Variability of the forest communities of the Dilj Mountain (Croatia) along environmental gradients

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INTRODUCTION

Dilj is a part of high-lying massif of Slavonia (NE Croatia), situated on the southern edge of the Pannonian Basin (Fig. 1.). Due to the position among different climate influences (Alpine in the west, Dinaric in the south, Pannonian in the east and the north) there is a vast diversity and abundance of flora and vegetation in this area. Unfortunately a plant life there is very poorly explored. Therefore the objective of this paper is a detailed research of the forest vegetation to define the characteristics of forest plant communities and to determine which ecological factors significantly influence the presence and the absence of certain communities.

Of all Slavonian mountains Dilj is the lowest-lying (471 m) and has a south/south-east position. The hills are crossed with a dense net of valleys and gullies separated by widely rounded ridges. Anthropogenic influence is very well expressed in the whole area. The natural forest vegetation is crossed with settlements, meadows, and pastures. However, the forest ecosystems cover the largest part of Dilj. Except for the far southern slopes the whole area characterises the extremely extensive agriculture. Lately many settlements are more and more untended since the inhabitants largely emigrate to the cities. Former agricultural fields, meadows, and pastures are in different succession stages.

The average annual air temperature in the researched area is around 11 °C, and it increases from the west to the east. The coldest month of the year is January, and the wormest is July. The average annual amount of precipitation decreases from the west (799 mm) to the east (728 mm).

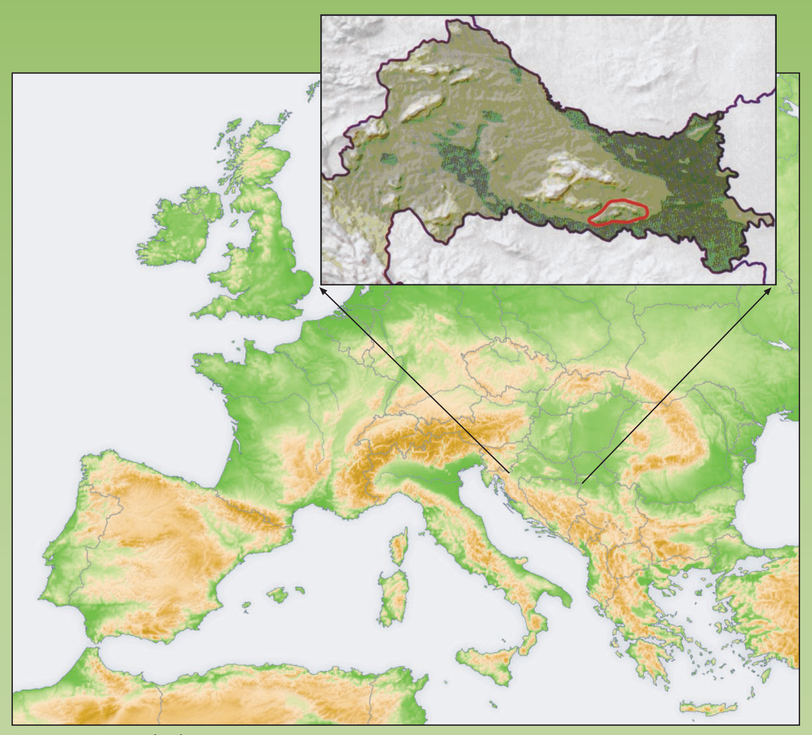

Figure 1. Researched area

MATERIAL AND METHODS

261 relevés were made following standard Central-European method (Braun-Blanquet 1964). The nomenclature of plants species follows Eherdorfer (1973). The cover values were transformed into the ordinal scale (van der Maarel 1979). The classification was done by Complete Linkage method using similarity ratio in SYNTAX 2000 (Podani 2001).

The slope, aspect and altitude is determined on the each plot. The ecological factors were estimated using Ellenberg indicator values (Ellenberg et al. 1991). The composit sample of the upper 20 cm of soil was taken from the each plot. The pH value was measured in the water (ISO 10390). C_{org} is determined by means of ISO 10694. Easily accessible P and K are determined using Al method. The descriptive statistical analysis of the environmental variables were made by standard procedures (Sokal and Rohlf 1981) using STATISTICA for WINDOWS 7.0. Redundancy Analysis (RDA) was made by CANOCO 4.02 (Ter Braak and Šmilauer 2002). The choice of the ordination method was made on the basis of lenght of the longest gradient of the DCCA (Lepš and Šimlauer 2005).

Contributions of every environmental variable to the overall variability have been calculated in two ways - using marginal effects (contributions of every variable independently) and conditional effects (variable with the largest contribution was used first and the contribution of others depended on variables already included in the model).

