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PLANT DIVERSITY OF SELECTED *Quercus robur* L. AND *Quercus petraea* (Matt.) Liebl. FORESTS IN SLOVENIA

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Abstract

In Slovenia, the plant species diversity on 225 research plots dominated by pedunculate oak (*Quercus robur* L.) and by sessile oak (*Quercus petraea* (Matt.) Liebl.) has been analysed. Plots of *Q. robur* are located in five, and plots of *Q. petraea* in four semi-natural managed forest complexes. In the tree layer, 28 species were found beside the dominant two oak species, with *Carpinus betulus* L., *Picea abies* (L.) Karst., *Quercus cerris* L. and *Fagus sylvatica* L. having significant shares of growing stock. Based on the understorey vegetation (shrub and herb layer, terricolous mosses), the Detrended Correspondence Analysis (DCA) made a clear distinction between plots with dominant *Q. robur* and those with *Q. petraea*. The understorey vegetation also proved to be a valuable indicator of the site conditions and of forest management in the past. Based on ordination, lowland pedunculate oak forests of relatively long standing near to natural management have been separated from the pedunculate oak forests where spruce was favoured by the forest management, and from the man-made pedunculate oak stands on primary sites of *Q. petraea*. DCA clearly differentiated the sessile oak forests in warmer climate of Sub-Mediterranean region, and in warmer meso-sites of Pre-Pannonian region from other sessile oak forests. The main gradients of vegetation structure and of species diversity, as well main ecological gradients in different oak forests were obtained by ordination technique.

Key words: floristic composition, vegetation structure, biodiversity, growing stock, *Quercus robur, Quercus petraea*, DCA, Slovenia

RASTLINSKA VRSTNA DIVERZITETA IZBRANIH DOBOVIH IN GRADNOVIH GOZDOV V SLOVENIJI

Izvleček

Na 225 raziskovalnih ploskvah v dobovih (Quercus robur L.*) in gradnovih (Quercus petraea* (Matt.) Liebl.*) gozdovih smo analizirali rastlinsko vrstno pestrost. Dobove ploskve so postavljene v petih, gradnove pa v štirih gospodarjenih gozdnih kompleksih. V drevesni plasti preučevanih gozdnih ekosistemov se poleg dominantnih vrst hrasta pojavlja še 28 vrst, med katerimi so v lesni zalogi bolj zastopani beli gaber (Carpinus betulus L.), smreka (Picea abies (L.) Karst.), cer (Quercus cerris L.) in bukev (Fagus sylvatica L.). Ordinacija DCA (Detrended Correspondence Analysis) je samo na osnovi vrst v pritalnih plasteh vegetacije (grmovna in zeliščna plast, na tleh rastoči mahovi) jasno ločila ploskve s prevladujočim dobom od ploskev z gradnom. Vrste pritalnih plasti so dober indikator rastiščnih razmer kot tudi gospodarjenja z gozdovi v preteklosti. Na tej osnovi je ordinacija ločila nižinske dobove gozdove z razmeroma sonaravnim gospodarjenjem v daljšem obdobju od dobovih gozdov, v katerih so v preteklosti pospeševali smreko, in od umetno zasnovanega dobovega gozda na primarnih rastiščih gradna. Analiza je ločila tudi gradnov gozd, ki uspeva v toplejšem podnebju v submediteranskem območju, in gradnov gozd na toplejših rastiščih v predpanonskem območju od preostalih dveh gradnovih gozdov. Ordinacija raziskovalnih ploskev dobro odseva razlike v floristični sestavi hrastovih gozdov, nakazuje gradiente pestrosti pritalnih plasti vegetacije in glavne ekološke gradiente.*

Ključne besede: floristična sestava, struktura vegetacije, biodiverziteta, lesna zaloga, Quercus robur, Quercus petraea, DCA, Slovenia

INTRODUCTION
UVOD

Biodiversity has become an increasingly popular topic within the discussion of sustainability in the last decade, though the maintenance of diversity of forest ecosystems has been required for many years (SWINDEL / CONDE / SMITH 1984, SCHULER 1998). Biodiversity and heterogeneous vegetation structure play an important role in stable forests.

Biodiversity changes could be a valuable indicator of global warming too. Global warming is altering the distribution and abundance of plants. Application of a basic law of ecology predicts that many species will vanish if temperatures continue to rise (POUNDS / PUSCHENDORF 2004). Many forest understorey plants are sensitive indicators of environmental changes (ØKLAND et al. 2004).

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High biodiversity based on high variability of forest sites is one of the main characteristics of the European lowland oak forests. The lowland oak forests and other floodplain forest ecosystems could be considered as being biodiversity hotspots in Europe. However, due to human impact, which results from their vicinity to settlements, these forests are one of the most altered forest communities in Europe. Additionally, strong sources of air pollutants or changes of groundwater level and other causes diminish the stability and resistance of lowland forests. The floodplain forest ecosystems, especially oak forests throughout Europe, have always been under heavy anthropogenic impact (KLIMO / HAGER 2001).

