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CLASSIFICATION OF FOREST VEGETATION ON THE SOUTH SLOPE OF VITOSHA MOUNTAIN, WESTERN BULGARIA

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Abstract

In the last decades numerous studies have presented vegetation classifications. Some of them highly subjective, relying entirely on qualitative data, others more objective, based on quantitative information, susceptible to statistical tests. On that ground, vegetation organization was viewed either as composed of recognizable community units or as a continuum with gradually changing composition, provoking continuous debate. This study represents numerical classification of forest vegetation on the south slope of Vitosha Mountain, Western Bulgaria. We hypothesized that described community types will not hold the statistical test for their consistence. Stratified sampling procedure and nested 0.1 ha sampling plots were used. Obtained field samples were classified with TWINSPAN clustering method. Resulting groups were tested for statistical difference for the most important environmental gradients and vegetation variables. 114 field samples were collected and grouped in nine forest community types. Six of them are dominated by *Fagus sylvatica* L. Two are coniferous forests (plantations), where *Pinus nigra* Arn. and *Pinus sylvestris* L. are most abundant. The last one is mixed oak forest. Beech forests predominate at higher elevation, in more mesic habitats and on steeper slopes. Most of the beech communities have significantly higher canopy closure and lower shrub and herb strata cover. Mixed oak forest and coniferous communities are richest in almost all life and growth forms. They are more susceptible to invasion, because of their proximity to populated areas and severe disturbance regime, therefore richer on alien species. Mixed oak forest and coniferous communities also have significantly higher species richness per 0.1 ha and 1 m^2, as well as higher alpha diversity and evenness. All forest communities in the studied region are poor in rare, protected and endemic species. Despite the significant differences between some of the *Fagus sylvatica* communities and the mixed forests, they are generally unrecognizable statistically from each other. Therefore, the vegetation of the studied area is considered as having continuum organization. Numerical classification, relying on quantitative and statistically testable data, will objectify and simplify vegetation understanding and improve future management activities.

Key words: numerical classification, TWINSPAN, forest vegetation, community types.

Introduction

The question about vegetation organization, whether it is composed of recognizable community units or as a continuum with gradually changing composition, has a long history of debate between the different ecology schools (Austin 2005).

Communities are assumed to have consistent floristic composition, uniform physiognomy, occupy unique environment, and occurring in several locations. On the other hand, continuum concept states that each species has individualistic response to biotic and abiotic conditions and when vegetation is viewed in the context of environmental gradients, its composition and structure changes continuously (Austin 2005).

Cluster analyses in vegetation ecology are used for classification of samples, species or environmental variables. Despite the continuous nature of the data, classification is a method for identification of cluster among the raw data and helps to reveal the hidden data structure, i.e. continuum division on system of provisional types or classes. The basic objectives in classification studies are: 1) gathering information on species coexistence (hidden data structure); 2) establishing of community types in descriptive investigation (vegetation mapping); and 3) revealing the relationship between vegetation and environmental gradients through analysis of delineated groups in the context of environmental variables (van Tongeren 2004).

In the last 20 years several classifications of beech forests on the Balkans have been presented, basically from neighboring Serbia. These are concerned mainly with syntaxa naming, and their rearrangement in hierarchical syntaxonomical scheme, as well as revision of already proposed names (Tzonev et al. 2006). Several floristic beech forest analyses have been carried out on the Balkan Peninsula nowadays. They cover the territories of Macedonia (Dzwonko et al. 1999, Dzwonko and Loster 2000), Greece (Dzwonko and Loster 2000, Bergmeier and Dimopoulos 2001, Tsiripidis et. al. 2007b) and Bulgaria (Tzonev et al. 2006).

Beech forests in Bulgaria are broadly distributed and cover approximately 17 % (together with *Fagus orientalis* Lipsky forests) of the forested territory (Garelkov and Stiptsov 1995). Existing studies have mainly local scale and most of them follow Russian school methodology (Tzonev et al. 2006). Recently, attempts for phytosociological classification of beech communities have been made (Pavlov 1998), as well as forest typological ones (Garelkov and Stiptsov 1995). In the last years, local studies using Braun-Blanquet approach, have been realized too (Pavlov and Dimitrov 2003, Dimitrov and Glogov 2003).

Previous classification studies were burdened with high extent of subjectivity. First, subjectivity comes from the employed field method and sampling procedures. Second, the type of gathered information (mainly qualitative) and its further processing results in unsuitable for statistical tests community types. Development of numerical classification methods though is solving this issue. Unfortunately, these methods are weakly known or reluctantly used by great number of ecologists.

Despite the numerous botanical and ecological studies so far they have not brought an integrated picture about the pattern (composition and structure) of the studied vegetation. This particular territory has been chosen because it is weakly known and relatively spared from human disturbances nowadays.

In contrast to the previous studies, setting of sample plots in the current investigation is based not on intuitively identification of plant associations, but rather on the relationship of the samples with environmental gradients. Following this way, the current study aims to reveal the relationship between vegetation and environment on the basis of species population response to environmental gradients (Whittaker 1956), considering it more objective and adequate.

The current study is an attempt to expand and clarify the accumulated knowledge on the basis of more objectively gathered samples, quantitative data and statistical test of the described community types. Quantifying and objectifying of classification process will facilitate vegetation understanding in terms of its composition and structure and will improve the future management of the area. This paper also tries to answer the question whether plant communities are clearly recognizable units in the environmental space or part of the vegetation continuum, indistinguishable from each other? Answering this question will bring support to one of the competing paradigms and help clarifying vegetation ecology theory.

Study area

Vitosha Mountain is located in Western Bulgaria. Since it is a relatively young mountain (Shipkova 2005), it is characterized with compactness and well expressed elevation gradient. The mountain has steep slopes and variable expositions. Its vegetation has varied and rich species composition. Most of the mountain's territory is declared Nature Park by the Bulgarian legislation. The current study embraces the south slope of the mountain, covering all forested habitats. GPS coordinates of that territory are between N42°32' E23°09' and N42°26' E23°21'. This area covers 118 km^2.

Vitosha Mountain is formed during the late Cretaceous and early Tertiary period. The most widely distributed bedrocks are Paleozoic sediments and early Mesozoic sediments. The highest peak is Cherni peak reaching 2290 m (Shipkova 2005).

Mean annual rainfall is between 650–700 mm in the mountain's base and around 1000 mm in the highest parts. Annual rainfall distribution has one peak and most of the precipitation falls in April-July period. The most arid period is late summer and early autumn. The highest parts of the mountain (above 1800 m) almost all year round are exposed to strong southwest and west winds, reaching up to 8 m•s^{-1} (Koleva 2005).

Vitosha Mountain has a great variety of soils. The lowest mountainous parts are dominated by *Chromic Cambisols*. In the elevation belt 1400–1750 m the most widely distributed are *Cambisols*. In the highest parts of the mountain (1750–1900 m) *Mollic Cambisols* prevail. In the subalpine and alpine zones *Umbrosols* are formed. *Fluvisols* are present along the lower river beds (Malinov 2005).

Vitosha's natural vegetation was developed during the last ice age. According to palaeobotanical studies the floristic composition of the territory has not changed essentially. Substantial vegetation alteration took place later, mainly due to human activity. During the 15–19 centuries, mining, primitive metallurgy and nomadic cattle-breeding were developed in the region. The need of wood materials led to forest clearing over most of the mountain. Finding of pasture for the numerous herds necessitated setting of periodical fires in the high mountainous parts. This resulted in almost complete destruction of the natural vegetation. These factors, together with the steep relief and the exposed to heavy rain soils, led to developing of erosion processes and subsequent degradation of the natural habitats (Meshinev 2005).

Material and Methods

Sampling

In the summers of 2008 and 2009, systematically, along a preliminary drawn vertical transects on the south slope of Vitosha Mountain, 114 0.1 ha (20x50 m) vegetation plots were laid (Figure 1). Totally nine transects, following the main and intermediate Earth directions (E, EES, ES, SSE, S, SSW, SW, SWW, and W) were set. Transects start at around 900 m and reach the tree line. The plots were set at uniform distance of 50 m altitude along the vertical transect. Starting position of transects is randomly chosen after numbering of five possible starting points and pulling one of them. Sampling places are located in such a way so they can cover the maximum variety of expositions, slope inclinations, slope topography and elevations. There is no need for sampling sites representing some obvious or assumed species association, neither transition between them. The exact sampling sites are chosen visually keeping the requirement for vegetation homogeneity, i.e. they should not be located in the forest periphery or in large open forest patches. Forest communities under intensive human influence (intensive livestock grazing or logging) were avoided. In order to avoid spatial autocorrelation the distance between neighboring sampling plots was at least 200 m.

