	.	14	6
<i>Acer platanoides</i> (E ₃)	.	8	28 ^{18.6}	.	42 ^{32.1}	8	8	6	5	.	14 ^{4.8}	.	5	3
<i>Actaea spicata</i>	17 ^{7.4}	4	.	6	21 ^{11.0}	40 ^{29.0}	25 ^{14.8}	10	.	.	.	.	9	.
<i>Chamerion angustifolium</i>	.	.	.	.	.	.	42 ^{60.7}	.	.	.	.	.	.	3
<i>Primula elatior</i>	10 ^{7.2}	4	.	6 ^{1.4}	5	.	42 ^{47.9}	.	.	.	.	.	.	.
<i>Stellaria media</i>	21 ^{11.2}	.	.	12 ^{2.6}	.	.	50 ^{39.6}	.	27 ^{17.6}	9	.	8	.	.
<i>Cardamine impatiens</i>	3	.	3	.	5 ^{1.0}	.	33 ^{38.4}	2	14 ^{12.1}	.	3	.	.	.
<i>Oxalis acetosella</i>	48 ^{15.3}	4	.	59 ^{22.1}	21	30 ^{3.5}	83 ^{37.9}	30 ^{3.5}	45 ^{13.5}	.	.	.	23	.
<i>Prenanthes purpurea</i>	.	.	.	12 ^{9.4}	5	12 ^{10.4}	33 ^{37.9}	2	.	.	.	.	.	.
<i>Acer pseudoplatanus</i> (E ₂)	.	.	3	.	11 ^{6.9}	10 ^{6.2}	33 ^{35.7}	2	9 ^{5.1}	.	.	.	.	3
<i>Senecio nemorensis</i> agg.	28 ^{1.5}	31 ^{3.5}	12	47 ^{13.9}	58 ^{20.9}	45 ^{12.6}	75 ^{31.8}	30 ^{3.0}	.	.	14	.	14	.
<i>Abies alba</i> (E ₂)	3	4	3	18 ^{9.8}	.	2	33 ^{25.7}	4	5	.	6	.	32 ^{24.2}	3
<i>Alnus glutinosa</i> (E ₃)	.	.	.	.	.	.	.	.	100 ¹⁰⁰	.	.	.	.	.
<i>Stellaria nemorum</i>	.	.	.	.	.	.	.	.	64 ^{78.7}	.	.	.	.	.
<i>Aegopodium podagraria</i>	28 ^{16.1}	.	.	.	5	2	8	2	95 ^{78.6}	.	.	.	.	.
<i>Carex remota</i>	.	.	.	6 ^{2.1}	.	.	.	.	55 ^{68.6}	.	.	.	.	.
<i>Lamium maculatum</i>	.	.	6	.	16 ^{11.2}	.	.	.	64 ^{66.6}	.	.	.	.	.
<i>Festuca gigantea</i>	21 ^{8.7}	8	3	12	11	10	.	4	82 ^{63.2}	.	3	.	.	.
<i>Caltha palustris</i>	.	.	.	.	.	.	.	.	41 ^{62.6}	.	.	.	.	.
<i>Alnus glutinosa</i> (E ₂)	.	.	.	.	.	.	.	.	41 ^{62.6}	.	.	.	.	.
<i>Equisetum arvense</i>	.	.	.	.	.	.	.	.	41 ^{62.6}	.	.	.	.	.
<i>Poa trivialis</i>	.	.	.	.	.	.	.	.	41 ^{58.9}	.	.	.	5 ^{2.0}	.
<i>Sambucus nigra</i> (E ₂)	.	.	.	6	16 ^{6.9}	18 ^{8.6}	8	4	68 ^{58.3}	.	3	.	.	.
<i>Cirsium oleraceum</i>	31 ^{1.0}	.	.	.	.	.	.	.	36 ^{55.9}	.	.	.	.	.
<i>Urtica dioica</i>	7	.	.	29 ^{6.6}	37 ^{11.8}	45 ^{17.5}	50 ^{20.9}	.	100 ^{55.7}	.	6	.	5	.
<i>Rubus caesius</i>	.	.	.	.	.	2	.	2	41 ^{55.2}	.	6 ^{2.8}	.	.	.
<i>Salix fragilis</i> (E ₃)	.	.	.	.	.	.	.	.	32 ^{55.0}	.	.	.	.	.
<i>Geranium phaeum</i>	.	.	.	.	.	.	.	.	32 ^{55.0}	.	.	.	.	.
<i>Lycopus europaeus</i>	.	.	.	.	.	.	.	.	32 ^{55.0}	.	.	.	.	.
<i>Padus avium</i> (E ₂)	.	.	.	.	.	.	.	.	32 ^{55.0}	.	.	.	.	.
<i>Euonymus europaeus</i> (E ₂)	10 ^{9.1}	4	.	.	.	.	.	.	41 ^{52.7}	.	.	.	.	.
<i>Lysimachia vulgaris</i>	.	.	.	.	.	.	.	.	32 ^{52.1}	3 ^{1.1}	.	.	.	.
<i>Stachys sylvatica</i>	3	15	9	53 ^{22.7}	21	38 ^{12.0}	17	20	95 ^{52.1}	.	6	.	5	.
<i>Impatiens noli-tangere</i>	17	8	6	12	16	25 ^{5.4}	42 ^{17.5}	14	82 ^{46.8}	.	8	.	14	3
<i>Glechoma hederacea</i>	21 ^{8.0}	23 ^{10.1}	19 ^{6.3}	.	11	8	.	8	64 ^{45.4}	.	8	.	.	.
<i>Milium effusum</i>	10 ^{4.0}	4	.	6	11 ^{4.2}	2	17 ^{10.9}	4	41 ^{37.7}	.	.	.	.	.
<i>Acer campestre</i> (E ₂)	31 ^{10.3}	35 ^{12.9}	31 ^{10.4}	6	.	.	.	2	68 ^{37.7}	31 ^{10.4}	19 ^{1.7}	15	.	.
<i>Galeobdolon luteum</i> agg.	28 ^{9.3}	15	6	18 ^{1.6}	42 ^{20.4}	15	.	24 ^{6.5}	64 ^{36.9}	.	6	.	.	.
<i>Lysimachia nummularia</i>	17 ^{13.4}	12 ^{6.7}	.	.	.	.	.	.	36 ^{36.0}	12 ^{7.8}	.	.	5	.
<i>Galium aparine</i>	24 ^{1.9}	27 ^{3.8}	56 ^{23.7}	.	21	8	.	6	68 ^{31.8}	6	36 ^{10.0}	8	23 ^{1.0}	15
<i>Rubus idaeus</i>	10	.	3	29 ^{11.7}	11	10	33 ^{14.8}	8	50 ^{27.9}	.	11	.	32 ^{13.6}	6
<i>Festuca heterophylla</i>	.	15 ^{13.1}	3	.	.	.	.	.	.	44 ^{49.0}	6	.	.	3

TABLE 1. Cont.