In Slovenia, as a main or admixed tree species five autochthonous oak species (*Quercus robur agg.*, *Q. petraea agg.*, *Q. cerris, Q. pubescens*, *and Q. ilex*) represent less than 8 % of the total growing stock (SMOLEJ / HAGER 1995). The oak forests grow mostly in the lowland areas and their hilly margins, where the abundance of forest cover is low, but human population density is high. The greatest threat to native biodiversity of lowland oak forests is the loss and fragmentation of natural habitats.

Generally speaking, the loss and degradation of remnant native vegetation results in the loss of biodiversity. One of the significant threats to native biological diversity of floodplain forests and other lowland forests are invasions caused by alien species (KLIMO / HAGER 2001).

In Slovenian lowlands, there has been a noticeable decline and physiological weakening of pedunculate oak (*Quercus robur*), connected with dry climate, unfavourable precipitation patterns and human influences through hydromeliorations and changes in the water table (ČATER / LEVANIČ 2004).

Many studies of oaks in Slovenia from different aspects have been done, such as phytosociological (e.g. ACCETTO 1974, PUNCER / ZUPANČIČ 1979, ŠUGAR et al. 1995, DAKSKOBLER 1997, ZUPANČIČ 1997), from phytoindication aspects (SMOLE 1993, SMOLE / KUTNAR 1994a, 1994b, KUTNAR 1997), from ecophysiological aspects (ČATER / SIMONČIČ / BATIČ 1999, ČATER / BATIČ 1999, 2000), from morphological aspect (SMOLE / BATIČ 1992, BATIČ et al. 1997, TRAJBER et al. 2001), from morphological and genetic aspects (BATIČ / SINKOVIČ / JAVORNIK 1995, BREZNIKAR et al. 2000), and from many others (e.g. SMOLEJ / HAGER 1995, ROGL et al. 1996, ČATER / KUTNAR / ACCETTO 2001, ČATER / LEVANIČ 2004). These studies did not focus much on the evaluation of oak forest biodiversity in a narrow sense, and related vegetation-stand structure as a crucial component of stable forests.

The aim of our study was to determine biodiversity and the main gradients of the vegetation structure of selected pedunculate oak (*Quercus robur* L.) and sessile oak (*Quercus petraea* (Matt.) Liebl.) forests in Slovenia.

MATERIAL AND METHODS
MATERIAL IN METODE

STUDY AREA AND RESEARCH PLOTS
ŠTUDIJSKO OBMOČJE IN RAZISKOVALNE METODE

A total of nine oak forest complexes were selected in different parts of Slovenia (SMOLEJ 1995). All nine oak complexes are semi-natural managed forests. Five forest complexes of pedunculate oak (*Quercus robur* L.) are located mostly in the eastern part of Slovenia (Fig. 1): I. Polom, II. Krakovski gozd, III. Dobrava, IV. Cigonca, V. Hraščica.

Four forest complexes of sessile oak (*Quercus petraea* (Matt.) Liebl.) are more dispersed (Fig. 1): 1. Panovec, 2. Bojanci, 3. Pišece, 4. Bukovnica.

Most of the *Q. robur* complexes are located in the floodplains of rivers on the margins of Pannonian basin (SMOLEJ 1995). On the *Q. robur* complexes deep hydromorphic soil prevails (KALAN 1995), which developed under the influence of either water-logging above less permeable soil layers (pseudogley soils) or of a high groundwater-table (gley soils – amphigleys and hypogleys). The exception is the Polom complex, which differs from the others essentially. It lies in the rolly permeable lime hill country near Kočevje, where some surface waterflow can appear occasionally, but there is no direct groundwater influence. The selected *Q. petraea* complexes are placed on more or less permeable hilly terrain with very different types of forest soils out of direct groundwater influences.

Due to ecological regions in Slovenia (KUTNAR et al. 2002), all complexes of *Q. robur* except Polom are located in different sub-regions of the Pre-Pannonian region. The Polom complex lies in the Pre-Dinaric region. The three of four *Q.*