On the place chosen, 50 m plastic tape was laid on the ground, perpendicular to the topographic horizontals. From the two ends of the tape toward its two sides, perpendicular to it, 10 m distance was meas-

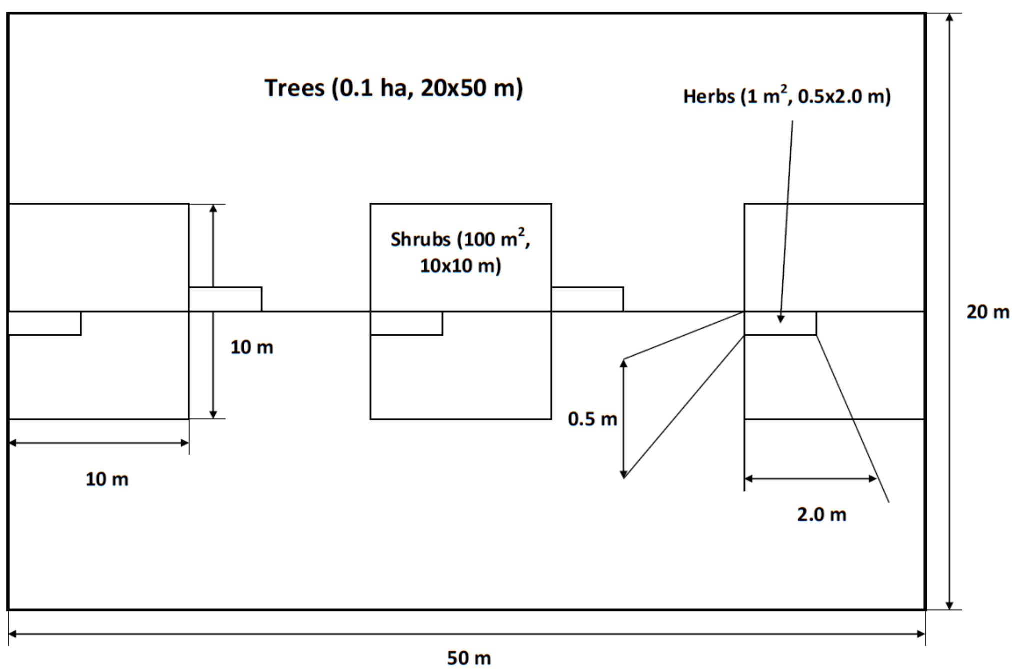

Fig. 1. Nested sampling plot, modified from Whittaker (1956, 1960).

ured and metal stakes were fixed into the ground. Obtained in this way rectangular plot has 20x50 m sides (Figure 1). First, total tree stratum cover was measured visually in percents. Then diameter of all tree and shrub stems >1 cm at breast height (≈1.30 cm) was measured by species and grouped by diameter classes.

In the 0.1 ha plot, along the tape, at interval of 10 m (as it shown on Figure 1), three quadrate 10x10 m subplots were set. In these subplots, total cover of shrubs <1 cm at breast height or less than 2 m high, was measured visually and then by species. Along the tape again, at intervals of 8 m, five sub subplots 0.5x2 m (with the long side parallel to the tape) were set. Whether to be on the left or right side of the tape was determined by throwing a coin. In these sub subplots, total cover of herb stratum was measured visually and then by species also. Depending on the spatial heterogeneity of the herb stratum, in some of the plots between 2 and 10 sub subplots with an area of 1 m^2 were laid, but generally five, as shown on Figure 1. Finally, the whole 0.1 ha sampling plot was searched again and on the species not recorded already was given minimal score for the Importance Value (IV).

IV is a generalized expression of the quantitative share of different species in the plant communities. It combines measured on the field particular values like cover, density, frequency, biomass etc. of the plant species. IV calculation for the different species in all vegetation strata was done in the following way:

Tree and shrub stems >1 cm at breast height (canopy stratum):

IV=relative density (number of individuals) per 0.1 ha.

Tree and shrub stems <1 cm at breast height (or less than 2 m height) (shrub stratum):

IV=mean cover per 100 m^2 +frequency$\cdot 2^{-1}$.

Trees, shrubs and herbs (herb stratum):

IV=mean cover per 1 m^2+frequency$\cdot 2^{-1}$.

IVs for a given species from different strata were summed. Cover was estimated visually in percents (0–100 %) and frequency was calculated by the following formula:

$$C_f = \frac{a}{b}.100(\%), \qquad (1)$$

where:

a=number of subplots (for shrub stratum) or sub subplot (for herb stratum), where the species was present;

b=total number of sampling subplots or sub subplots.

In each 0.1 ha plot elevation was measured with barometric altimeter. At the beginning of the tape, the exact coordinates were measured with GPS (General Pointing System) device. Slope inclination in each 0.1 ha plot was measured in degrees with clinometer. Exposition was determined with GPS compass. Gathered in this way data were used directly in the analyses or were categorized.

Expositions were categorized in the following way (Whittaker 1960): 1=N, NE, NNE, deep moist ravines near temporary or permanent streams; 2=EEN, NNW; 3=E, NW; 4=EES, WWN; 5=SE, W; 6=SSE, WWS; 7=S, SW, SSW, ridges and hills. Categorized in this way the expositions are arranged from the moistest to the most xeric. Slope topography was categorized in similar manner: 1=concave slope; 2=flat slope; 3=convex slope. Measured slope inclination and elevation were directly used in the analyses without further change.

Unidentified on the field individuals were taken as herbarium specimens and transported to the University of Forestry's laboratory for species identification. Nomenclature and systematic follow Jordanov (1989) and Kojuharov (1995), as well as Delipavlov (1992) and Javorka (1975).

Classification

In the current study TWINSPAN classification (Two Way INdicator SPecies Analysis) (Hill 1979) was used. The basic idea in TWINSPAN is that each group of samples can be identified on the basis of indicator species, i.e. such species that prevail at the one side of the dichotomy. TWINSPAN gives the opportunity of processing qualitative and quantitative data. The software TWINSPAN not only classifies the samples but produces two-way ordered data table (samples x species). In the construction of the TWINSPAN table, two-way weighted average algorithm of Correspondence Analysis (CA) (Hill 1973) was used. Combination of the two has made the method one of the most popular among the vegetation ecologists nowadays (van Tongeren 2004).

As a measure of relative homogeneity of the community types, index of homotoneity was used (Curtis 1959). Curtis (1959) defined it as the sum of frequency of the dominant species divided by the sum of frequency of all species and multiplied by 100, i.e. it is the average frequency of dominant species. Dominant species (sensu Curtis 1959, Peet 1981) were specified by calculation of frequency of all species in given community type. Then, the mean species number in that community type was calculated [this is the species density, *d*, of Curtis (1959)]. Dominant species are these *d* species with greater frequency. Homotoneity index has the advantage of relatively independency of the sample number in the community type, because species density reaches constant after the first few samples (Peet 1974, Peet 1981).

Species Diversity

We estimated species diversity using the heterogeneity index of Hill (1973) N_2. It is less dependent on species number and sample size (Baev and Penev 1995). Moreover, it is simple and easy for interpretation (Peet 1974). The index was calculated as follows:

$$N_2 = (\sum_i p_i^2)^{-1}, (i = 1,2,3\ldots,S), 0 \le N_2 \le S, \quad (2)$$

where, p_i is the sample proportion, belonging to i-th species.

The second diversity aspect, used in this study, is evenness, which Pielou (1975) defines as the relationship of diversity index and the maximum diversity value, which the sample can have, given the same species number. Hill's (1973) index of evenness *E'* was used. According to Peet (1974) it depends only on the diversity indexes and does not depend on the sample size. It is a "new and useful way for species diversity investigation" (Peet 1974). It was calculated as follows:

$$E' = \frac{N_2}{N_1} = \frac{\left(\sum_i p_i^2\right)^{-1}}{exp\left[-\sum_i p_i ln(p_i)\right]}, \quad (3)$$

where, p_i is the sample proportion, belonging to i-th species.

Community types were compared and tested for statistically significant difference with nonparametric (when the distribution was not normal) Kruskal-Wallis ANOVA on Ranks, Dunn's test. When the distribution was normal we used One-Way ANOVA, Holm-Sidak method. In all analyses the significance level was $P \leq 0.05$. The following software products were used: STATISTICA, version 8.0 (StatSoft 2007), TWINSPAN for Windows (Hill and Šmilauer 2005), version 2.3, CANOCO for Windows, version 4.51 (ter Braak and Šmilauer 2003), CanoDraw for Windows, version 4.1 (Šmilauer 2003), SigmaPlot for Windows, version 11.0 (Systat Software Inc. 2008).

Results

In the summers of 2008 and 2009, 114 0.1 ha sampling plots were set. 353 vascular plant species were found. Nine of these were not determined to species level, because of unsuitable phenological phase or missing parts and have been excluded from the following analyses.