Ellenberg indicator values have been passively projected (*Supp. env. var.*) on the RDA plot.

RESULTS AND DISCUSSION

Hierarchical classification identified 10 sintaxa of forest vegetation (Fig. 2.). Classification and comparison with literature relevés of similar vegetation is presented in details in Škvorc (2006).

The analysis of relationship between plant communities and explored environmental variables has shown that the distribution of forest plant communities in the explored area depends on the combination of different pedological and orographic factors, i.e. that not one of the environmental factors for itself cannot explain the overall variability. The similar results were obtained in other similar researches of the vegetation-environment relationship (Elgersma et al. 2002; Attorre et al. 2003).

The variables that explain the largest part of species' variabilities are the aspect and the soil pH (Tab. 2). The conditional effect of Corg. and the content of K is less than their marginal contribution due to the fact that they correlate with soil acidity. The share of accessible phosphorus is not significant (Tab. 2). The quantity of nutrients in the soil is important factor for distribution of forest plant communities although due to large variability within the communities it is very difficult to come to the conclusion to what extent are they relevant for their differentiation (Fig. 3; Baričević 2002). It is to presume that the quantity of nutrients would have greater importance for poor soils which were not the object of this research where the lack of particular nutrient would be limitating factor for distribution of particular vegetation types.

From the analyzed Ellenberg indicator values all plant communities EIV for light differentiate the best so the tendency from the communities with the least values (beech forests) through oak hornbeam forests, sessile oak forests and finally pubescet oak forests is clearly observed. On the other side EIV for humidity has been differentiated by the communities in the opposite direction, from the most humid beech forests to the driest pubescent oak forests (Fig. 3, 4).

By their ecologic requirements the pubescent oak forests (*Orno-Quercetum pubescentis*) differ the most from all other researched plant communities. Most important ecological factors for subsequent arrival of this association are: aspect, pH, and the quantity of nutrients in the soil. Stands of this association appear mainly on the southern aspects (Fig. 3, 4).

On the basis of explored ecological conditions of subsequent arrival beech forests differ very well from other forests in the researched area. Although in literature a clear ecological differentiation of these forests is emphasized (Vukelić and Rauš 1998), in the lowest mountain with very well intended relief and different soil types often are the limits among vegetation types very diffuse (Baričević 2002; Škvorc 2006). The results of the study confirm the clear differentiation of beech forests even in such conditions on the basis of the combination of diverse ecological factors which create specific microconditions for subsequent arrival of these communities. The most important ecological factors in this case are: altitude, aspect, and EIV for humidity, light, and temperature. In other words beech forests take up completely the peak parts of Dilj, and in lower parts they alternate with other communities appearing mostly in the north expositions (N, NE, NW) (Tab. 2, Fig 3, 4).

A subass. *Vicio-Fagetum caricetosum flaccae* as compared to a *Vicio-Fagetum typicum* appears in southern aspects in soils with significantly higher pH values and larger content of $C_{org.}$ and accessible potassium, as well as in habitats with higher EIV for light and lower for humidity (Fig. 4). From the results it is noticeable that the habitats of this subassociation are much more similar to the habitats of pubescent oak than to the ones of beech forests. In consequence the floristic structure consists of some species characteristic for pubescent oak forests (Škvorc 2006). The implication is that subass. *caricetosum flaccae* appears through succession of pubescent oak forests in order that beech arrives in such termophile habitats and gradually changes the microclimate making the conditions for subsequent arrival of other species characteristic for beech forests.