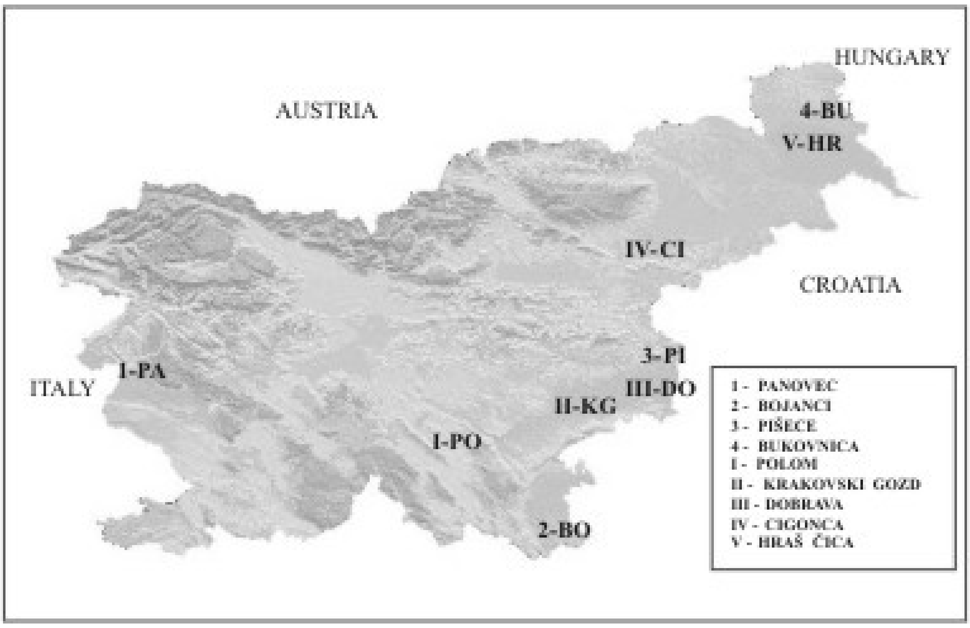

Fig. 1: Location of the oak forest research complexes in Slovenia

Slika 1: Položaj hrastovih raziskovalnih kompleksov v Sloveniji

petraea complexes are located in different parts of the Pre-Pannonian region. The exception is Panovec complex that is situated in the Sub-Mediterranean region.

The potential natural forest vegetation of complexes has been described (SMOLE 1993, 1995, SMOLE / KUTNAR 1994a, 1994b). The Polom complex was described as a potential site of sessile oak-beech forest *Hedero-Fagetum* KOŠ. (62, 79) 94 nom.nov. (syn.: *Querco-Fagetum* KOŠ.62). The vegetation of the Dobrava, Cigonca and Hraščica complexes were described as forests of pedunculate oak and hornbeam *Querco roboris-Carpinetum* SOÓ 40. The Krakovski gozd complex belongs to the *Pseudostellario-Quercetum roboris* ACC.73 association.

The Panovec complex belongs to the Sub-Mediterranean oak forests *Carici umbrosae-Quercetum petraeae* POLD. 82 var. geogr. *Sesleria autumnalis* DAKS.87. The forest of the Bojanci complex was described as an association of *Epimedio-Carpinetum* (HT.38) BORH.63. The Pišece complex lies in a region of potential beech forest (*Hacquetio-Fagetum* KOŠ.62 var. geogr. *Ruscus hypoglossum* (MAR.& ZUP.78) KOŠ.79), and the Bukovnica in region of potential hornbeam forest (*Pruno padi-Carpinetum betuli* (MAR. & ZUP.84) MAR.94).

Each quadratic (100×100 metres) complex (Fig. 1) was divided in 25 square (20×20 metres) plots (SMOLEJ 1995).

FIELD SAMPLING
TERENSKO DELO

Trees with diameter at breast high (DBH) exceeding 10 centimetres were taken into account (AZAROV 1995). The understorey vegetation of the research plots was surveyed according to the standard Central European method (BRAUN-BLANQUET 1964). The cover of all species in shrub, herb and moss layer (only terricolous mosses) was estimated. The cover of the young trees (DBH <10 cm) was estimated in the same way as other plants in understorey layers. The sources of the nomenclature were MARTINČIČ et al. (1999) for vascular plants; MARTINČIČ (2003) for mosses.

DATA ANALYSIS
ANALIZA PODATKOV

The vegetation of 225 research plots was analysed. On all research plots, based on phytosociological relevés of the understorey vegetation, the following parameters were calculated:

a) species richness (S),

b) sum of cover estimations of all species per plot,

c) mean species cover,

d) Shannon [$H' = - \Sigma (p_i \log (p_i))$] diversity index,

e) Simpson [$D = 1 - \Sigma p_i^2$] diversity index, and

f) Evenness [$E = H'/\ln (S)$];

p_i – share of plant species of total.

Based on field measurement, the growing stock of trees was analysed by AZAROV (1995). We also calculated the number of trees per plot and the number of different tree species. Based on the results of AZAROV (1995), we estimated the total growing stock (GS) and growing stock of the most common tree species: *Quercus robur* L., *Quercus petraea* (Matt.) Liebl., *Carpinus betulus* L., *Fagus sylvatica* L., *Picea abies* (L.) Karst., *Acer campestre* L., *Quercus cerris* L., *Alnus glutinosa* (L.) Gaertn., and *Tilia cordata* Mill.

The main structure gradients of vegetation were extracted by the detrended correspondence analysis (DCA) (HILL / GAUCH 1980). The floristic composition was used as a criterion for ordination of the research plots. The DCA was carried out with the PC-ORD program (McCUNE / MEFFORD 1999). The Spearman correlation coefficients were calculated between the DCA axes (plot scores) and: a) tree layer parameters; b) understorey (shrub, herb, moss) vegetation parameters;