DCA (Detrended Correspondence Analysis) (Hill and Gauch 1980) gradient length of forest vegetation data was 4.574 SD units, thus justifying employment of TWINSPAN method with its CA division algorithm. Analysis was carried out with the default options checked. Three levels of division were used because they gave us the desired combination between detail and interpretation capability (Table 1). TWINSPAN classification resulted in eight community types. One of the TWINSPAN groups (containing samples from pine plantations) was divided additionally into two community types (*Pinus sylvestris-Fragaria vesca* and *Pinus nigra-Crataegus monogyna*) because they had different dominant tree species and were significantly different in some environmental and vegetation variables. Mean species number per 0.1 ha was 34.4 species, and 4.4 m^{-2}. In six of all forest communities, *Fagus sylvatica* was the dominant tree species. In the other three community types *Pinus sylvestris, Pinus nigra, Quercus cerris* L.*, Quercus petraea* (Matt.) Liebl., *Carpinus betulus* L.*, Crataegus monogyna* Jacq. and *Cornus mas* L. dominated.

Studying the Wisconsin vegetation, Curtis (1959) found that homotoneity varied between 34.5 and 70.3. Peet (1981) studied geographically restricted and less diversified forest communities and found that their homotoniety varies between 54.5 and 78.5. We obtained values from 52.3 to 70.5 (Table 2). Most homogenous are coniferous forests and *Fagus sylvatica-Hepatica nobilis* community type.

TWINSPAN analysis of the studied vegetation showed compositional gradient beginning from mesic beech forest (from left to right in Table 1), through submesic and subxeric beech communities, to subxeric and xeric coniferous forest, and xeric oak community. Mesic beech forest was represented by *Fagus sylvatica-Hepatica nobilis* and *Fagus sylvatica-Physospermum cornubiense*. Submesic beech forest included *Fagus sylvatica-Gallium odoratum, Fagus sylvatica-Luzula luzuloides* and *Fagus sylvatica-Festuca drymeja*. The last beech community, *Fagus sylvatica-Corylus avellana-Brachypodium pinnatum*, had more xeric nature. *Pinus sylvestris-Fragaria vesca, Pinus nigra-Crataegus monogyna* and *Quercus cerris-Cornus mas* forest communities were also located in the xeric part of moisture gradient.

Forest Community Type Description

Community names are combination of two or three species names with greatest Importance Value (Table 1). Most often, these were the dominant species in the different vegetation strata. In this section detailed description of community types is presented.

Fagus sylvatica-Hepatica nobilis (*n*=8). Communities of this type are distributed at mean elevation of 1214±30.7 m on steepest slopes with north, northeast and northwest exposition. Slope topography is variable, but mainly with flat and convex form. These forests prefer mesic habitats. Most important species are *Acer campestre* L., *Carpinus betulus, Acer pseudoplatanus* L., *Acer platanoides* L. and *Fraxinus ornus* L. Dominant shrubs are *Cornus mas*, *Crataegus monogyna, Lonicera xylosteum* L., *Corylus avellana* L. and *Rosa canina* L. Herb species with highest IV are *Physospermum cornubiense* (L.) DC., *Lamiastrum galeobdolon* L., *Campanula rapunculoides* L., *Viola riviniana* Rchb., *Galium odoratum* (L.) Scop., *Lathyrus vernus* Bernh. and *Cruciata glabra* (L.) Ehrend. Mean species richness per 0.1 ha is higher compared to the other beech communities. That applies to the mean species richness per 1 m^2 also. This community type has relatively high species diversity and evenness.

Fagus sylvatica-Physospermum cornubiense (*n*=12). These communities are distributed at mean elevation of 1268±19.6 m, mainly on steeper north and northwest facing slopes, in mesic and submesic habitats. Slopes have variable topography, but basically with flat and concave surface. Tree species with highest importance are *Carpinus betulus, Populus tremula* L., *Prunus avium* L., *Acer campestre, Crataegus monogyna* and *Prunus cerasifera* Ehrh. The shrubs and herbs are poorly represented. Most important are shrubs like *Rosa canina* and *Corylus avellana,* and herbs like *Helleborus odorus* Waldst. & Kit., *Viola riviniana, Luzula luzuloides* (Lam.) Dandy, *Lamiastrum galeobdolon, Melica uniflora* Retz., *Galium odoratum, Mycelis muralis* (L.) Dumort. and *Hepatica nobilis* Mill. These forests are poorer on species at the two scales. Diversity and evenness indexes are lesser too.

Fagus sylvatica-Galium odoratum (*n*=13). These forests are distributed at mean elevation of 1433±39.1 m, mainly on flat and concave steep slopes with northern and eastern exposition and mesic habitat conditions. Dominant trees, together with the *Fagus sylvatica*, are *Picea abies* (L.) Karst., *Pinus sylvestris, Tilia platyphyllos* Scop. and *Sorbus aucuparia* L. The herbs are well represented. The most important species are *Oxalis acetosella* L., *Lamiastrum galeobdolon, Aremonia agrimonoides* (L.) DC., *Mycelis muralis, Luzula luzuloides* and *Dryopteris filix-mas* (L.) Schott. With the greatest importance values among the shrubs are *Rubus idaeus* L., *Corylus avellana* and *Lonicera xylosteum*. Mean species richness per 0.1 ha is high for beech forest as well as that at 1 m^2. Diversity and evenness are also higher.

Fagus sylvatica-Luzula luzuloides (*n*=23). This community type is found at mean elevation of 1415±26.0 m, mostly on convex or rarely on flat steep slopes, on variable expositions, but mainly on east, northwest and southeast ones. The mean tree stratum cover is rather high. Together with *Fagus sylvatica*, here dominate species like *Picea abies, Prunus cerasifera, Crataegus monogyna* and *Sorbus aucu-*

Table 1. TWINSPAN classification of forest vegetation. For all environmental gradients and vegetation variables, means ±SE are shown.

TWINSPAN level 1	**Forest communities dominated by (*Fagus sylvatica*)**						**Mixed forest communities dominated by *Pinus* and *Quercus* genera**		
TWINSPAN level 2	**Mesic beech forests**			**Submesic beech forests**		**Subxeric and xeric beech forests**	**Subxeric and xeric coniferous forests (plantations)**		**Mixed xeric oak forests**
Community types	*Fagus sylvatica-Hepatica nobilis* (*n*=8)	*Fagus sylvatica-Physospermum cornubiense* (*n*=12)	*Fagus sylvatica-Galium odoratum* (*n*=13)	*Fagus sylvatica-Luzula luzuloides* (*n*=23)	*Fagus sylvatica-Festuca drymeja* (*n*=17)	*Fagus sylvatica-Corylus avellana-Brachypodium pinnatum* (*n*=15)	*Pinus sylvestris-Fragaria vesca* (*n*=15)	*Pinus nigra-Crataegus monogyna* (*n*=5)	*Quercus cerris-Cornus mas* (*n*=6)
Community type abbreviation	A	B	C	D	E	F	G	H	I
Environmental gradients									
Mean elevation, m	1214±30.7	1268±19.6	1433±39.1	1415±26.0	1332±20.7	1310±40.6	1304±29.0	989±24.3	1024±18.3
Mean moisture index (xerophytism)*	1.50±0.27	2.75±0.45	2.38±0.46	3.04±0.32	3.00±0.54	5.13±0.43	4.27±0.56	3.20±0.97	3.83±0.70
Mean slope inclination, °	28.25±1.78	20.83±1.97	21.77±1.64	23.39±1.20	20.53±1.40	19.27±1.50	13.00±1.80	13.80±2.48	19.00±2.52
Mean topography index (slope convexity)**	2.00±0.27	1.92±0.19	1.92±0.21	2.48±0.14	2.29±0.11	2.07±0.15	1.93±0.12	2.20±0.20	2.50±0.22
Mean cover, %									
Tree stratum, 0.1 ha	86.25±1.83	87.50±0.97	84.23±2.76	86.87±1.98	88.06±1.64	72.33±4.97	74.00±2.85	67.00±2.55	69.17±7.00
Shrub stratum, 100 m^2	0.89±0.41	0.93±0.36	1.61±0.53	1.29±0.41	1.89±0.79	13.99±5.99	6.70±2.31	4.39±1.87	4.64±3.16
Herb stratum, 1 m^2	7.61±2.73	3.73±1.04	17.36±4.71	3.56±0.61	6.72±2.33	12.61±2.85	25.66±3.94	8.54±1.97	15.54±3.65
Life form (Raunkiaer 1934) (mean species number per 0.1 ha)									
Phanerophytes	9.38±0.92	4.75±0.46	5.31±1.02	2.87±0.37	2.00±0.31	9.73±0.78	12.47±0.98	19.60±1.29	12.83±2.33
Chamaephytes	-	-	0.15±0.10	0.35±0.12	0.29±0.14	-	0.53±0.19	0.60±0.24	0.67±0.33
Hemicryptophytes	21.88±1.19	18.00±1.96	26.15±3.26	16.26±1.28	7.53±0.88	25.40±2.07	28.93±2.17	35.40±5.77	29.83±3.95
Cryptophytes	4.50±0.33	1.33±0.33	1.85±0.32	0.35±0.10	0.06±0.06	0.40±0.13	0.20±0.11	-	1.17±0.17
Therophytes	0.25±0.16	0.67±0.33	0.85±0.37	1.00±0.24	0.47±0.19	0.80±0.34	2.27±0.38	1.60±0.51	1.00±0.37
Growth form (mean species number per 0.1 ha)									
Trees	3.75±0.56	3.00±0.33	3.00±0.48	1.43±0.14	1.65±0.24	4.00±0.57	5.13±0.53	9.40±1.08	4.83±0.87
Shrubs	5.63±0.75	1.75±0.37	2.46±0.58	1.78±0.38	0.65±0.19	5.73±0.42	7.87±0.72	10.80±0.97	8.67±1.45
Semishrubs	-	-	-	-	-	-	0.07±0.07	-	-
Perennials	26.00±1.32	19.17±2.10	27.31±3.14	16.26±1.28	7.59±0.90	25.20±1.89	28.20±2.11	34.20±5.46	30.67±4.22
Biennials	0.25±0.16	-	0.38±0.18	-	-	0.33±0.16	0.47±0.19	1.00±0.55	0.67±0.49
Annuals	0.38±0.26	0.83±0.41	1.15±0.39	1.35±0.27	0.47±0.19	1.07±0.36	2.67±0.44	1.80±0.58	0.67±033