Cluster number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Number of relevés	29	29	32	17	19	40	12	50	22	32	36	13	22	33	
<i>Lathyrus niger</i>	31 ^{10.3}	31 ^{10.1}	16	.	.	10	.	8	.	72 ^{40.5}	22 ^{3.8}	31 ^{10.1}	9	9	
<i>Fragaria moschata</i>	28 ^{12.5}	19 ^{5.5}	28 ^{12.9}	.	.	.	.	.	.	59 ^{39.0}	19 ^{5.7}	15 ^{2.3}	5	3
<i>Pyrethrum corymbosum</i>	.	15 ^{5.6}	12 ^{2.9}	.	.	.	.	.	.	50 ^{38.3}	31 ^{19.9}	8	5	12 ^{2.5}
<i>Lathyrus vernus</i>	52 ^{14.9}	54 ^{16.3}	50 ^{13.9}	.	11	20	8	28	.	88 ^{37.1}	53 ^{15.6}	.	9	15	
<i>Melittis melissophyllum</i>	34 ^{12.0}	38 ^{14.8}	19	6	5	12	.	10	.	69 ^{36.7}	25 ^{5.1}	23 ^{3.7}	9	.	
<i>Convallaria majalis</i>	10 ^{7.2}	12 ^{8.7}	3	.	.	2	.	.	.	31 ^{34.3}	6 ^{1.0}	.	.	3	
<i>Galium schultesii</i>	69 ^{14.8}	73 ^{17.1}	75 ^{18.2}	12	5	2	33	16	.	97 ^{30.5}	78 ^{19.8}	31	50 ^{4.2}	55 ^{6.7}	
<i>Hypericum hirsutum</i>	31 ^{20.6}	.	9	6	5	2	25 ^{14.9}	4	.	41 ^{29.7}	.	8	.	.	
<i>Carex montana</i>	10 ^{4.6}	19 ^{14.8}	.	.	5	8 ^{1.4}	.	4	.	31 ^{28.5}	3	8 ^{1.6}	.	.	
<i>Dactylis polygama</i>	41 ^{13.2}	35 ^{8.6}	56 ^{23.1}	.	.	.	.	8	5	62 ^{27.3}	58 ^{24.5}	8	5	27 ^{3.7}
<i>Stellaria holostea</i>	41 ^{13.0}	31 ^{5.9}	28 ^{4.1}	.	16	.	.	6	32 ^{6.6}	62 ^{27.2}	33 ^{7.6}	8	23	27 ^{3.6}	
<i>Crataegus monogyna</i> (E ₂)	7	12	16 ^{2.9}	12	.	2	.	2	27 ^{12.8}	44 ^{26.7}	11	38 ^{22.2}	.	.	
<i>Rosa canina</i> agg. (E ₂)	21	27	53 ^{17.5}	41 ^{9.9}	21	10	.	26	14	.	72 ^{29.6}	.	14	61 ^{22.2}	
<i>Campanula persicifolia</i>	24	46 ^{12.5}	34 ^{5.1}	.	5	.	8	6	.	56 ^{18.9}	72 ^{28.9}	23	50 ^{14.9}	42 ^{10.2}	
<i>Campanula rapunculoides</i>	48 ^{16.4}	54 ^{20.1}	53 ^{19.6}	6	21	15	.	16	5	9	64 ^{26.6}	8	18	9	
<i>Festuca rupicola</i>	.	.	.	.	.	.	.	.	.	.	.	100 ¹⁰⁰	.	.
<i>Seseli osseum</i>	.	.	.	.	.	.	.	.	.	.	.	85 ^{89.7}	.	3
<i>Poa compressa</i>	.	.	.	.	.	.	.	.	.	.	.	77 ^{86.9}	.	.
<i>Dorycnium pentaphyllum</i> agg.	.	.	.	.	.	.	.	.	.	.	.	77 ^{86.9}	.	.
<i>Pilosella bauhini</i>	.	.	.	.	.	.	.	.	.	.	11 ^{2.8}	92 ^{84.1}	5	9
<i>Teucrium chamaedrys</i>	.	.	.	.	.	2	.	.	.	3	3	77 ^{74.9}	.	15 ^{8.6}
<i>Poa pratensis</i> agg.	.	4	.	.	.	.	.	.	.	31 ^{18.3}	6	92 ^{72.8}	.	18 ^{6.6}
<i>Fragaria viridis</i>	.	.	.	.	.	.	.	.	.	.	.	54 ^{72.1}	.	.
<i>Tithymalus cyparissias</i>	.	15 ^{2.5}	6	.	.	.	.	.	.	12	22 ^{8.2}	92 ^{67.1}	5	21 ^{7.4}
<i>Eryngium campestre</i>	.	.	.	.	.	.	.	.	.	.	.	46 ^{66.6}	.	.
<i>Poa pannonica</i> subsp. <i>scabra</i>	.	.	.	.	.	.	.	.	.	.	.	46 ^{66.6}	.	.
<i>Dianthus armeria</i>	.	.	.	.	.	.	.	.	.	9 ^{6.5}	.	54 ^{65.9}	.	.
<i>Trifolium alpestre</i>	.	.	3	.	.	.	.	.	.	3	14 ^{6.9}	69 ^{65.7}	5	91 ⁸
<i>Galium verum</i>	17 ^{5.0}	8	.	6	.	.	.	.	.	25 ^{11.7}	8	85 ^{63.6}	9	3
<i>Prunus spinosa</i> (E ₂)	3	.	.	.	.	.	.	.	9 ^{3.0}	16 ^{10.4}	.	62 ^{62.4}	.	.
<i>Chamaecytisus supinus</i>	.	.	.	.	.	.	.	.	.	16 ^{13.6}	.	54 ^{62.4}	.	.
<i>Viola hirta</i>	.	4	.	.	.	.	.	.	.	28 ^{23.8}	.	62 ^{60.9}	.	.