RESULTS AND DISCUSSION
REZULTATI IN RAZPRAVA

On 225 research plots, a total of 30 tree and shrub species with a diameter at breast high over 10 centimetres were found. The most common tree species are following (in parentheses are numbers of research plots with their presence): *Quercus robur* (124 plots), *Quercus petraea* (100), *Carpinus betulus* (90), *Fagus sylvatica* (56), *Picea abies* (50), *Acer campestre* (42), *Quercus cerris* (18), *Alnus glutinosa* (16), and *Tilia cordata* (16). Other less common tree and shrub species with a diameter at breast high over 10 centimetres are following (order of precedence is due to frequency of species): *Pinus nigra*, *Pyrus pyraster*, *Sorbus torminalis*, *Prunus avium*, *Crataegus monogyna*, *Pinus sylvestris*, *Ostrya carpinifolia*, *Fraxinus ornus*, *Larix decidua*, *Populus tremula*, *Acer pseudoplatanus*, *Abies alba*, *Sorbus aria*, *Fraxinus excelsior*, *Betula pendula*, *Acer platanoides*, *Ulmus glabra*, *Crataegus laevigata*, *Ulmus laevis*, *Corylus avellana* and *Ilex aquifolium*. The total number of trees and shrubs with a diameter at breast high over 10 centimetres was 4,003. On average, almost 18 individual trees (shrubs) (DBH>10 cm) per 20×20 metres plot were found. The number of individual trees (shrubs) per plot ranges between 4 and 35. The estimation of total growing stock per plot varies from 5.1 to 48.8 m^3.

Based on the floristic composition (presence/absence), nine oak-forest complexes are well-separated in the plot ordination space (Figs. 2, 3, 4). DCA analysis clearly differentiates between the *Quercus robur* and the *Q. petraea* dominated plots respectively. In DCA1 vs. DCA2 ordination (Figs. 2 and 3), plots of *Quercus robur* are below the diagonal of graph (start from point DCA1=0, DCA2=0), and plots of *Q. petraea* are above this diagonal.

As a result of similarity of floristic composition (Figs. 2 and 3), in 3-D ordination space, the Dobrava and Cigonca plots are grouped close together. There are swamped, gleyed soils resulting from impact of high groundwater-table. The Hraščica and Krakovski gozd plots are quite similar in floristic composition (Fig. 2). However, in 3-D ordination space (Fig. 3), significant differences between these plots are shown (Krakovski gozd plots obtained higher DCA3 scores than Hraščica plots). It is mainly a result of different soil conditions of these plots (KALAN 1995). On the Hraščica plots, eutric brown soils were found, and gleyed swampy soils were found on the Krakovski gozd plots. As a result of intensive groundwater influence on the Krakovski gozd, Cigonca and Dobrava plots, the similarity in Figure 3 is shown.

Due to differences in site and climate conditions, the third DCA axis segregates the Bojanci plots from the Bukovnica plots. The Panovec and Pišece plots obtain low scores along the DCA1 axis (Figs. 2 and 3). Resulting from similar local climate conditions, they lie close together in ordination space. Although they originate from different parts, their floristic composition shows quite similar site conditions. Due to relative humidity and cold soils on the flysch of Panovec plots, as well due to moderate northern exposure of plots, the effect of the warm Mediterranean climate is not so pronounced. However, the Pišece plots are situated on very warm southern slopes in the Pre-Pannonian region.

In the Polom region, the *Q. robur* acorns were an important nutrition source for domestic pigs in the past (SMOLEJ 1995). Thus, in this region the forest stands dominated by the *Q. robur* are man-made. The oak trees are growing under conditions in which groundwater has no direct influence. Potentially, the Polom region is site of mixed forest of *Q. petraea* and *Fagus sylvatica*. Consequently, the understorey vegetation of the Polom plots is more similar to that on plots overgrown with *Q. petraea* forests than with *Q. robur* forests. Therefore, the Polom plots lie quite closer to *Q. petraea* plots in ordination space (Figs. 2 and 3).

Vectors of *Q. robur* and of *Q. petraea* show an increase in the growing stock of these two tree species (Figs. 2 and 3). Based only on the floristic composition of understorey layers, the differentiation between *Q. robur* and *Q. petraea* dominated plots has been confirmed. The understorey vegetation has indicated very specific site conditions of plots.

Besides similar floristic composition, the Cigonca and Dobrava plots have significant shares of *Picea abies* in the tree layer (Figs. 2 and 3). In last decades, the Norway spruce has been favoured by forest management. The significant positive correlation was found between the first DCA axis and the growing stock of *Picea abies* (Table 1).

Apart from these tree species, in DCA analysis (Fig. 3) only the vector of the growing stock of *Fagus sylvatica* is shown. The growing stock of beech was found to increase towards the Bukovnica plots. Among the nine common tree species that have been analysed (Table 1), the weak negative correlation between the DCA2 axis and *Carpinus betulus* growing stock, and between the DCA2 and *Acer campestre* growing stock is also shown.

The number of different tree species increases slightly towards plots in lower parts of the DCA ordination space (Fig. 2, Table 1).

In the understorey vegetation layers, a total of 256 species was recorded. On average, 31 plant species per plot were