* – For more details see exposure categorization; most xeric sites are with highest values; ** – for more details see slope topography categorization.

Table 2. TWINSPAN indicator species, diversity and homotoniety of forest community types (for the diversity indexes, means ±SE are shown).

Indicator species	A	B	C	D	E	F	G	H	I
Athyrium filix-femina (L.) Roth.	0[a]/0[b]	0.4/8.3	**3/62**	0/0	0/0	0/0	1/20	0/0	0/0
Clematis vitalba L.	0/0	0/0	0.4/8	0/0	0/0	0/0	0.4/6.6	**8.8/80**	**2.5/50**
Cornus mas*	9/38	0.4/8.3	0/0	0/0	0/0	3.7/7	0.7/13	**6/80**	**41/67**
Crataegus monogyna	6/38	2/42	0.4/8	1.2/13	0/0	**8/87**	**9/67**	**41/100**	**27/83**
Dactylis glomerata L.	0/0	0.4/8	2.4/23	0.9/13	0.3/6	**10/100**	**7/60**	**24/100**	**23/83**
Epilobium montanum L.	0/0	0.8/16.7	2.3/31	2.4/48	0.3/5.9	1/20	**6/86.7**	5/60	0/0
Euphorbia cyparissias L.	0/0	0/0	0.4/8	0/0	0/0	**2/33**	**5/87**	**10/80**	**8/50**
Fragaria vesca L.	0.6/13	0.4/8	7/39	0.4/9	0/0	**11/87**	**24/100**	**17/80**	**0.8/17**
Galium odoratum	12.5/50	7.6/58	**22/92**	4.3/35	0/0	0.7/13	2.4/33	0/0	0/0
Helleborus odorus	**7/100***	**11/100**	6/54	4.5/52	0.3/6	11/7	2/40	4/60	19/83
Hepatica nobilis	**22/100**	6.4/41.7	3/23	0.9/17.4	1.2/5.9	0.5/6.7	0.4/6.7	0/0	5.2/33
Juniperus communis	0.6/12.5	0.4/8.3	0/0	1.5/4.3	0.6/12	**9/40**	**19/80**	0/0	0/0
Lamiastrum galeobdolon	**16/75**	**8/83**	**17/77**	**7/57**	**3/53**	0/0	1.4/13	0/0	3/17
Lonicera xylosteum	**4.4/88**	0/0	7/23	0/0	0/0	4/20	19/40	0/0	0/0
Mycelis muralis	5/50	6.7/75	10/77	5.6/61	1/23.5	3.8/33	**21/86.7**	**7.4/80**	0/0
Oxalis acetosella	0/0	0/0	**17/85**	1.3/9	0.3/9	0/0	3.4/6.7	0/0	0/0
Physospermum cornubiense	**19.5/100**	**11/75**	0.4/8	1/8.7	2/17.6	9/67	0.4/6.6	0/0	6/83
Pinus nigra	0/0	0.2/8.3	0/0	0/0	0.4/6	0/0	8/20	**58/100**	0/0
Pinus sylvestris	0/0	0.1/8	8/30	0.1/4	2/18	18/40	**72/100**	33/60	0/0
Quercus cerris	2.5/50	0.4/8.3	0/0	0/0	0/0	12/33	2/40	**22/100**	**54/100**
Rosa canina	3/38	7/42	0.8/15	0.7/13	0.6/12	**20/100**	**32/100**	**26/80**	**14/33**
Senecio nemorensis L.	0.6/13	0.8/17	5/54	2.4/48	0/0	1.7/27	**5.6/87**	1/20	0/0
Silene italica (L.) Pers.	0/0	0/0	0/0	0/0	0/0	0/0	0.3/6.6	**4/80**	**5/83**
Sorbus torminalis (L.) Crantz	0.6/12.5	0/0	0/0	0/0	0/0	0/0	0/0	**7.4/100**	**3/33**
Veronica officinalis	0/0	0.4/8	1/15.4	4/26	1/23.5	1/13	**7/73**	3/40	0/0
Viburnum lantana L.	**2.8/75**	0/0	0/0	0/0	0/0	0.4/13	4/27	6/60	9/50
Diversity									
Mean number of alien species per 0.1 ha	0.50±0.27	0.92±0.29	1.62±0.57	1.17±0.17	0.47±0.17	2.73±0.44	4.40±0.58	7.40±1.54	2.33±0.80
Mean number rare, protected and endemic species per 0.1 ha	-	-	0.08±0.08	-	-	-	-	-	-
Mean species number per 0.1 ha	36±1.9	24.8±2.5	34.3±4.4	20.8±1.5	10.4±1.0	36.3±2.6	44.4±3.1	57.2±7.3	45.5±5.6
Mean species number per 1 m^2	4.12±0.64	2.49±0.45	4.58±0.71	2.09±0.26	1.70±0.26	4.74±0.83	5.61±0.63	6.25±0.94	7.87±1.56
Heterogeneity – N_2	10.40±1.58	5.93±0.92	11.65±2.07	4.75±0.47	2.56±0.23	13.21±1.75	18.54±1.80	24.81±2.76	18.67±2.38
Evenness – E'	0.54±0.05	0.51±0.02	0.60±0.03	0.51±0.01	0.62±0.02	0.60±0.03	0.67±0.02	0.68±0.01	0.67±0.03
Homotoneity	70.5	62.0	60.0	58.9	52.3	61.1	62.5	67.5	57.9

[a] – Mean Importance Value; [b] – Frequency, %; * – With **Bold** are noted Importance Values and Frequencies of indicator species for the corresponding communities;
** – With **Bold** are noted species, which are used for community names. ***E'*** – mean evenness index of Hill (1973); N_2 – mean heterogeneity index of Hill (1973).

paria. Shrubs and herbs are exceptionally poorly represented. Despite that, in the shrub stratum are more frequent species like *Juniperus communis* L. and *Rubus idaeus*, and in the herb layer species like *Poa nemoralis* L., *Viola riviniana, Lamiastrum galeobdolon, Cruciata glabra, Mycelis muralis, Aremonia agrimonoides, Euphorbia amygdaloides* L., *Cardamine bulbifera* (L.) Crantz, *Helleborus odorus, Galium odoratum, Veronica officinalis* L. and *Vaccinium myrtillus* L. Species richness here is one of the least. Similarly, diversity and evenness are very low.

Fagus sylvatica-Festuca drymeja (*n*=17). This community type is distributed at mean elevation of 1332±20.7 m. Slope expositions are highly variable, but north, west and northwest facing slopes prevail. The habitats are submesic with mostly flat steep slope surface, or occasionally convex. Canopy closure here is highest among all forest communities. Together with *Fagus sylvatica,* species with great importance are like *Pinus sylvestris, Populus tremula, Pinus nigra* and *Prunus cerasifera*. The shrubs are almost lacking. Most important species are *Vaccinium myrtillus*, *Rosa canina* and *Juniperus communis*. The herbs are also poorly represented. With the highest importance are *Luzula luzuloides, Cardamine bulbifera, Hieracium murorum agg L., Poa nemoralis, Lamiastrum galeobdolon, Festuca heterophylla* Lam., *Cruciata glabra, Calamagrostis arundinacea* (L.) Roth and *Luzula sylvatica* (Hudson) Gaudin. Species richness is extremely low at the two scales of measurement. Diversity index is also very low. However, evenness here is highest among all beech communities.