<i>Cota tinctoria</i>	.	.	.	.	.	.	.	.	.	.	.	38 ^{60.6}	.	.
<i>Rosa gallica</i>	.	.	.	.	.	.	.	.	.	.	.	38 ^{60.6}	.	.
<i>Agrimonia eupatoria</i>	.	.	.	.	.	.	.	.	.	.	.	38 ^{60.6}	.	.
<i>Verbascum austriacum</i>	.	4	.	.	.	.	.	.	.	16 ^{9.7}	8 ^{1.7}	62 ^{60.2}	.	6
<i>Trifolium campestre</i>	.	.	.	.	.	.	.	.	.	9 ^{7.7}	.	46 ^{60.0}	.	.
<i>Pimpinella saxifraga</i> agg.	.	.	.	.	.	2	.	.	.	.	6	54 ^{59.5}	5	9 ^{4.5}
<i>Silene nutans</i> agg.	.	4	.	.	.	.	.	.	.	25 ^{12.2}	17 ^{4.9}	77 ^{58.0}	.	33 ^{19.6}
<i>Juniperus communis</i> (E ₂)	.	.	.	.	.	.	.	.	.	3	.	46 ^{56.6}	.	12 ^{10.5}
<i>Pyrus communis</i> agg. (E ₂)	3	4	.	.	.	.	.	.	5	12 ^{7.6}	3	54 ^{55.9}	.	3
<i>Trifolium arvense</i>	.	.	.	.	.	.	.	.	.	.	.	38 ^{55.8}	.	6 ^{4.6}
<i>Agrostis capillaris</i>	.	.	.	.	.	.	.	.	.	25 ^{22.0}	.	54 ^{55.5}	.	6
<i>Achillea millefolium</i> agg.	.	.	.	.	.	.	.	.	.	.	6 ^{1.2}	46 ^{54.5}	5	9 ^{5.8}
<i>Carex caryophylla</i>	.	.	.	.	.	.	.	.	.	.	.	31 ^{54.0}	.	.
<i>Inula conyzae</i>	.	.	.	.	.	.	.	.	.	3 ^{1.3}	.	31 ^{51.2}	.	.
<i>Allium senescens</i> subsp. <i>montanum</i>	.	.	.	.	.	.	.	.	.	.	6	46 ^{51.1}	.	21 ^{20.0}
<i>Pseudolysimachion spicatum</i>	.	.	.	.	.	27	.	.	.	.	.	31 ^{46.6}	.	9 ^{10.4}
<i>Festuca ovina</i> agg.	.	.	.	.	.	.	.	.	.	25 ^{17.1}	11 ^{3.0}	54 ^{46.3}	.	24 ^{16.3}
<i>Quercus cerris</i> (E ₃)	3	.	12	.	.	.	.	.	.	25 ^{16.8}	17 ^{8.4}	54 ^{45.8}	5	.
<i>Vicia cassubica</i>	.	.	.	.	.	.	.	.	.	19 ^{19.1}	6 ^{1.4}	38 ^{45.5}	.	.
<i>Genista tinctoria</i>	7	12	6	.	.	.	.	2	.	53 ^{23.3}	44 ^{17.3}	77 ^{39.9}	23 ^{2.1}	52 ^{22.2}
<i>Hypericum perforatum</i>	.	12	3	12	.	.	.	4	.	50 ^{23.7}	31 ^{9.5}	69 ^{37.7}	23 ^{3.8}	42 ^{18.2}	
<i>Vincetoxicum hirsundinaria</i>	.	23 ^{7.5}	12	6	.	5	.	.	.	25 ^{9.1}	31 ^{13.6}	54 ^{32.3}	9	27 ^{10.9}	
<i>Vaccinium myrtillus</i>	.	.	.	.	.	.	17 ^{20.0}	.	.	.	.	.	32 ^{43.0}	.
<i>Polypodium vulgare</i>	10	12	3	6	11	5	8	.	.	.	28 ^{11.9}	.	64 ^{41.2}	39 ^{21.4}	
<i>Sorbus aucuparia</i> (E ₂)	.	.	.	24 ^{20.0}	.	2	17 ^{12.1}	.	.	.	.	.	41 ^{40.0}	3
<i>Genista pilosa</i>	.	4	.	.	.	.	.	.	.	.	17 ^{6.1}	.	32 ^{20.1}	88 ^{71.9}
<i>Cardaminopsis arenosa</i>	.	19 ^{1.5}	9	.	.	.	.	2	.	.	50 ^{24.2}	38 ^{15.7}	45 ^{20.8}	76 ^{43.1}
<i>Hylotelephium maximum</i>	14	19	16	.	5	.	.	.	.	16	47 ^{18.6}	54 ^{23.1}	32 ^{7.9}	82 ^{42.4}
<i>Galium mollugo</i> agg.	.	.	3	.	.	.	8 ^{1.6}	2	.	6	28 ^{23.0}	.	92 ⁵	39 ^{35.7}	
<i>Digitalis grandiflora</i>	7	19 ^{2.6}	28 ^{9.4}	.	5	.	8	2	.	34 ^{14.1}	47 ^{23.9}	8	5	58 ^{31.8}	
<i>Dalanum ladanum</i>	3	4	31 ^{22.4}	.	5	5	.	4	.	.	22 ^{13.5}	.	9	36 ^{27.5}	
DS common for several vegetation types															
<i>Quercus petraea</i> agg. (E ₂)	10	8	6	.	.	.	.	.	.	75 ^{34.3}	39 ^{10.5}	85 ^{40.7}	32 ^{5.9}	67 ^{28.8}
<i>Carex pilosa</i>	100 ^{41.3}	31	25	71 ^{23.7}	21	45 ^{8.4}	.	94 ^{37.7}	9	22	8	.	9	.	
<i>Glechoma hirsuta</i>	59 ^{27.2}	31 ^{7.7}	56 ^{25.5}	6	42 ^{15.7}	5	8	14	23 ^{2.1}	9	22 ^{1.8}	.	.	.	