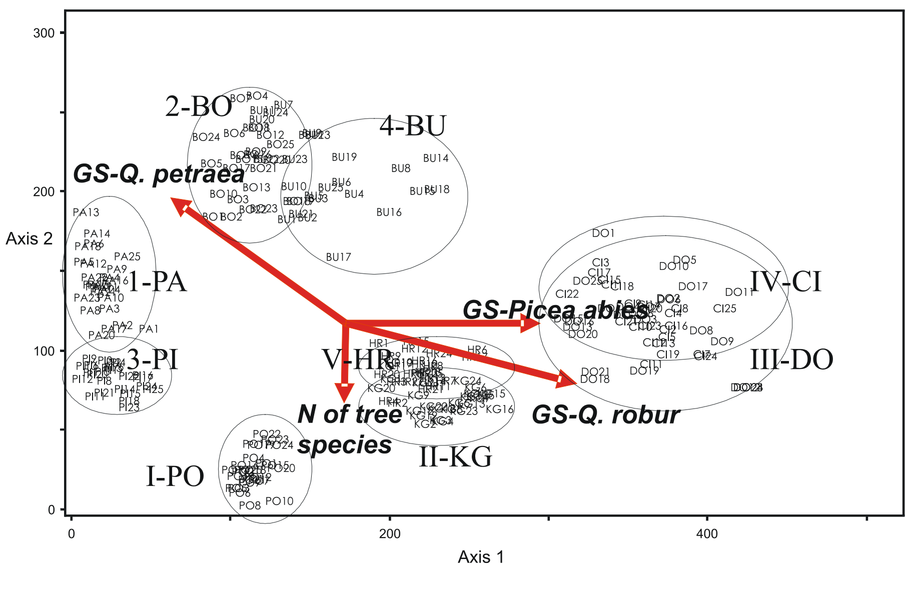

Fig. 2: DCA analysis of research plots and vectors of tree layer parameters (Axis 1 vs. Axis 2)

Slika 2: DCA-analiza raziskovalnih ploskev in vektorji parametrov drevesne plasti (os 1: os 2)

Legend. *Q. robur* complexes : PO-Polom (I), KG-Krakovski gozd (II), DO-Dobrava (III), CI-Cigonca (IV), HR-Hraščica (V); *Q. petraea* complexes: PA-Panovec (1), BO-Bojanci (2), PI-Pišece (3), BU-Bukovnica (4); GS-*Q. robur* (-*Q. petraea*, -*Picea abies*) – growing stock of *Q. robur* (*Q. petraea*, *Picea abies*)

Legenda. Kompleks doba Q. robur: PO-Polom (I), KG-Krakovski gozd (II), DO-Dobrava (III), CI-Cigonca (IV), HR-Hraščica (V); Kompleks gradna Q. petraea: PA-Panovec (1), BO-Bojanci (2), PI-Pišece (3), BU-Bukovnica (4); GS-Q. robur (-Q. petraea, -Picea abies) – lesna zaloga Q. robur (Q. petraea, Picea abies) found. The number of species per plot ranges between 4 and 70.

On all 225 research plots, *Carpinus betulus* is the most frequent plant species of understorey vegetation that is present on 173 research plots (Appendix 1). Other very common plant species are *Acer campestre* (129 plots) and *Prunus avium* (128 plots). In the understorey vegetation, the dominant tree species *Quercus robur* (113 plots) and *Quercus petraea* (94 plots) are also frequent. Other common woody plant species are *Corylus avellana* (109), *Ligustrum vulgare* L. (90), *Crataegus monogyna* Jacq. (86), and *Euonymus europaea* L. (83).

The herb species with high frequencies are *Anemone nemorosa* L. (124), *Athyrium filix-femina* (L.) Roth (116), *Polygonatum multiflorum* (L.) All. (111), *Viola reichenbachiana* Jord. ex Boreau (94), *Carex brizoides* L. (90), *Galium sylvaticum* L. (85), and *Ajuga reptans* L. (80).

Species richness was found to increase towards the Polom plots (Fig. 4), where the mean number of species in the understorey layers is 62 (Appendix 2). On average, a high number of species has been found on the Pišece plots (49 species/plot), and on the Krakovski gozd plots (45 species/plot). On the Dobrava and on Cigonca plots, we found very few species (9 and 12 species/plot).

Due to the high number of species, and due to the relative balance of their cover, the Polom, Pišece, and Krakovski gozd plots have high diversity indexes (H' and D), and the evenness index (E) is also high on these plots (Appendix 2). Due to the predominance of *Corylus avellana* in the shrub layer of the Polom plots, evenness is slightly lower on these plots than on the plots of other two complexes.

The mean species cover increases towards the Dobrava and Cigonca plots (Fig. 4), with positive correlation with the first DCA axis (Table 1). Besides the low number of species, the majority of these plots are completely overgrown by *Carex brizoides*.

The sum of all species cover is high on the Polom and Krakovski gozd plots. These are plots with a high number of species in the herb layer, and in the shrub layer as well.

CONCLUSIONS
ZAKLJUČKI

Research of oak forest ecosystems in Slovenia (SMOLEJ / HAGER 1995) was supposed to explain most of the predominating factors (e.g. drought, frost, air pollution) in the process of oak decline, and was a contribution to the wider