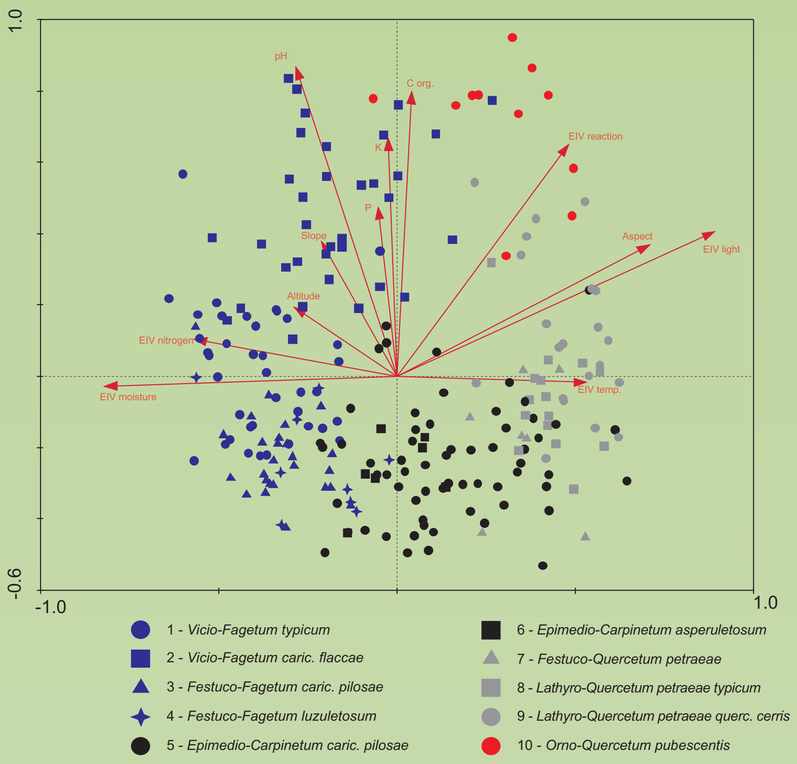

Figure 4. Redundancy analysis plot

As opposed to the *Vicio-Fagetum* which appears on neutral to slightly alkaline soil a *Festuco-Fagetum* appears on acid sandy soil (Vukelić and Rauš 1998). These differences reflect on the other ecological factors so the *Festuco-Fagetum* appears on soil containing less Corg. and accessible phosphorus and potassium. *Vicio-Fagetum typicum* appears at higher altitudes in all the expositions while the *Festuco-Fagetum* appears at lower altitudes in northern aspects where it alternates with sessile oak and hornbeam forests which appear in eastern and western aspects.

Thermophilic sessile oak forests (*Lathyro-Quercetum*) as compared to the sessile oak forests with hornbeam (*Epimedio-Carpinetum*) significantly differ by the fact that it appears mainly in southern aspects (SE, SW, S) and in habitats with higher EIV for light.

A subass. *Lathyro-Quercetum queretosum cerris* in relation to a tipical one appears mainly at lower altitudes and in habitats with lower EIV for humidity. Besides that it slightly differs by higher EIV for light. Stands with Turkey oak in the explored area are mainly degraded (Škvorc 2006) which we can associate with a large variability of explored characteristics (Fig. 3).

Stands of *Epimedio-Carpinetum asperuletosum* present in the explored area mostly degraded stands of tipical sessile oak and hornbeam forests which appear in wide gullies and hollows (Škvorc 2006) where after felling sessile oak restores with difficulty (frost, cold air) so hornbeam takes over the dominant part in tree layer (Müller 1992; Wallnöfer et al. 1993).

Of all the analized plant communities a *Festuco-Quercetum* differentiates the least towards analyzed ecological variables (Fig. 3). According to these characteristics it is the most similar to a *Lathyro-Quercetum typicum* and to a lesser degree to *Epimedio-Carpinetum caricetosum pilosae.* Characteristics of this association should be researched in details in larger geographical area.

In the future explorations of Dilj vegetation and of other similar mountain areas more attention should be payed to syndynamic processes since it is clear that they significantly influence the appearance of forest vegetation today. In this matter the attention should be on the environmental factors, above all on those which in this research turn out to be significant for the diferentiation of forest vegetation (pH value, aspect, altitude). Moreover it would be very useful to include other factors which were not encluded in this research as for example shaded relief, curvature, etc.

Tablica 1. Summary of Redundancy Analysis

Axes	1	2	3	4	Total inertia
Eigenvalues	0,140	0,086	0,017	0,016	1,000
Species-environment correlations	0,837	0,838	0,595	0,594	
Cumulative percentage variance					
of species data	14,0	22,6	24,4	26,0	
of species-environment relation	52,0	83,8	90,1	96,0	
Sum of all eigenvalues					1,000
Sum of all canonical eigenvalues					0,269

Table 2. Marginal and conditional effect

Marginal effects		Conditional effects			
Variable	λ1	Variable	λ A	P	F
Aspect	0,11	Aspect	0,11	0,002	27,49
pH	0,09	pH	0,10	0,002	28,67
Corg.	0,07	Altitude	0,03	0,002	7,31
K	0,05	Slope	0,02	0,002	4,87
Altitude	0,04	Corg.	0,01	0,002	2,62
Slope	0,03	K	0,01	0,002	2,70
P	0,03	P	0,01	0,070	1,42