Fagus sylvatica-Corylus avellana-Brachypodium pinnatum (*n*=15). These forests are distributed at mean elevation of 1310±40.6 m, on subxeric or, more rarely, on xeric, southeast and west facing steep slopes with flat and convex surface. Besides *Fagus sylvatica*, other important trees are *Pinus sylvestris, Quercus cerris, Prunus cerasifera, Quercus petraea, Crataegus monogyna* and *Carpinus betulus*. Shrub and herb strata are well developed. Among the shrubs dominate *Rosa canina, Juniperus communis, Rubus idaeus, Lonicera xylosteum* and *Cornus mas*. Herb layer is dominated by species like *Cruciata glabra, Pteridium aquilinum* (L.) Kuhn, *Poa nemoralis, Viola riviniana, Helleborus odorus, Fragaria vesca, Dactylis glomerata* and *Aremonia agrimonoides*. The higher species richness is due to the greater number of herbs. Species diversity is greatest among all beech communities and evenness is among the highest too.

Pinus sylvestris-Fragaria vesca (*n*=15). This community type is formed at mean elevation of 1304±29.0 m, mainly in subxeric or, more rarely, in submesic habitats with southeastern or southwestern exposition and flat gentler slope surface. Tree canopy closure is relatively low. Together with *Pinus sylvestris,* here dominate trees like *Fagus sylvatica, Prunus cerasifera, Pinus nigra, Sorbus aucuparia* and *Picea abies*. Shrub and herb strata are well developed. Among the shrubs prevail species like *Rosa canina, Corylus avellana, Juniperus communis, Rubus idaeus* and *Evonymus europaeus* L. Among the herbs dominant are species like *Mycelis muralis, Poa nemoralis, Aremonia agrimonoides, Geranium robertianum* L., *Brachypodium pinnatum* (L.) P. Beauv., *Calamagrostis arundinacea* and *Viola riviniana*. Herb cover in these plantations reaches its maximum among all forests in the region. Species richness at the two scales is relatively high. The evenness of these forests is very high. The same applies to diversity index.

Pinus nigra-Crataegus monogyna (*n*=5). These conifer communities are distributed at lower mean elevation of 989±24.3 m in submesic habitats on flat gentler slopes, mainly with northern and western exposition. Tree canopy closure is lowest among all described forests. Other important trees are *Pinus sylvestris, Fagus sylvatica, Quercus petraea, Quercus cerris, Carpinus betulus, Prunus cerasifera, Quercus frainetto* Ten.*, Fraxinus ornus, Pyrus pyraster* Burgsd. and *Populus tremula.* Despite the relatively open canopy, shrub and herb cover is lesser. Dominant shrubs are *Rosa canina, Corylus avellana, Prunus spinosa* L. and *Ligustrum vulgare* L*.* Herb stratum is dominated by *Dactylis glomerata, Aremonia agrimonoides, Poa nemoralis, Hypericum perforatum* L.*, Euphorbia cyparissias* and *Fragaria vesca*. Species richness is extremely high and reaches its maximum among all forest communities in the studied territory. Diversity and evenness indexes also reach its maxima.

Quercus cerris-Cornus mas (*n*=6). These oak forests are distributed at mean elevation of 1024±18.3 m. The habitats are submesic or subxeric with southwestern and eastern exposition. Slopes have convex topography and moderate inclination. Mean canopy cover is not very high. Other principal trees are *Carpinus betulus, Quercus petraea, Fraxinus ornus, Crataegus monogyna, Acer campestre, Prunus cerasifera* and *Quercus pubescens* Wild*.* Shrubs and herbs are abundant. Dominant shrubs are *Corylus avellana, Rosa canina, Prunus spinosa, Chamaecytisus hirsutus* (L.) Link, *Cornus sanguineum* and *Viburnum lantana.* Main herbs are *Helleborus odorus, Dactylis glomerata, Poa nemoralis, Brachypodium pinnatum, Carex montana* L.*, Aremonia agrimonoides, Viola hirta* L. and *Festuca heterophylla*. Mean species richness is very high. Mean diversity and evenness values are also high, comparable to *Pinus sylvestris* communities. The lower elevation and proximity to populated areas of the last two community types expose them to more extensive human influence. These disturbances are mainly livestock grazing, as well as variable forestry activities, such as logging, forest road clearing, etc.

Community Type Comparison

Described community types were tested for significant differences for the main environmental gradients and most important vegetation variables measured by us (Leathwick and Rogers 1996). When variable distribution was not normal, nonparametric Kruskal-Wallis ANOVA on Ranks, Dunn's test was used. In the cases with normal variable distribution, parametric One-Way ANOVA, Holm-Sidak method was employed.

We have found significant differences between the community types for almost all environmental gradients, except one (Figure 2). Beech forests, together with *Pinus sylvestris-Fragaria vesca* community, are found on significantly higher elevation. Differences by this gradient are most pronounced, especially between mixed oak forest and *Pinus nigra* community (Figure 2a). We have also found significant differences relative to other two main environmental gradients – moisture index and slope inclination. Generally, beech forests are distributed on steepest slopes (Figure 2c) and in more mesic habitats (Figure 2b). Slope topography (convexity)

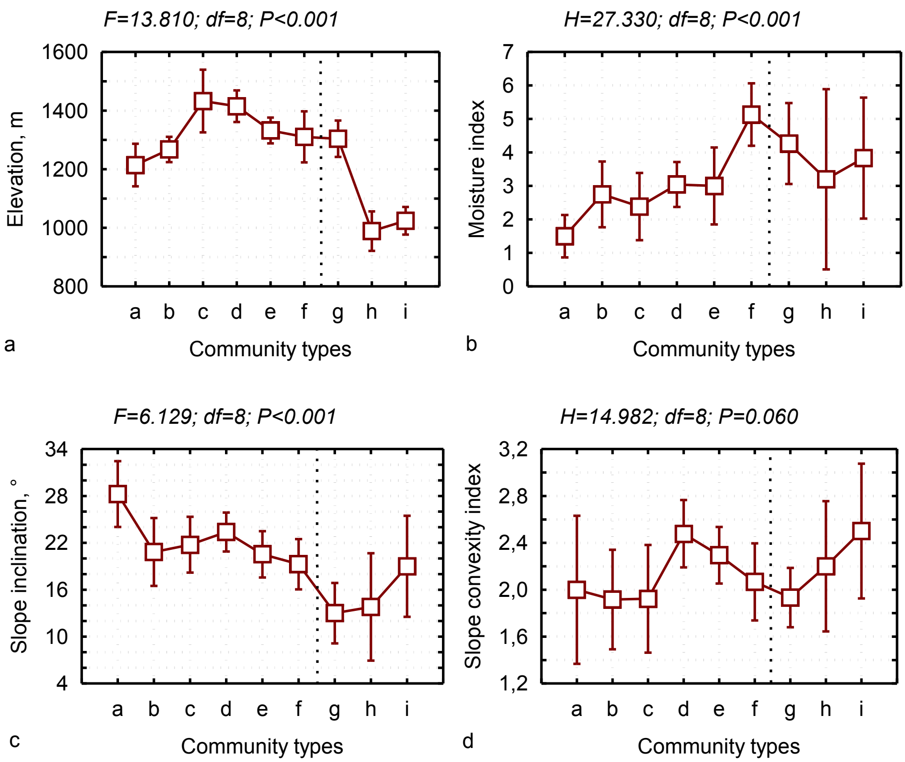

Fig. 2. Community type comparison by the main environmental gradients.

Mean value ± 0.95 confidence interval for all forest communities are shown. Means, which whiskers do not overlap, are significantly different. a) Mean elevation; b) Mean moisture index – higher values mean more xeric conditions; c) Mean slope inclination; d) Mean convexity index. Punctuated vertical line separates beech forests from the other communities. For the full community names see Table 1 and the text. *H* value shows the result from Dunn's test (Kruskal-Wallis ANOVA on Ranks) on the hypothesis that there is not statistically significant difference between tested communities. *F* value shows the test result on the same hypothesis using One Way ANOVA, (Holm-Sidak method).

cannot be used as reliable variable for forest community discrimination in the studied territory (Figure 2d).

Forest communities are compared by the mean cover of tree, shrub and herb strata (Figure 3).