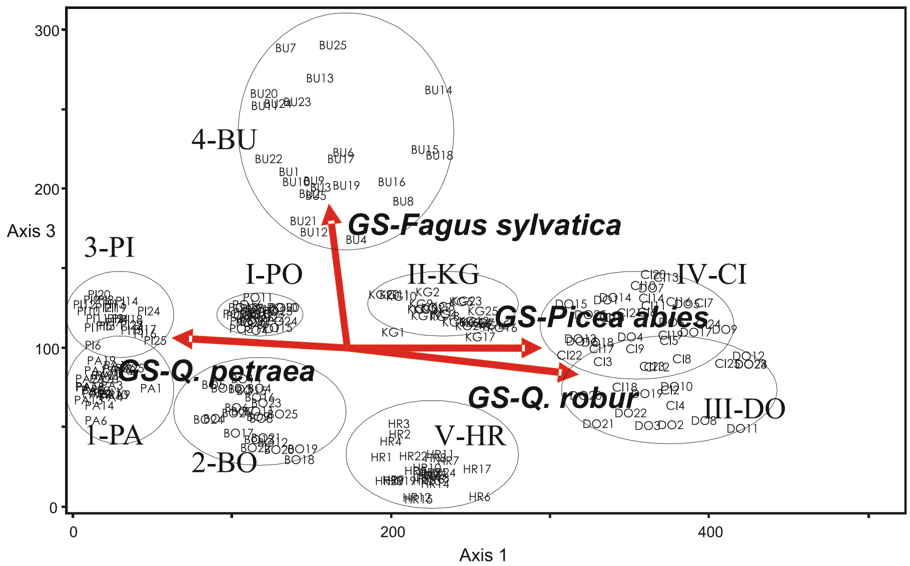

Fig. 3: DCA analysis of research plots and vectors of tree layer parameters (Axis 1 vs. Axis 3)

Slika 3: DCA-analiza raziskovalnih ploskev in vektorji parametrov drevesne plasti (os 1: os 3)

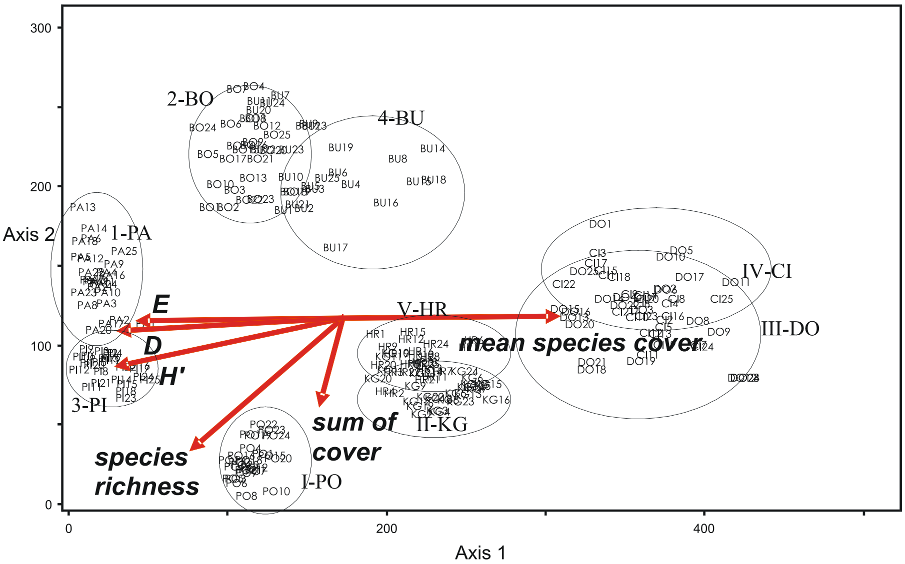

Fig. 4: DCA analysis of research plots and parameters of understorey vegetation (Axis 1 vs. Axis 2)

Slika 4: DCA-analiza raziskovalnih ploskev in parametri pritalnih plasti vegetacije (os 1: os 2)

Legend. *Q. robur* complexes: PO-Polom (I), KG-Krakovski gozd (II), DO-Dobrava (III), CI-Cigonca (IV), HR-Hraščica (V); *Q. petraea* complexes: PA-Panovec (1), BO-Bojanci (2), PI-Pišece (3), BU-Bukovnica (4);

E - Evenness index, H' - Shannon diversity index, D - Simpson diversity index.

Legenda. Kompleks doba Q. robur: PO-Polom (I), KG-Krakovski gozd (II), DO-Dobrava (III), CI-Cigonca (IV), HR-Hraščica (V); Kompleks gradna Q. petraea: PA-Panovec (1), BO-Bojanci (2), PI-Pišece (3), BU-Bukovnica (4);

E – indeks poravnanosti; H' – Shannonov indeks pestrosti, D – Simpsonov indeks pestrosti.

ecological understanding of oaks and oak sites in Slovenia as a part of the wider area of oak forest communities in Europe.

In the present study, the biodiversity and vegetation structure of oak forests in Slovenia have been analysed. The importance of conserving biodiversity for a sustainable future is widely accepted. Areas of remnant native vegetation support a range of biodiversity.

Our attention has been focused on species diversity in relation to forest stand structure. With the ordination technique, the diversity of the vegetation structure of different oak forests was obtained. The ordination has differentiated clearly between plots dominated by *Q. robur*, and those with *Q. petraea*. Due to specific site conditions and human influences, the differences in biodiversity of understorey vegetation and tree layer parameters have been shown as well. With the ordination of oak forest based on the floristic composition, the main ecological gradients were also indicated (e.g. soil-moisture gradient). Warmer oak sites (Panovec and Pišece plots) are clearly separate from the other oak forests of mesic conditions.

The plant species diversity proved to be a valuable indicator of the site conditions and of forest management in the past as well.