TABLE 1. Cont.

Cluster number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Number of relevés	29	29	32	17	19	40	12	50	22	32	36	13	22	33
<i>Alliaria petiolata</i>	17	15	69 ^{29.0}	6	47 ^{15.1}	25	.	18	86 ^{40.5}	6	42 ^{11.4}	.	5	.
<i>Geum urbanum</i>	31 ^{7.2}	15	59 ^{26.7}	.	16	5	8	12	82 ^{42.1}	28 ^{5.2}	28 ^{5.0}	.	.	3
<i>Impatiens parviflora</i>	28 ^{6.1}	15	56 ^{26.4}	12	11	25 ^{4.3}	.	22	77 ^{41.2}	.	14	.	.	6
<i>Abies alba</i> (E ₃)	7	4	.	76 ^{35.3}	42 ^{12.6}	45 ^{14.5}	100 ^{50.8}	22	.	.	8	.	14	3
<i>Circaea lutetiana</i>	14	8	3	53 ^{26.5}	16	38 ^{15.1}	33 ^{12.0}	20 ^{2.2}	55 ^{27.7}	.	.	.	.	.
<i>Fagus sylvatica</i> (E ₃)	72 ^{10.5}	69 ^{8.7}	50	88 ^{19.3}	79 ^{14.1}	100 ^{25.8}	33	100 ^{25.8}	5	6	22	.	91 ^{20.8}	33
<i>Viola riviniana</i>	31 ^{15.1}	8	9	.	.	.	50 ^{30.9}	2	9	66 ^{43.8}	.	.	5	.
<i>Hieracium sabaudum</i>	24	23	22	6	.	.	.	.	.	91 ^{43.5}	22	85 ^{39.6}	18	42 ^{12.1}
<i>Astragalus glycyphyllos</i>	21	19	19	.	5	2	.	6	.	72 ^{36.4}	61 ^{28.9}	54 ^{23.8}	5	12
<i>Carex muricata</i> agg.	7	12	9	.	5	2	.	2	.	53 ^{34.8}	33 ^{18.0}	46 ^{28.9}	.	.
<i>Veronica officinalis</i>	14	15	19	18	.	.	.	18	.	72 ^{33.3}	22	77 ^{36.7}	27 ^{3.5}	27 ^{3.5}
<i>Quercus cerris</i> (E ₂)	.	.	3	.	.	.	.	.	.	34 ^{33.2}	.	46 ^{47.0}	.	.
<i>Ligustrum vulgare</i> (E ₂)	24 ^{4.6}	31 ^{9.4}	6	.	.	2	.	.	9	62 ^{32.4}	22 ^{3.2}	85 ^{48.4}	5	3
<i>Clinopodium vulgare</i>	21	42 ^{11.2}	56 ^{20.1}	.	.	.	.	4	.	75 ^{32.1}	58 ^{21.4}	77 ^{33.4}	.	15
<i>Securigera varia</i>	.	8	6	.	.	2	.	.	.	22 ^{9.6}	47 ^{32.0}	54 ^{37.9}	.	15 ^{3.6}
<i>Galium glaucum</i>	.	.	3	.	.	.	.	.	.	6	25 ^{13.1}	62 ^{46.1}	.	52 ^{37.0}
<i>Linaria genistifolia</i>	.	.	.	.	.	.	.	.	.	.	6	38 ^{37.2}	.	42 ^{41.8}
<i>Steris viscaria</i>	3	.	.	.	.	.	.	.	.	9	14 ^{5.2}	38 ^{29.4}	5	52 ^{42.3}
<i>Lembotropis nigricans</i>	3	12 ^{2.5}	.	.	.	.	.	.	.	19 ^{9.6}	3	38 ^{28.7}	14 ^{4.6}	36 ^{26.7}
<i>Avenella flexuosa</i>	.	4	3	12	5	.	25 ^{8.9}	.	.	6	14	8	64 ^{39.8}	55 ^{32.5}
<i>Luzula luzuloides</i>	52 ^{3.7}	50 ^{2.8}	38	53 ^{4.4}	26	22	33	50 ^{2.8}	.	41	64 ^{10.5}	8	100 ^{30.6}	94 ^{27.3}
Other species with occurrence in more than 12 vegetation types														
<i>Poa nemoralis</i>	48	100 ^{22.0}	94 ^{18.4}	53	37	10	25	28	27	97 ^{20.2}	100 ^{22.0}	100 ^{22.0}	50	91 ^{16.8}
<i>Scrophularia nodosa</i>	31 ^{9.7}	12	28 ^{7.6}	18	16	25 ^{5.3}	17	24 ^{4.6}	5	41 ^{16.6}	6	8	14	6
<i>Mycelis muralis</i>	66 ^{8.0}	62 ^{5.8}	41	53 ^{1.0}	84 ^{18.3}	62 ^{6.3}	92 ^{22.5}	56 ^{2.7}	18	66 ^{8.0}	47	15	45	9
<i>Geranium robertianum</i>	52 ^{3.3}	31	75 ^{16.3}	59 ^{7.3}	84 ^{21.4}	55 ^{5.1}	75 ^{16.3}	40	55 ^{4.9}	28	42	15	27	3
<i>Veronica chamaedrys</i>	52	88 ^{20.0}	88 ^{19.5}	6	.	2	42	28	5	97 ^{24.7}	92 ^{21.8}	92 ^{22.2}	55 ^{1.2}	88 ^{19.7}
<i>Hieracium murorum</i>	17	50 ^{15.6}	9	6	5	8	33 ^{5.0}	2	.	53 ^{17.6}	42 ^{10.3}	31 ^{3.4}	55 ^{18.5}	45 ^{12.7}
<i>Carpinus betulus</i> (E ₂)	79 ^{17.5}	81 ^{18.3}	75 ^{15.1}	82 ^{19.2}	32	18	17	38	36	38	78 ^{16.7}	.	41	55 ^{3.8}
<i>Fagus sylvatica</i> (E ₂)	55 ^{5.0}	58 ^{6.4}	31	82 ^{20.1}	53 ^{3.5}	78 ^{17.4}	58 ^{6.7}	82 ^{19.9}	14	12	28	.	64 ^{9.7}	33
<i>Carpinus betulus</i> (E ₃)	100 ^{22.8}	96 ^{20.6}	100 ^{22.8}	94 ^{19.5}	95 ^{19.8}	55	.	66 ^{3.6}	36	28	72 ^{7.1}	8	45	39
<i>Symphytum tuberosum</i>	55 ^{24.8}	35 ^{10.5}	25 ^{3.7}	.	16	5	8	12	36 ^{11.7}	44 ^{16.8}	8	23 ^{2.4}	5	3
<i>Quercus petraea</i> agg. (E ₃)	83 ^{9.9}	77 ^{6.5}	97 ^{18.2}	100 ^{20.0}	42	30	.	46	.	88 ^{12.7}	100 ^{20.0}	100 ^{20.0}	59	100 ^{20.0}
<i>Fallopia convolvulus</i>	.	12	50 ^{21.7}	18	11	8	.	8	5	22 ^{1.9}	53 ^{23.7}	38 ^{13.6}	9	36 ^{12.1}
<i>Epilobium montanum</i>	21 ^{5.5}	19 ^{4.3}	16 ^{1.4}	12	11	20 ^{4.9}	25 ^{9.0}	26 ^{9.8}	14	3	6	.	23 ^{7.1}	.
<i>Brachypodium sylvaticum</i>	24 ^{6.8}	15	9	41 ^{19.9}	5	8	33 ^{13.9}	2	23 ^{5.7}	22 ^{5.1}	8	23 ^{6.0}	.	.
<i>Ligustrum vulgare</i>	45 ^{15.5}	50 ^{19.0}	44 ^{14.8}	29 ^{5.2}	11	8	.	8	14	28 ^{4.3}	50 ^{19.0}	15	.	3
<i>Dentaria bulbifera</i>	59 ^{13.1}	27	69 ^{19.0}	29	63 ^{15.8}	70 ^{19.7}	42 ^{3.3}	76 ^{23.2}	5	12	22	.	23	6

Legend: Cluster number 1 – Carici pilosae-Carpinetum var. typicum, 2 – Carici pilosae-Carpinetum var. *Poa nemoralis*, 3 – Melico uniflorae-Quercetum, 4 – *Rubus hirtus* agg.-*Quercus petraea* agg. community, 5 – Aceri-Carpinetum, 6 – Dentario bulbiferae-Fagetum, 7 – Dryopteris filix-mas-*Abies alba* community, 8 – Carici pilosae-Fagetum, 9 – Stellario-Alnetum glutinosae, 10 – Festuco heterophyllae-Quercetum, 11 – *Poa nemoralis*-Quercetum dalecham-pii, 12 – *Poa scabrae*-Quercetum, 13 – *Luzulo nemorosae*-Fagetum, 14 – *Luzulo albidae*-Quercetum petraeae.

close relation to the Pannonian oak-hornbeam forests on eutrophic soils (*Primulo veris*-Carpinetum association).

Cluster 3: Melico uniflorae-Quercetum petraeae

The mixed oak-hornbeam forests are formed by *Quercus petraea* agg. in the tree layer, less often also by *Carpinus betulus* and *Q. cerris*. They grow on gentle slopes with warmer and drier microclimate. The shrub layer with low coverage is usually well developed. The species composition of the herb layer changes depending on the site conditions (nutrient availability and soil moisture), but the prevailing species are mostly the diagnostic taxa of the Carpinion betuli alliance and the Fagetalia order (*Melica uniflora*, *Lathyrus vernus*, *Glechoma hirsuta*, *Galium schultesii*, *Alliaria petiolata*, *Veronica chamaedrys*, *Geum urbanum*, *Clinopodium vulgare*, *Stellaria holostea*, *Moehringia trinervia*, *Campanula rapunculoides*). This floristically medium-rich community represents the transition types to subxerophilous oak forests.

Cluster 4: *Rubus hirtus* agg.-*Quercus petraea* agg. community

The community includes broad-leaved mesophilous forests with dominance of *Rubus hirtus* agg. Distribution is concentrated on flat areas and gentle slopes. The tree layer is created by *Quercus petraea* agg., primary accompanied by *Carpinus betulus* and *Fagus sylvatica*, locally by *Abies alba*. The shrub layer is usually represented by the dominant *Corylus avellana*. The herb layer displays a significant number of species with affinities to mesic habitats (*Ajuga reptans*, *Carex digitata*, *C. pilosa*, *C. sylvatica*, *Fragaria vesca*, *Geranium robertianum*, *Mycelis muralis*, *Oxalis acetosella*, *Senecio nemorensis* agg., *Viola reichenbachiana*). The ferns enrich the floristic spectrum, but species of Fagion sylvaticae alliance can also be found. A higher frequency of nutrient-demanding species supports a classification of these forests within the Carpinion betuli alliance.

TABLE 2. Syntaxonomical synopsis of forest vegetation units in the presented area.