Significant differences were found among them in the cover of all three vegetation layers. Beech communities have higher canopy closure, compared to the other groups, except *Fagus sylvatica-Corylus avellana-Brachypodium pinnatum* community, standing closer to the mixed forests (Figure 3a). Differences among the forest communities were weaker in shrub layer coverage (Figure 3b). Shrub cover is greater in oak and coniferous forests as well as *Fagus sylvatica-Corylus*

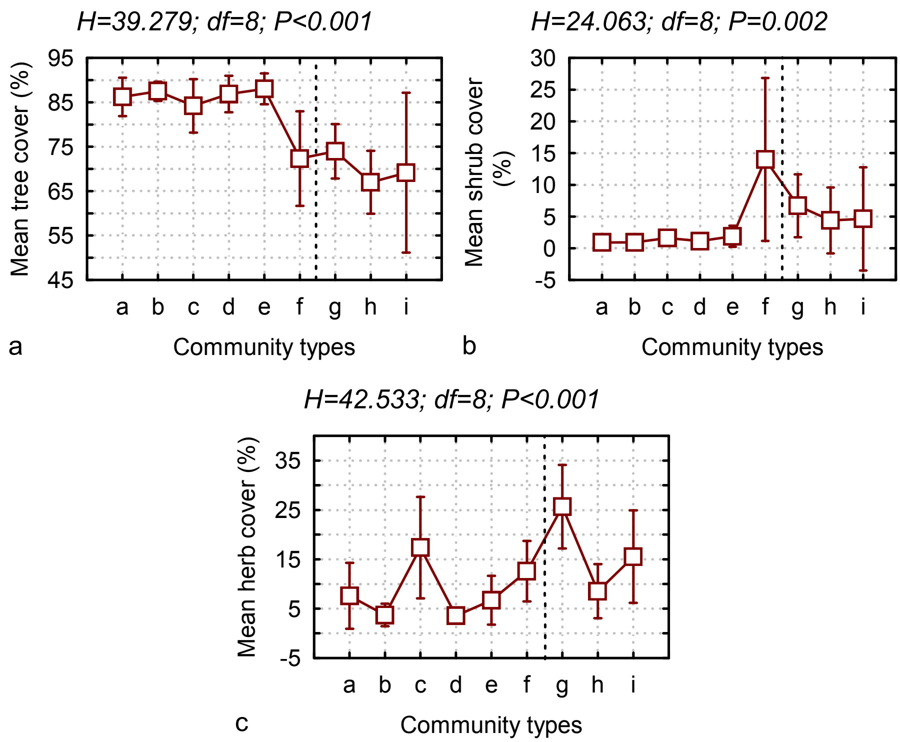

Fig. 3. Community type comparison by vegetation strata coverage.

Mean value ± 0.95 confidence interval for all forest communities are shown. Means, which whiskers do not overlap, are significantly different. a) Mean cover of tree stratum per 0.1 ha; b) Mean cover of shrub stratum per 100 m^2; c) Mean cover of herb stratum per 1 m^2. Punctuated vertical line separates beech forests from the other communities. *H* value shows the result from Dunn's test (Kruskal-Wallis ANOVA on Ranks) on the hypothesis that there is not statistically significant difference between tested communities.

avellana-Brachypodium pinnatum community. Herb layer is most abundant in *Fagus sylvatica-Galium odoratum* and *Pinus sylvestris-Fragaria vesca* (Figure 3c), but not significantly higher, compared to most forest communities.

We compared forest communities by the life form number per 0.1 ha (Figure 4).

Phanerophytes are more numerous in the mixed forests. Again, *Fagus sylvatica-Corylus avellana-Brachypodium pinnatum* community is closer to the mixed forest communities than to other beech forests (Figure 4a). Chamaephytes are least numerous in the studied forests among all life form groups, but they have significantly higher numbers in mixed forests than the beech communities (Figure 4b). The same is the situation with hemicryptophytes and therophytes (Figure 4c, Figure 4e). The opposite holds for the cryptophyte group (Figure 4d). Mesic and submesic beech forests have more cryptophytes than subxeric beech and mixed communities.

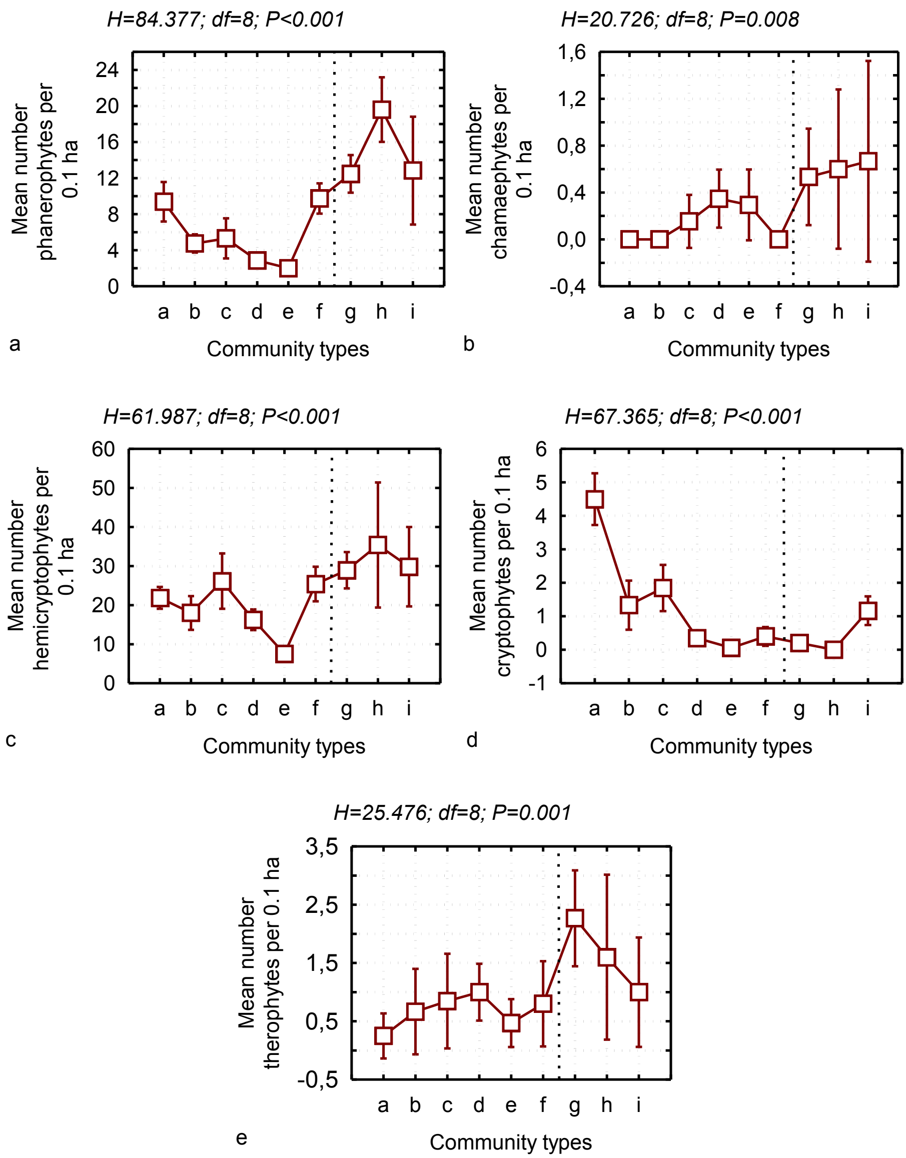

Fig. 4. Community type comparison by life form number per 0.1 ha.

Mean value ± 0.95 confidence interval for all forest communities are shown. Means, which whiskers do not overlap, are significantly different. a) Mean number of phanerophytes per 0.1 ha; b) Mean number of chamaephytes per 0.1 ha; c) Mean number of hemicryptophytes per 0.1 ha; d) Mean number of cryptophytes per 0.1 ha; e) Mean number of therophytes per 0.1 ha. Punctuated vertical line separates beech forests from other communities. *H* value shows the result from Dunn's test (Kruskal-Wallis ANOVA on Ranks) on the hypothesis that there is not statistically significant difference between tested communities.