Although heavy anthropogenic impacts have been present in the past, a variety of oak forests still exists in Slovenia. The *Quercus robur* and *Quercus petraea* dominated forests create a wide range of different types with heterogeneous vegetation structure. In the studied oak forests, a high number of tree-layer species and high species richness of understorey layers have been recorded. But in some cases, such as Dobrava and Cigonca plots, forest management practices in the past could be one of the reasons for significant biodiversity impoverishment. Forest management practices often have a major impact on biodiversity, causing changes to site conditions, tree species composition and forest structure (MITCHELL / KIRBY 1989).

Table 1: Spearman rank correlations between DCA scores and 1) tree layer parameters, 2) understorey vegetation parameters.

Preglednica 1: Spearmanova korelacija rangov med DCA-koordinatami in 1) parametri drevesne plasti, 2) parametri pritalnih plasti vegetacije

Spearman R	DCA1		DCA2		DCA3	
1)						
NUMBER OF TREES (STEMS) / *ŠTEVILO DREVES*	-0,259	***	0,006	/	-0,024	/
NUMBER OF TREE SPECIES / *ŠTEVILO DREVESNIH VRST*	0,010	/	-0,487	***	0,298	***
TOTAL GROWING STOCK (GS) / *CELOTNA LESNA ZALOGA (LZ)*	0,367	***	-0,026	/	-0,047	/
GS / LZ - Quercus robur	0,770	***	-0,408	***	-0,133	*
GS */ LZ - Quercus petraea*	-0,694	***	0,547	***	0,069	/
GS */ LZ - Quercus cerris*	-0,367	***	-0,221	***	0,122	/
GS / LZ - Carpinus betulus	0,264	***	-0,516	***	-0,106	/
GS */ LZ - Acer campestre*	0,001	/	-0,421	***	0,014	/
GS */ LZ - Alnus glutinosa*	0,307	***	-0,167	*	0,132	*
GS */ LZ - Fagus sylvatica*	-0,295	***	0,342	***	0,443	***
GS */ LZ - Picea abies*	0,707	***	0,112	/	0,022	/
GS */ LZ - Tilia cordata*	-0,154	*	-0,323	***	0,082	/
2)						
SPECIES RICHNESS (S) / *VRSTNO BOGASTVO (S)*	-0,617	***	-0,602	***	0,060	/
SUM OF SPECIES COVER / *SEŠTEVEK ZASTIRANJA VSEH VRST*	-0,299	***	-0,461	***	-0,154	*
MEAN SPECIES COVER /*POVPREČNA STOPNJA ZASTIRANJA NA VRSTO*	0,614	***	0,143	*	-0,395	***
EVENNESS (E) /*INDEKS PORAVNANOSTI (E)*	-0,571	***	-0,164	*	0,276	***
SHANNON DIVERSITY INDEX (H') / *SHANNONOV DIVERZITETNI INDEKS (H')*	-0,627	***	-0,506	***	0,130	/
SIMPSON DIVERSITY INDEX (D) / *SIMPSONOV DIVERZITETNI INDEKS (D)*	-0,617	***	-0,422	***	0,142	*

SUMMARY
POVZETEK

Velika biodiverziteta v povezavi z raznolikostjo gozdnih rastišč je ena izmed značilnosti nižinskih hrastovih gozdov v Evropi. Po drugi strani pa so ti gozdovi zaradi neposrednih človekovih vplivov tudi med najbolj ogroženimi in spremenjenimi. Nižinski poplavni gozdovi in še posebej hrastovi gozdovi so bili vseskozi pod močnimi antropogenimi pritiski (KLIMO / HAGER 2001).

Pet avtohtonih vrst hrasta (*Quercus robur agg.*, *Q. petraea agg.*, *Q. cerris, Q. pubescens in Q. ilex*) v Sloveniji sestavlja manj kot 8 % celotne lesne zaloge (SMOLEJ / HAGER, 1995). Večina hrastov uspeva v nižinah in gričevnatem obrobju, kjer je delež gozdov razmeroma majhen, gostota prebivalstva pa največja.

Biodiverziteta ima poseben pomen pri trajnostnemu gospodarjenju z gozdom. Vrstna diverziteta in heterogena struktura vegetacije sta pomembni za stabilno funkcioniranje gozdnih ekosistemov.

Namen raziskave je bil ugotoviti vrstno diverziteto in glavne strukturne gradiente vegetacije izbranih hrastovih gozdov v Sloveniji. V okviru raziskave smo analizirali sedanje stanje vegetacije, ki je rezultat dolgotrajne prilagoditve vegetacije na rastišče (vegetacija kot indikator rastiščnih razmer) in hkrati rezultat sprememb zaradi človekovega delovanja (vegetacija kot indikator gospodarjenja z gozdom).

V različnih delih Slovenije smo izbrali devet gozdnih kompleksov (SMOLEJ 1995). Vsi so v kategoriji gospodarskih gozdov. Večina od petih izbranih dobovih kompleksov (I. Polom, II. Krakovski gozd, III. Dobrava, IV. Cigonca, V. Hraščica) leži v vzhodnem delu Slovenije (slika 1). Štirje gra-

dnovi kompleksi (1. Panovec, 2. Bojanci, 3. Pišece, 4. Bukovnica) pa so bolj raztreseni.