Quercetea robori-petraeae Br.-Bl. et R. Tx. ex Oberd. 1957
 Quercetalia roboris R. Tx. 1931
 Genisto germanicae-Quercion Neuhäusl et Neuhäuslová-Novotná 1967
 Luzulo albidiae-Quercetum petraeae Hiltzer 1932

Quercio-Fagetea Br.-Bl. et Vlieger in Vlieger 1937
 Fagetalia Pawłowski in Pawłowski et al. 1928
 Alnion incanae Pawłowski in Pawłowski et al. 1928
 Stellario-Alnetum glutinosae Lohmeyer 1957
 Carpinion betuli Issler 1931
 Festuco heterophyllae-Quercetum Neuhäusl et Neuhäuslová-Novotná 1964
 Carici pilosae-Carpinetum Neuhäusl et Neuhäuslová-Novotná 1964
 var. typicum
 var. Poa nemoralis
 Melico uniflorae-Quercetum petraeae Gergely 1962
 Rubus hirtus agg.-Quercus petraea agg. community
 Tilio-Acerion Klika 1955
 Aceri-Carpinetum Klika 1941
 Fagion sylvaticae Luquet 1926
 Carici pilosae-Fagetum Oberd. 1957
 Dentario bulbiferae-Fagetum Zlatník 1938
 Dryopteris filix-mas-Abies alba community
 Luzulo-Fagion Lohmeyer et R. Tx. in R. Tx. 1954
 Luzulo nemorosae-Fagetum Meusel 1937
 Quercetalia pubescenti-petraeae Klika 1933
 Quercion confertae-cerris Horvat 1954
 Poo nemoralis-Quercetum dalechampii Šomšák et Háberová 1979
 Poo scabrae-Quercetum (Magyar 1933) Neuhäusl et Neuhäuslová-Novotná 1964

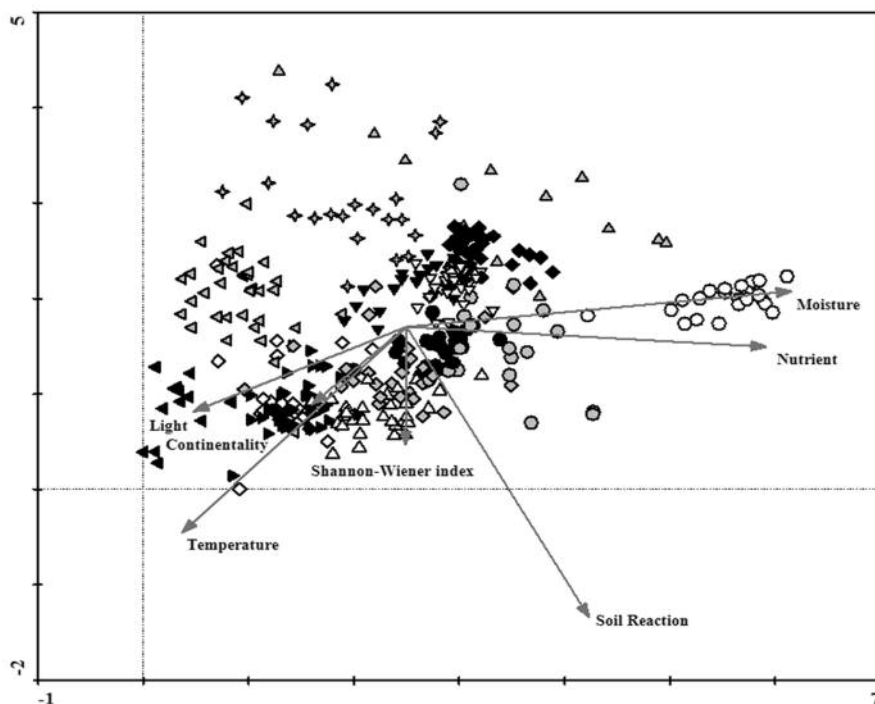


Fig. 3. Detrended correspondence analysis (DCA) ordination diagram of the forest vegetation relevés from the Štiavnické vrchy Mts (length of gradient 6.113; eigenvalues of the first two axes are 0.727 and 0.484; total inertia 13.956). Ellenberg indicator values for relevés and Shannon-Wiener index diversity were used as supplementary variables. Correlation coefficients between first two axes and environmental variables: Light (-0.738 and -0.040), Temperature (-0.757 and 0.483), Continentality (-0.423 and -0.066), Moisture (0.954 and -0.098), Soil reaction (0.204 and 0.729), Nutrients (0.920 and 0.101) and Shannon-Wiener index (-0.152 and 0.021). Black circles (cluster 1), grey diamonds (cluster 2), white up-triangles (cluster 3), black down-triangles (cluster 4), grey circles (cluster 5), black diamonds (cluster 6), grey up-triangles (cluster 7), white down-triangles (cluster 8), white circles (cluster 9), white diamonds (cluster 10), black right-triangles (cluster 11), black left-triangles (cluster 12), stars (cluster 13), grey left-triangles (cluster 14). For the explanation of cluster numbers see Table 1.

Cluster 5: Aceri-Carpinetum

The thermophilous maple-hornbeam ravine and slopes forests occupying stony slopes or screes are characterised by a considerable species diversity of the tree layer. The mesophilous tree species (*Carpinus betulus*, *Tilia cordata*, *Acer pseudoplatanus* and *Fagus sylvatica*) prevail, whereas *Fraxinus excelsior* and *Acer platanoides* are individually admixed. Due to debris on surface, the shrub layer is weakly developed. A peculiar feature of the herb layer is a high proportion of nitrophilous species indicating favourable

humification (e.g. *Galeobdolon luteum* agg., *Mercurialis perennis*, *Glechoma hirsuta*, *Alliaria petiolata*, *Geranium robertianum*). Species of the Fagetalia order such as *Galium odoratum*, *Viola reichenbachiana*, *Dentaria bulbifera*, *Mycelis muralis* and *Dryopteris filix-mas* are also present. The percentage cover of the grasses *Melica uniflora* and *M. nutans* is generally low.

Cluster 6: Dentario bulbiferae-Fagetum

The mesotrophic closed canopy beech communities occurring on gentle slopes with deep siliceous soils are

species-poor and two-layered forests. The physiognomy of the tree layer is determined by *Fagus sylvatica*. Other woody species (*Carpinus betulus* and *Abies alba*) are less frequent. Except the dominant *Dentaria bulbifera*, the herb layer is mostly enriched by shade-tolerant species of the Fagetalia order (*Actaea spicata*, *Dryopteris filix-mas* and *Galium odoratum*). Several species including *Geranium robertianum* and *Mycelis muralis* indicate mesic and relatively base-rich habitat.

Cluster 7: *Dryopteris filix-mas*-*Abies alba* community

These stands mostly occur on the sites of natural beech forests that occupy the northern slopes. The recent tree species composition is markedly affected by human activities as exploitation of biomass and the following introduction of coniferous trees. The tree layer is built up of *Abies alba* with scattered occurrence of *Fagus sylvatica* and *Picea abies*. The nutrient-demanding species and flora elements of the Fagetalia order (*Galium odoratum*, *Senecio nemorensis* agg., *Dryopteris filix-mas*, *Mycelis muralis*) are constant components of the species-poor herb layer. The common presence of nitrophilous species such as *Cardamine impatiens*, *Geranium robertianum*, *Impatiens noli-tangere* and *Mercurialis perennis* indicates the good mineralization of humus. Apart from *Prenanthes purpurea*, mountain species are absent. Consequently, the floristic composition suggests their assignment to the Fagion sylvaticae alliance.