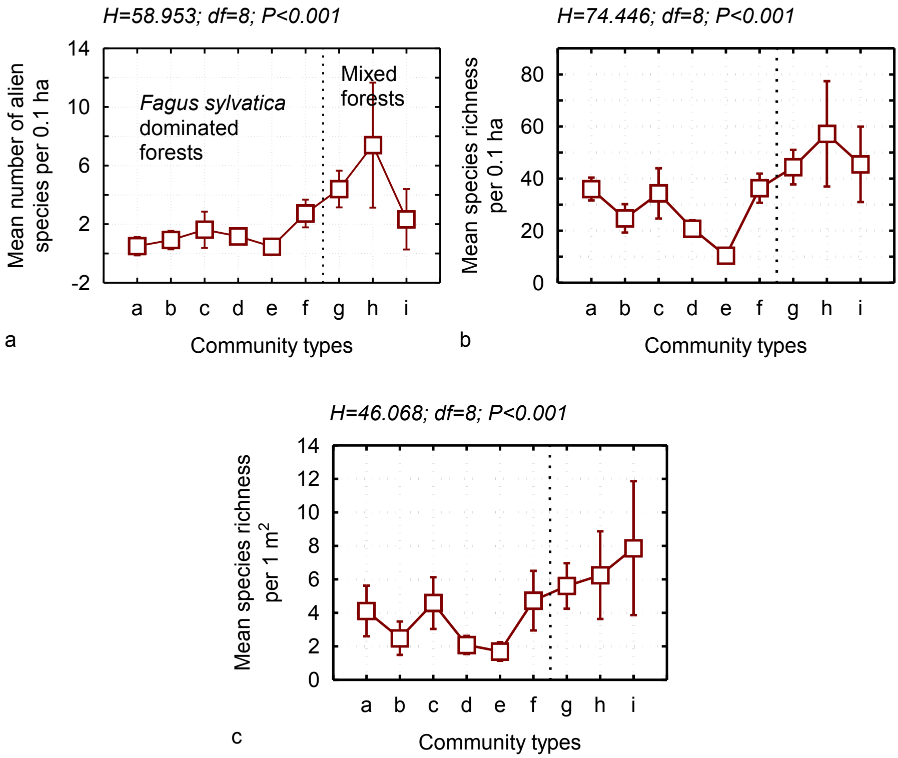

Fig. 5. Community type comparison by alien species number and species richness at the two scales of measurement.

Mean value ± 0.95 confidence interval for all forest communities are shown. Means, which whiskers do not overlap, are significantly different. a) Mean number of alien species per 0.1 ha; b) Mean species richness per 0.1 ha; c) Mean species richness per 1 m^2. Punctuated vertical line separates beech forests from other communities. *H* value shows the result from Dunn's test (Kruskal-Wallis ANOVA on Ranks) on the hypothesis that there is not statistically significant difference between tested communities.

The last comparison of forest communities is by alien species (sensu Richardson et al. 2000) and species richness at the two scales of measurement (Figure 5).

Mixed forest communities and coniferous plantations are more saturated with alien species (Figure 5a). Here, the most xeric *Fagus* community again stands closer to the mixed communities than to the other beech forests. The higher alien species richness of the oak and coniferous communities is probably due to their close proximity to populated areas in the region and to severe disturbance regime there, resulting mainly from human activity, like livestock grazing and logging.

Species richness at the two scales in the mixed oak forests and coniferous communities is also higher (Figure 5b and Figure 5c). Poorer on species are beech communities in submesic habitats (*Fagus sylvatica-Festuca drymeja* and *Fagus syl-*

vatica-Luzula luzuloides), except *Fagus sylvatica-Corylus avellana-Brachypodium pinnatum* community, which is closer to mesic beech forests. *Pinus nigra* community has higher species richness at 0.1 ha, but the oak forest is richest at the 1 m^2 scale. However, significantly lower species richness compared to most other communities is found only in *Fagus sylvatica-Luzula luzuloides* and *Fagus sylvatica-Festuca drymeja* community types.

Discussion

This study aimed classifying vegetation cover of the studied area in more objective and adequate numerical fashion. Testing the consistency of the obtained community types for a number of important vegetation variables and environmental gradients, we tried to reject the hypothesis that vegetation is organized as recognizable community units in the environmental space.

Most of the forest communities, described in this study, are dominated by *Fagus sylvatica*. Literature data, concerning classification of the other types are scarce. Therefore, the following discussion is focused mainly on the beech forests.

Dzwonko and Loster (2000) found clearly expressed geographical gradient in the beech forest floristic composition from southeastern Serbia, through Macedonia, to central Greece. Bergmeier and Dimopoulos (2001) distinguish the following beech forest groups in Greece: 1) beech forests in mesotrophic habitats; 2) beech forests in “cool acidic” habitats; 3) beech forests on carbonate places at higher elevation; and 4) beech forests in moderately warm and dry habitats. One of the beech communities from the first ecological group (*Galium odoratum-Fagus sylvatica* with diagnostic species *Galium odoratum, Epilobium montanum, Cardamine bulbifera*) coincide by name with our type *Fagus sylvatica-Galium odoratum* (with indicator species *Galium odoratum, Athyrium filix-femina, Lamiastrum galeobdolon* and *Oxalis acetosella*). However, we placed our community type in the group of submesic beech forests. Unfortunately, Bergmeier and Dimopoulos (2001) did not give quantitative data, on which basis, detailed comparison to be made. According to the authors, community differentiation follows complex “edaphic-climatic-phytogeographic” pattern of distribution. In their general physiognomy, the beech communities studied by them, resemble the Central European beech forests (Bergmeier and Dimopoulos 2001). However, our results point that the main environmental gradients, responsible for beech forest pattern in the studied territory are elevation and moisture gradients. Here should be noted that the scale of the two studies is different. Ours is more local. Despite that, Bergmeier and Dimopoulos (2001) did not publish detailed data for the species richness our results confirm their conclusion that the beech forests are generally poorer on plant species.

Tzonev et al. (2006) made classification scheme of the beech communities covering the entire territory of Bulgaria. They described altogether 12 community types dominated by *Fagus sylvatica*. The authors found environmental and geographic continuum of the described communities. Community arrangement, according to them, expresses the “geographical structured effects of the ecological factors, which change from west to east, as well as from west to northeast”. Three community types coincide by name with our groups.

These are *Fagus sylvatica-Galium odoratum*, *Fagus sylvatica-Luzula luzuloides* and *Fagus sylvatica-Festuca drymeja*. According to Tzonev et al. (2006), *Fagus sylvatica-Galium odoratum* is characterized with poor species composition and lower herb layer cover. This is in contradiction with our results, showing that this community type had richest species composition and greatest herb cover among all beech forests described in our study. We also contradict Tzonev et al.'s (2006) results relative to *Fagus sylvatica-Festuca drymeja* community type. According to them, this group is found on moist shady slopes, which they judge by the presence of some hygrophilous plant species like *Eupatorium cannabinum* L. and *Prunella vulgaris* L. On the contrary, our results show that this community type occupies relatively dry habitats. Therefore it is placed in the group of subxeric beech forests (see Table 1 and Figure 2b).

Our results support Tzonev et al.'s (2006), relative to the third community type (*Fagus sylvatica-Luzula luzuloides*), and particularly the conclusion that this is relatively poor on species forest community. It has already been mentioned that the lack of detailed quantitative data in the phytosociological studies, like Tzonev et al.'s (2006), resulting in inability for statistical tests and difficult comparison possibility.

Tzonev et al. (2006) made the conclusion that Bulgarian beech forests differentiate depending on soil, local topographic and climatic gradients, resembling the Central European beech communities. Unfortunately, they did not support this conclusion with enough data in their paper. However, on the ground of our results, we are inclined to agree with this conclusion.

In South Rhodopes (Northeast Greece) pure and mixed beech forests have been investigated with multivariate methods (Tsiripidis et al. 2007a). The authors classify studied communities in 12 "vegetation units", placing them in four ecological groups: mesophilous, acidophilous, calcareous, and thermophilous beech forests. Vegetation unit arrangement expressed the complex gradient from moist, rich and shady habitats toward dry, poor and warm ones (Tsiripidis et al. 2007a). One community type from the mesophilous group (*Fagus sylvatica-Galium odoratum*) coincides by name with one of our types. According to Tsiripidis et al. (2007a), these forests are formed on relatively higher elevation, mainly on convex slopes. They also were characterized with greater stand height. Principally, we agree with the latest conclusions, but these forests on the Vitosha Mountain south slope are distributed mainly on concave or flat slopes.

We have found similarity between most of the Tsiripidis et al.'s (2007a) *Calamagrostis arundinacea-Fagus sylvatica* type variants from the acidophilous group and our subxeric beech forest. The latter are distributed in poorer and dryer habitats at mean elevation of around 1300 m. They occupy slopes with steeper or less steep inclination, mainly on flat, or rarely, on convex slopes, which most often represent successional vegetation.

Similarity has been found also between one community type (*Brachypodium pinnatum-Fagus sylvatica*) from the Tsiripidis et al.'s (2007a) calcareous group and our *Fagus sylvatica-Corylus avellana-Brachypodium pinnatum* community type from the subxeric forest group.

Tsiripidis et al. (2007a) conclude that floristic differentiation of the Rhodope beech forests, resulting from the meso- and microclimatic (caused mainly from elevation differences), and soil (nutrient content and N) factors. Our considerations point that these factors are also the reason for vegetation pattern formation on the territory of the current study, resulting not only from elevation differences and soil characteristics, but from the moisture gradient influence as well.