Syntaxonomical scheme

Querco-Fagetea Br.-Bl. et Vlieger in Vlieger 1937
Quercetalia pubescentis Br.-Bl. (1931) 1932
Quercion pubescenti-petraeae Br.-Bl. 1932
***Orno-Quercetum pubescentis* Klika 1938**
***Lathyro-Quercetum petraeae* Ht. (1938) 1958**
subass. *typicum*
subass. *quercetosum cerris* Baričević 2002
Quercetalia robori-petraeae Tx. 1937
Castaneo-Quercion petraeae (Soó 1962) Vukelić 1990
***Festuco drymeiae-Quercetum petraeae* (Jank. 1968) Hruška 1974**
Fagetalia sylvaticae Pawlowski in Pawlowski et al. 1928
Carpinion betuli Issler 1931
Lonicero caprifoliae-Carpinenion betuli Vukelić 1990
***Carpino betuli-Quercetum roboris* (Anić 1959) Rauš 1969**
***Epimedio-Carpinetum betuli* (Ht. 1938) Borhidi 1963**
subass. *asperuletosum* Wraber 1961
subass. *caricetosum pilosae* Horvat 1950
Aremonio-Fagion (Ht. 1938) Borhidi in Török, Podani et Borhidi 1989
Epimedio-Fagenion Marinček et al. 1993
***Vicio oroboidi-Fagetum sylvaticae* (Ht. 1938) Pocs et Borhidi 1960**
subass. *typicum*
subass. *caricetosum flaccae* Škvorc 2006
***Festuco drymeiae-Fagetum* Cimperšek 1988 emend. Cerovečki 2002**
subass. *luzuletosum* Baričević 2002
subass. *caricetosum pilosae* Baričević 2002

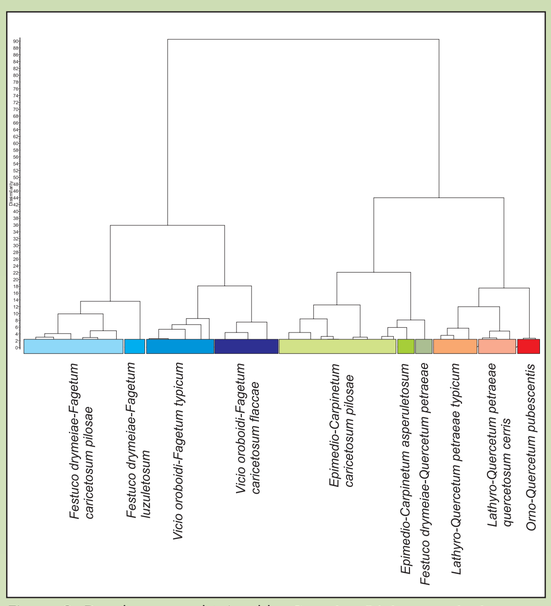

Figure 2. Dendrogram obtained by Complete Linkage method

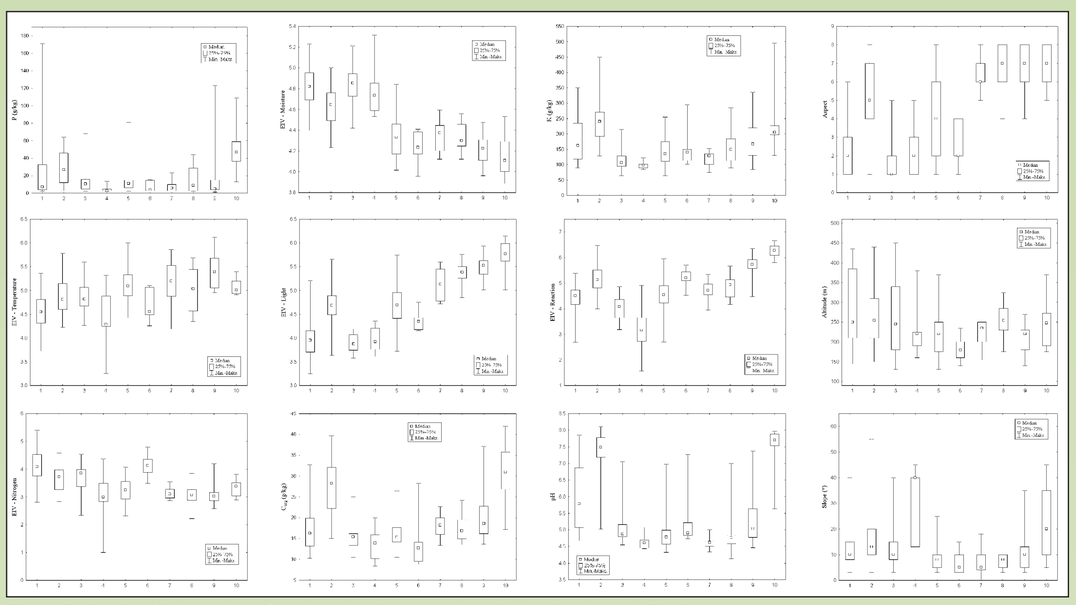

Figure 3. Box & Whiskers plots of analysed environmental variables. See legend Fig. 1

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