Cluster 8: *Carici pilosae*-Fagetum

Sedge mesophilous beech forests represent the typical vegetation of the Carpathian submontane belt. They are distributed on moderate slopes, their foothills or flat ridges areas; the *Carici pilosae*-Carpinetum association on warmer sites in colline belt replaced them. *Fagus sylvatica* is the dominant species of the tree layer; *Abies alba*, *Carpinus betulus* and *Quercus petraea* agg. are sporadically admixed. The overall physiognomy of the herb layer varies according to the canopy openness. It is mostly formed by dominant *Carex pilosa* which is accompanied by species of the Fagetalia order (e.g. *Dryopteris filix-mas*, *Pulmonaria officinalis* agg., *Viola reichenbachiana*).

Cluster 9: *Stellario*-*Alnetum glutinosae*

The riparian alder forests of nutrient-rich sites growing along small brooks in the colline belt belong to ecologically and floristically well-differentiated communities. The usually three-layered stands are most often created by *Alnus glutinosa* in the tree layer. The shrub layer is primarily formed by *Acer campestre* and *Sambucus nigra* with a frequent admixture of more hygrophilous shrub *Euonymus europaeus*. The intensity and the character of floods are reflected in their floristic combination. Consequently, the species-rich herb layer encompasses both hygrophytes and nitrophytes (e.g. *Aegopodium podagraria*, *Festuca gigantea*, *Impatiens noli-tangere*, *Stellaria nemorum*, *Stachys sylvatica*) together with spring species (*Cardamine amara*, *Carex remota*, *Chrysosplenium alternifolium*). Species of the Calthion alliance including *Poa trivialis* and *Caltha palustris* are distinctive.

Cluster 10: *Festuco heterophyllae*-Quercetum

The species-rich oak forests with *Festuca heterophylla* represent marginal community of the Carpinion betuli

alliance; they are related on flat ridges in the colline belt. The clear dominance of *Quercus petraea* agg., locally with presence of *Q. cerris* and *Carpinus betulus* in the tree layer along with appearance of shrubs (*Ligustrum vulgare*, *Crataegus monogyna*, *Acer campestre*) are distinguished patterns of these stands. The herb layer is dominated by *Poa nemoralis* in most cases, seldom also by *Melica uniflora* or *Luzula luzuloides*. The typical aspect is determined by the mesophilous herbs (e.g. *Ajuga reptans*, *Galium schultesii*, *Lathyrus vernus*, *Stellaria holostea*, *Veronica chamaedrys*, *Viola riviniana*), but acidophilous vascular plants, such as *Genista tinctoria*, *Hieracium murorum*, *H. sabaudum* and *Veronica officinalis* are also constant. The drier and warmer microclimate allows presence of several species of the Quercetalia pubescenti-petraeae order (*Astragalus glycyphyllos*, *Clinopodium vulgare*, *Lathyrus niger* and *Melittis melissophyllum*) indicating its close relationship to the thermophilous oak communities.

Cluster 11: *Poo nemoralis*-Quercetum dalechampii

The moderately opened canopy and floristically-rich oak communities are found commonly in drier habitats with shallow and nutrient-poor soils, mostly on silicates. The stands are characterised by prevalence of *Quercus petraea* agg. (rarely by *Q. cerris* and *Carpinus betulus*) in the tree layer and medium-tall grass *Poa nemoralis* in the herb layer. The development of shrubs is influenced by the intensity of forest management. The constant feature of the understorey vegetation is the occurrence of numerous mesophilous species (e.g. *Dactylis polygama*, *Galium schultesii*, *Melica uniflora*, *Cruciata glabra*, *Stellaria holostea*, *Campanula rapunculoides*, *Veronica chamaedrys*) together with acidophilous (*Genista tinctoria*, *Hieracium murorum*, *Luzula luzuloides*) and thermophilous oak species (*Astragalus glycyphyllos*, *Cardaminopsis arenosa*, *Clinopodium vulgare*, *Digitalis grandiflora*, *Hylotelephium maximum*, *Securigera varia*, *Vincetoxicum hirsutiflorum*). The association is widespread all over the Štiavnické vrchy Mts, mainly in the submontane belt.

Cluster 12: *Poo scabrae*-Quercetum

The thermophilous opened canopy oak forests with *Poa pannonica* subsp. *scabra* inhabit small stands particularly on south-facing slopes in the colline belt. The tree layer is created by *Quercus cerris* and *Q. petraea* agg., while *Ligustrum vulgare* frequently appears in the shrub layer. The heliophytes and acidophytes (e.g. *Pilosella bauhini*, *Poa angustifolia*, *P. nemoralis*, *Veronica officinalis*) are typical components of herb layer. The floristic spectrum includes generalists of dry grasslands as well as forest fringes (e.g. *Tithymalus cyparissias*, *Festuca rupicola*, *F. valesiaca* agg., *Galium verum*, *Poa compressa*, *Teucrium chamaedrys*). The abundant group of mesophilous species may enter to the communities on the contact zone with the Carpinion betuli vegetation. The centre of distribution of this species-rich community is in the warmest margins of region.

Cluster 13: *Luzulo nemorosae*-Fagetum

The acidophilous beech forests comprise species-poor stands lying on temperate slopes especially in the submontane belt. They are characterized by dominance of *Fagus sylvatica* with constant admixture of *Quercus petraea* agg.

Other woody species such as *Carpinus betulus* and *Abies alba* are only accompanying. The occasionally developed shrub layer is made up only with younger individuals of trees. The association is floristically well differentiated within the Fagetalia order through the presence of some oligotrophic elements (*Hieracium murorum*, *Luzula luzuloides*, *Polypodium vulgare*, *Vaccinium myrtillus*, *Veronica officinalis*).

Cluster 14: Luzulo albidiae-Quercetum petraeae

The relatively species poor acidophilous oak forests are characterised by the simple vertical structure, the regular occurrence of oligotrophic flora elements and the admixture of thermophilous species. The tree layer is usually composed of *Quercus petraea* agg., sometimes accompanied by *Carpinus betulus*. The grassy physiognomy of herb layer results from predominance of *Luzula luzuloides*, *Avenella flexuosa* and *Calamagrostis arundinacea*. Stands are confined to small patches, primarily at the ridge parts and convex spots on the shallow soils.