The role of geographical and ecological factors for the floristic differentiation of beech forests in Greece has been investigated (Tsiripidis et al. 2007b). Classification resulted in 14 groups of beech forests, distributed in northeastern and central parts of the country. Two of them are identical by name with our *Fagus sylvatica-Brachypodium pinnatum* and *Fagus sylvatica-Galium odoratum* community types. Discussing their results, Tsiripidis et al. (2007b) conclude that presented classification reflects the ecological and geographical gradients. They also comment that the results from such studies depend on the size of the studied territory, its position along assumed regional gradient, as well as on the capacity and quality of the data used. This is a statement that we share, but once again, according to our results, leading gradients, shaping the vegetation pattern in a relatively localized territory, are habitat moisture and elevation.

Community concept, considering them as actually existing units, composed of coexisting species, is applicable only within the boundaries of a specific territory, together with its complex of environmental gradients, i.e. plant community is a landscape phenomenon (Austin 2005). Our results show that beech communities are almost indistinguishable by the most variables tested, except *Fagus sylvatica-Corylus avellana-Brachypodium pinnatum*, which is closer to the mixed forest. Greater variance among the mixed forest communities for the most variables has also been found. Despite the statistical differences between the beech and mixed forests, we consider plant communities as segments or sections in the species population cenocline, indiscernible in the ecological space, but only in the landscape; therefore their limited usefulness in vegetation theory improvement. Moreover, we recognize that classification studies for practical purposes should be completely quantitative with statistical testing of described community types. Merely qualitative investigations are better being abandoned in future.

Plant community concept is preferable in the environmental management, given the condition that intended managerial activities are applied on a previously clearly defined area (Austin 2005). In conclusion, in the context of Austin's (2005) conclusion, we generalize that the presented classification is useful from practical view point, concerning different activities (for example, forestry or conservation measures), which affect parts of the studied territory, but it has limited capability in the improvement of the vegetation theory.

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References

Austin M. 2005. Vegetation and environment: discontinuities and continuities. In: Van der Maarel, E (ed.), Vegetation ecology, Blackwell Publishing: 52–84.

BAEV P., PENEV L. 1995. BIODIV. Program for Calculating Biological Diversity Parameters, Similarity, Niche Overlap, and Cluster Analysis, Version 5.1. Pensoft, Sofia – Moscow. 57 p.

BERGMEIER E., DIMOPOULOS P. 2001. *Fagus sylvatica* forest vegetation in Greece: Syntaxonomy and gradient analysis. Journal of Vegetation Science 12: 109–126.

CURTIS J. 1959. The vegetation of Wisconsin. Madison: University of Wisconsin Press. 657 p.

DELIPAVLOV D. (ed.) 1992. Bulgarian Vascular Plant Field Guide. Zemizdat, Sofia. 499 p. (In Bulgarian).

DIMITROV M., GLOGOV P. 2003. Character syntaxa of forest phytocenoses in Lozenska Mountain. In: Kostov G. (ed.): Collection of Scientific Reports "50 Years University of Forestry, Forest Management and Landscape Architecture. University of Forestry, Sofia: 15–20 (In Bulgarian).

DZWONKO Z., LOSTER S. 2000. Syntaxonomy and phytogeographical differentiation of the *Fagus* woods in the Southwest Balkan Peninsula. Journal of Vegetation Science 11: 667–678.

DZWONKO Z., LOSTER S., DUBIEL E., DRENKOVSKI R. 1999. Syntaxonomic analysis of beechwoods in Macedonia. Phytocoenologia 29: 153–175.

GARELKOV D., STPTSOV V. (eds.). 1995. Beech Forests in Bulgaria. Zemizdat, Sofia. 200 p. (In Bulgarian).

HILL M., GAUCH H. 1980. Detrended correspondence analysis: an improved ordination technique. Vegetatio 42: 47–58.

HILL M., ŠMILAUER P. 2005. TWINSPAN for Windows version 2.3. Centre for Ecology and Hydrology & University of South Bohemia, Huntingdon & Ceske Budejovice.

HILL M. 1973. Reciprocal averaging: an eigenvector method of ordination. Journal of Ecology 61: 237–49.

HILL M. 1979. DECORANA – A FORTRAN program for detrended correspondence analysis and reciprocal averaging. Cornell University Ithaca, New York. 52 p.

JAVORKA S. 1975. Iconography of the Flora from the South-Eastern part of Central Europe. Academia Kiado, Budapest. 585 p.

JORDANOV D. (ed.). 1963–1989. Flora of People's Republic of Bulgaria. Volume: I–IX. Bulgarian Academic Press, Sofia. (In Bulgarian).

KOJUHAROV S. (ed.). 1995. Flora of Republic of Bulgaria. Volume: X. Academic Press "Prof. Marin Drinov", Sofia. 428 p. (In Bulgarian).

KOLEVA E. 2005. Climate. In: Stanoeva S. (ed.). Management plan of Nature Park "Vitosha". MOEW, Sofia: 26–31 (In Bulgarian).

LEATHWICK J., ROGERS G. 1996. Modeling relationships between environment and canopy composition in secondary vegetation in central North Island, New Zealand. New Zealand Journal of Ecology 20: 147–161.

MALINOV I. 2005. Soils. In: Stanoeva S. (ed.). Management plan of Nature Park "Vitosha". MOEW, Sofia. 62–70 (In Bulgarian).

MISHINEV T. 2005. Vegetation. In: Stanoeva S. (ed.). Management plan of Nature Park "Vitosha". MOEW, Sofia: 72–85 (In Bulgarian).

PAVLOV D., DIMITROV M. 2003. Sintaxonomical analysis of beech forests in Petrochan Balkan (Western Stara Mountain). In: Kostov G. (ed.): Collection of Scientific Reports "50 Years University of Forestry, Forest Management and Landscape Architecture. University of Forestry, Sofia: 9–14 (In Bulgarian).

PAVLOV D. 1998. Phytocenological Bases of Forest Typology in Bulgaria. Dissertation, University of Forestry, Sofia, 298 p. (In Bulgarian).

PEET R. 1974. The measurement of species diversity. Annual Review of Ecology and Systematics 5: 285–307.

PEET R. 1981. Forest vegetation of Colorado Front Range. Vegetatio 45: 3–75.

PIELOU E. 1975. Ecological Diversity. New York, Wiley. 165 p.

RAUNKIAER C. 1934. The life forms of plants and statistical plant geography. Oxford: Clarendon Press. 632 p.

RICHARDSON D., PYŠEK P., REJMÁNEK M., BARBOUR M., PANETTA F., WEST C. 2000. Naturalization and invasion of alien plants:

Concepts and definitions. Diversity and Distribution 6: 93–107.

Shipkova K. 2005. Geology and geomorphology. In: Stanoeva S. (ed.). Management plan of Nature Park “Vitosha”. MOEW, Sofia, 32–49 (In Bulgarian).

Šmilauer P. 1999–2003. CanoDraw for Windows, version 4.1. Glenn Randers-Pehrson.

StatSoft Inc. 2007. STATISTICA (data analysis software system), version 8.0. Available: www.statsoft.com.

Systat Software Inc. 2008. SigmaPlot for Windows, version 11.0. Available: www.sigmaplot.com.

ter Braak C., Šmilauer P. 2003. CANOCO reference manual and User’s guide to Canoco for Windows: Software for Canonical Community Ordination (version 4). Microcomputer Power, Ithaca. 351 p.

Tsiripidis I., Vassiliki K., Alifragis D., Athanasiadis N. 2007a. Classification and gradient analysis of the beech forest vegetation of the southern Rodopi (Northeast Greece). Folia Geobotanica 42: 249–270.

Tsiripidis I., Bergmeier E., Dimopoulos P. 2007b. Geographical and ecological differentiation in Greek *Fagus* forest vegetation. Journal of Vegetation Science 18: 743–750.

Tzonev R., Dimitrov M., Chytrý M., Roussakova V., Dimova D., Gussev C., Pavlov D., Vulchev V., Vitkova A., Gogoushev G., Nikolov I., Borisova D., Ganeva A. 2006. Beech forest communities in Bulgaria. Phytocoenologia 36: 247–279.

van Tongeren O. 2004. Cluster analysis. In: ter Braak, C (ed.) Data Analysis in Community and Landscape Ecology. Cambridge University Press, Cambridge: 174–207.

Whittaker R. 1956. Vegetation of the Great Smoky Mountains. Ecological Monographs 26: 1–80.

Whittaker R. 1960. Vegetation of the Siskiyou Mountains, Oregon and California. Ecological Monographs 30: 279–338.