Ordination

The scatter plot of DCA, based on individual relevés, shows the distribution of particular vegetation types along the first and second ordination axis. DCA revealed that ten of the fourteen forest vegetation types can be differentiated along the first two ordination axes (Fig. 3). The main compositional gradient along the 1st axis can be explained by positive correlation of the moisture and nutrient; the negative correlations are ordered along the second axis with respect to soil reaction and temperature. Distribution of relevés in the ordination space shows a continuous ecological transition among the associations. The right part of the scatter-plot is occupied by relevés of the Stellario-Alnetum glutinosae, which occur in the nutrient-rich soils along streams with intense impact of human activities. Duo to their specific ecological conditions such as presence of wet soils together with numerous hygrophilous and nitrophilous species, they are best distinguished within the presented vegetation types. Vegetation plots of the Luzulo albidiae-Quercetum petraeae are situated on the opposite end of the ordination diagram. The stands are developed on shallow acidic soils with low nutrient content, and their relation to warmer places of southern slopes with more arid microclimate is marked. Acidophilous beech forests (Luzulo nemorosae-Fagetum) dominate the left upper part of the ordination space, being well differentiated from the Luzulo albidiae-Quercetum petraeae, which occurs on the mineral poor soils of the northern slopes in the submontane belt. The thermophilous open dry oak forests (Poo scabrae-Quercetum) have the highest requirements of the light conditions. The central part of the scatter-plot is occupied by the Carici pilosae-Carpinetum, partially by *Rubus hirtus* agg.-*Quercus petraea* agg. community and the Carici pilosae-Fagetum. Appearance of common oak-hornbeam and beech forest species (e.g. *Carex pilosa*) is associated with the above-mentioned communities. Similar relationship of these forests to the first two axes is conditioned by their ecological valence. The Melico uniflorae-Quercetum petraeae has a transitional position between mesophilous sedge oak-hornbeam forest and subxerophilous oak forest. This pattern is also reflected in the accepted syntaxonomical classification. The *Dryopteris filix-mas*-*Abies alba*

community belonging to the Fagion sylvaticae alliance is remarkable different, more oceanic and linked to colder places. The relevés of the Aceri-Carpinetum are positively correlated with nutrient and moisture; these edaphically conditioned ravine forests are typical for sites in lower-altitudinal areas.

Relationships between the defined associations with individual environmental factors are illustrated in figure 4. The Ellenberg indicator values for moisture are significantly different among the groups of forest stands. The riparian alder forests of Stellario-Alnetum glutinosae (cluster 9) display conspicuous relation on moist and nutrient-rich sites, while Poo scabrae-Quercetum (cluster 12) and Luzulo albidiae-Quercetum petraeae (cluster 14) prefer most xeric habitats. Furthermore, the above-mentioned oak forests also exhibit highest light requirements. Luzulo nemorosae-Fagetum (cluster 13) includes forest stands with the most acidic soil reaction.

DISCUSSION AND CONCLUSION

The deciduous forests represent the prevailing natural vegetation of temperate and submediterranean Europe (Willner et al. 2009). In Slovakia the Querco-Fagetea class is divided into nine alliances containing hygrophilous, mesophilous and (sub)xerophilous forest communities (Jarolímek et al. 2008). There is a high similarity between the national syntaxonomical concept and the structure of forest vegetation classification of Štiavnické vrchy Mts. Thermophilous oak communities related to loess and limestone (Quercion pubescenti-petraeae) or less typically to other basic rock (Quercion petraeae; Aceri tatarici-Quercion) are the only ones missing in the presented area. Acidophilous oak forests are represented with the Luzulo albidiae-Quercetum petraeae association (Quercetea robori-petraeae class). Although the dominant *Luzula luzuloides* is the common oligotrophic forest species, vegetation of the Luzulo albidiae-Quercetum petraeae is, in terms of the national classification, relatively rare. A possible explanation lies in (i) the general distribution of acidophilous oak woodlands that are less abundant eastward the Central Europe (Härdtle 2004) and (ii) the transformation of its stands to pine or larch plantations (Moravec 1998). Moreover, the lack of suitable habitats was also emphasized in the geobotanical map of Slovakia (Michalko et al. 1986), where this distinctive community of acidic substrates with an extremely low nutrient supply was not mentioned. Outside the Slovakia this community is often reported under different names. The original description of this community is from the western part of Czech Republic (Hilitzer 1932), but it has been recorded in various European countries (Pallas 1996). The acidophilous oak forests of Genisto germanicae-Quercion alliance are broadly considered to be not sufficiently known vegetation type in the territory of Slovakia. Communities classified within this alliance require syntaxonomical revision in the future. Likewise the previous community, the contemporary phytosociological data of the Stellario-Alnetum glutinosae are becoming more rare. This status is apparently caused by a large-scale reduction of habitats resulting from the direct or indirect influence of human activities, such as stream regulation and drainage. Up to now, these forests with fluctuating

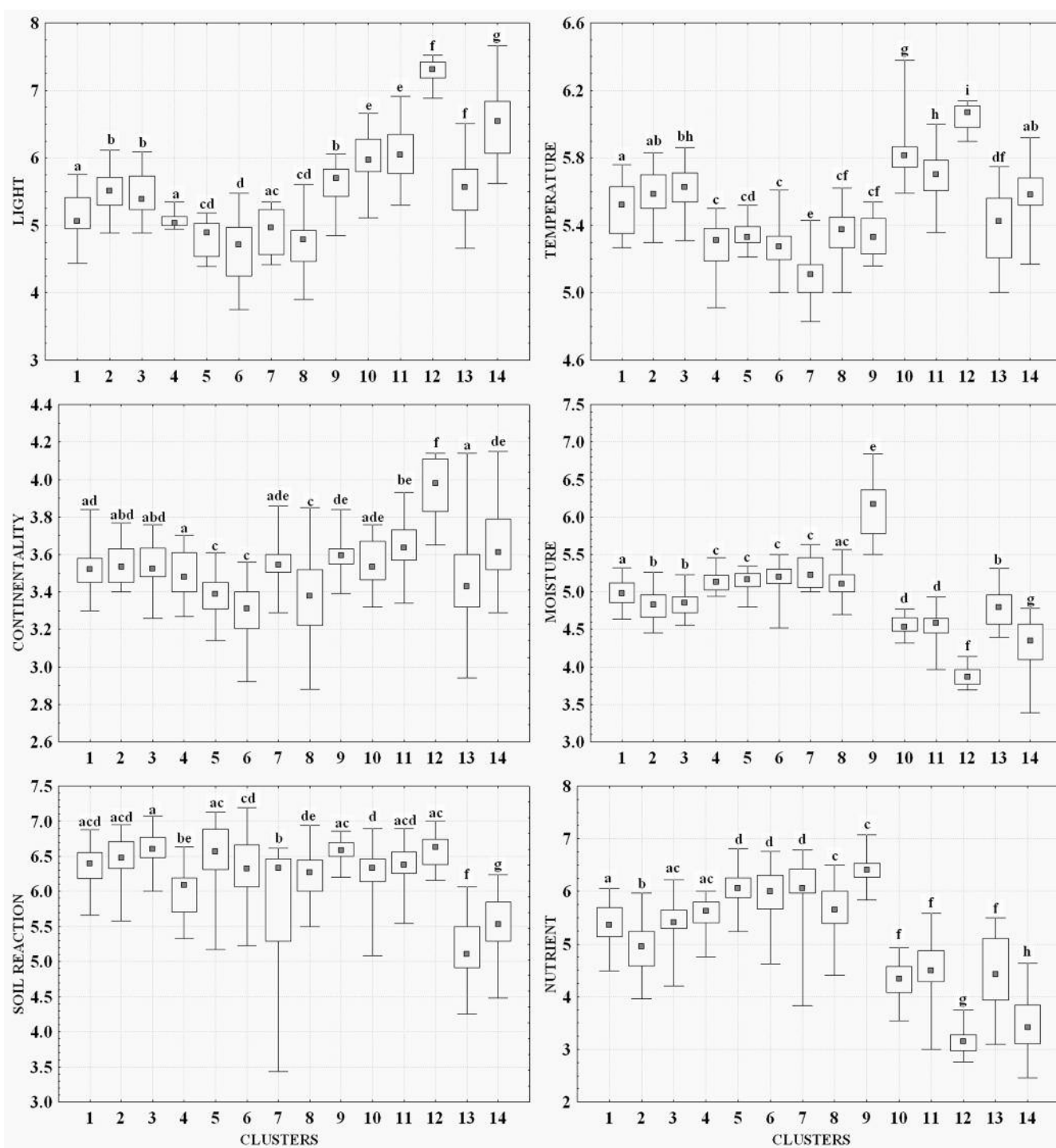


Fig. 4. Box and Whisker plots of the average Ellenberg indicator values for relevés of individual clusters 1-14. The boxes show medians and upper and lower quartiles, while the whiskers indicate the minimum and maximum values. Significant differences among clusters (one-way ANOVA and post-hoc Duncan test, $P < 0.05$) are marked by labels (a-i).

groundwater level were noticed mainly from lowlands and uplands of southern part of Slovakia (Záhorská nížina lowland, Malé Karpaty Mts, Krupinská vrchovina and Cerová vrchovina uplands, Muránska planina plateau), less often from basins and lower mountains, including Volovské vrchy, Vihorlatské vrchy and Zemplínske vrchy Mts (Mikyška 1939; Kárpáti et al. 1963; Miadok 1978).

The oak-hornbeam forests of the Carpinion betuli alliance belong to the important elements of the Carpathian vegetation. They have been intensively discussed because of their geographical and ecological differentiation (Neuhäuslová-Novotná 1964; Neuhäusl 1977; Knollová

and Chytrý 2004). Several stands of these mesic broad-leaved forests are autochthonous, but many others are developed on natural beech- and partially on oak habitats (Ellenberg 1982). The distribution centre of the Carpinion betuli communities is located in lower-altitudinal areas with subcontinental climate. These conditions are typical for many parts of Slovak volcanic mountains. The most frequently dominating community is the Carici pilosae-Carpinetum that was described as an association for the first time from Štiavnické vrchy Mts by Neuhäusl and Neuhäuslová-Novotná (1964). The geographical range of this association comprises Slovakia, the adjacent parts of

the Czech Republic (Moravia region), Austria, Hungary, Poland, Ukraine, and Romania (Moravec et al. 2000; Willner and Grabherr 2007; Onyshchenko 2010). Due to the small number of available relevés and their relatively large variability in species composition, it was not possible to distinguish the community *Primulo veris-Carpinetum* reported by Neuhäusl and Neuhäuslová (1964) from southern foothills of Štiavnické vrchy Mts and occurring also in other parts of the Pannonian region (chiefly uplands of Danube basin). The oak-hornbeam forests of *Festuco heterophyllae-Quercetum* with transitional character between the *Carpinion betuli* and *Quercion petraeae* alliances are less frequent.

There are several studies devoted to floristic differentiation patterns of central European beech forests (Klika 1936; Matuszkiewicz and Matuszkiewicz 1973; Moravec 1985, 1999; Matuszkiewicz 2000; Willner 2002; Boublík et al. 2007; Ujházyová 2007). If the markedly wide ecological amplitude of *Fagus sylvatica* and its high competitive ability are taken into account (Leuschner et al. 2006), the beech forest vegetation undoubtedly belongs to the most extended group of forest communities in the Western Carpathians. Except the acidophilous beech forests, these vegetation types represent stands of mesotrophic to eutrophic, more humid and cold habitats in comparison with the *Carpinion betuli* communities. In the studied area they were assigned to two alliances: the forests of the *Fagion sylvaticae* contain mainly nutrient-demanding species and are developed on mineral-rich soils with mull form of humus, while the forests of the *Luzulo-Fagion* are distributed on acidic soils with occurrence of typically oligotrophic species. The mesotrophic communities of the *Carici pilosae-Fagetum* and *Dentario bulbiferae-Fagetum* are floristically relatively difficult to distinguish from other Central European beech associations. The findings of the present study are in accordance with previous observations (Moravec et al. 2000; Ujházy et al. 2004), that the diagnostic species of other beech forest vegetation types were absent. Both these communities were recorded by numerous phytosociological relevés, and they are generally regarded as the most common and widespread associations of the *Eu-Fagion* suballiance in Slovakia. Natural beech forests were strongly exploited in the last centuries and their species composition was partially altered by the introduction of coniferous trees (Härdtle et al. 2005). Stands with prevailing *Abies alba* in the tree layer (*Dryopteris filix-mas-Abies alba* community; cluster 7, Table 1) occupy gentle slopes with north aspect at altitudes between 550-900 m. The herb layer is species-poor, elements of mountain flora are absent and acidic-tolerant species are scattered. Additionally to the herbs of nutrient-rich soils (*Mercurialis perennis*, *Geranium robertianum*, *Cardamine impatiens*), the group of beech forest species (*Galium odoratum*, *Senecio nemorensis* agg., *Dryopteris filix-mas*) reflects position of these forests within the *Fagion sylvaticae* alliance.

The distribution of *Fagus sylvatica* is primarily limited by longer drought periods, but it is also sensitive to late spring frosts (Bolte et al. 2007). The low soil water availability determinates its occurrence along the moisture gradient. Owing to physiological drought stress, *Fagus sylvatica* is substituted by more drought-tolerant tree species (*Q. cerris*, *Q. pubescens*, *Q. petraea* agg.) in colline belt. As a

consequence, drier habitats with stony soils are covered by subxerophilous and thermophilous forest communities. In the case of Štiavnické vrchy Mts, they can be found as part of the canopy-opened oak forests, namely the *Poo nemoralis-Quercetum dalechampii* and *Poo scabrae-Quercetum* associations. Within the range of these two communities, the stands of the *Poo nemoralis-Quercetum dalechampii* are more mesophilous and often concentrated in relatively high-altitudinal areas (400-775 m a.s.l.). In total, Carpathian subendemic tall grass *Poa pannonica* subsp. *scabra* grows on sunny and stony slopes in some types of forest and grassland vegetation. It largely occurs on southern fringes of the Western Carpathians (e.g. Pohronský Inovec, Kremnické vrchy, Štiavnické vrchy, Javorie Mts, Slovenský kras karst), in the northern part of the Hungarian Central Range as well as in Ukraine and Romania (Kliment 1999). For the territory of Slovakia, all available phytosociological relevés of *Poo scabrae-Quercetum* have been collected only within the Central Slovak volcanic mountains (Krupinská vrchovina upland and Štiavnické vrchy Mts). This peculiar community is surrounded by forests of the *Festuco heterophyllae-Quercetum* or *Quercetum petraeae-cerris* associations on mineral-rich and deep soils (Neuhäusl and Neuhäuslová 1964; Roleček 2005).

Vegetation-environmental patterns of deciduous forest are evidently scale dependent across the subcontinental part of Central Europe. Environmental variables connected with different soil and light conditions are generally significant in the determination of forest vegetation distribution at local level, whereas geographical and/or climatic gradient has a decisive role at large-scale (Ellenberg 1982; Knollová and Chytrý 2004). The results of DCA analysis supported that both moisture and soil nutrient are among the most important gradients affecting floristic composition in the study area. Significant influence of soil water supply and available nutrients on species composition of forest vegetation has been already published (e.g. Douda 2008; Leuschner and Lenzion 2009; Slezák and Petrášová 2010).

The mountain units situated on the boundary between the Carpathian and Pannonian region represent regional diversity hotspots of flora elements and plant communities. The present study underscores variability of forest vegetation in the Štiavnické vrchy Mts. Ecological range of recorded vegetation units is expressed with their assignment to the *Quercetea robori-petraeae* and *Querco-Fagetea* classes. Floristic differentiation of deciduous forests is simultaneously controlled by soil moisture and nutrient availability.

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