Raziskovalni kompleksi velikosti 100×100 metrov so bili razdeljeni na 25 kvadratnih (20×20 m) ploskev (SMOLEJ 1995).

V študiji smo posebej obravnavali drevesno plast na eni strani in pritalne plasti vegetacije (grmovna, zeliščna in mahovna) na drugi strani. V drevesni plasti so bili zajeti vsi osebki, katerih prsni premer je presegal 10 centimetrov. Na osnovi predhodne raziskave (AZAROV 1995) smo ugotovili lesno zalogo (LZ) po ploskvah in ocenili LZ najpogostejših drevesnih vrst *Quercus robur*, *Quercus petraea*, *Carpinus betulus*, *Fagus sylvatica*, *Picea abies*, *Acer campestre*, *Quercus cerris*, *Alnus glutinosa* in *Tilia cordata*. Poleg tega smo ugotovili število dreves (osebkov) in število različnih drevesnih vrst na vseh 225 ploskvah.

Vegetacijo pritalnih plasti smo popisali po standardni srednjeevropski metodi (BRAUN-BLANQUET 1964). Na tej osnovi smo ocenili stopnjo zastiranja vrst v grmovni, zeliščni in mahovni plasti (vključeni samo na tleh rastoči mahovi). V popis in oceno pritalnih plasti vegetacije smo vključili tudi drevesa, katerih prsni premer še ne presega 10 centimetrov. Na osnovi popisa pritalnih plasti vegetacije smo za vsako ploskev izračunali vrstno bogastvo, seštevek zastiranja vseh vrst, povprečno stopnjo zastiranja na vrsto, indeks poravnanosti (E), Shannonov diverzitetni indeks (H') in Simpsonov diverzitetni indeks (D).

Glavne strukturne gradiente smo analizirali z ordinacijo DCA (*Detrended Correspondence Analysis*) (HILL / GAUCH 1980), ki je temeljila na floristični sestavi raziskovalnih ploskev. Analiza je bila napravljena z računalniškim paketom PC-ORD (McCUNE / MEFFORD 1999). Izračunali smo tudi Spearmanovo korelacijo rangov med DCA-koordinatami in: a) parametri drevesne plasti; b) parametri pritalnih plasti vegetacije.

Na 225 raziskovalnih ploskvah smo ugotovili 30 drevesnih in grmovnih vrst s prsnim premerom nad 10 centimetrov. Najpogostejše vrste v drevesni plasti (v oklepaju je število ploskev, na katerih se pojavljajo) so *Quercus robur* (124 ploskev), *Quercus petraea* (100), *Carpinus betulus* (90), *Fagus sylvatica* (56), *Picea abies* (50), *Acer campestre* (42), *Quercus cerris* (18), *Alnus glutinosa* (16) in *Tilia cordata* (16).

Druge manj pogoste drevesne in grmovne vrste s prsnim premerom nad 10 centimetrov so (vrstni red v skladu s frekvenco pojavljanja dreves po ploskvah): *Pinus nigra*, *Pyrus pyraster*, *Sorbus torminalis*, *Prunus avium*, *Crataegus monogyna*, *Pinus sylvestris*, *Ostrya carpinifolia*, *Fraxinus ornus*, *Larix decidua*, *Populus tremula*, *Acer pseudoplatanus*, *Abies alba*, *Sorbus aria*, *Fraxinus excelsior*, *Betula pendula*, *Acer platanoides*, *Ulmus glabra*, *Crataegus laevigata*, *Ulmus laevis*, *Corylus avellana* in *Ilex aquifolium*. Na vseh ploskvah smo evidentirali 4003 dreves (grmov), ki so presegali merski prag. Število dreves (grmov) na ploskev se giblje med 4 in 35 (povprečno skoraj 18). Ocena LZ na ploskev se giblje med 5 in 49 m^3.

Ordinacija DCA je samo na osnovi floristične sestave (prisotnost/odsotnost) pritalnih plasti vegetacije jasno ločila komplekse s prevladujočim dobom (pod diagonalo na slikah 2 in 3) od kompleksov s prevladujočim gradnom (nad diagonalo).

Zaradi floristične podobnosti se ploskve dobovih kompleksov Dobrava in Cigonca, ki se pojavljajo na močvirnih, oglejenih tleh kot rezultat vpliva visoke podtalnice, v ordinaciji nahajajo skupaj (slika 2 in 3). Razmeroma podobna sta si tudi dobova kompleksa Hraščica in Krakovski gozd (slika 2), vendar pa se določene razlike pokažejo s tretjo ordinacijsko osjo (slika 3). Razlike v floristični sestavi lahko v veliki meri povežemo z razlikami v tleh. V kompleksu Hraščica prevladujejo evtrična rjava tla, medtem ko so tla v Krakovskem gozdu neprimerno bolj izpostavljena procesom oglejevanja zaradi vpliva podtalnice (KALAN 1995).

Gradnova kompleksa Panovec in Pišece sta si v primerjavi z drugimi gradnovi kompleksi najbolj podobna, čeprav ležita v povsem različnih delih Slovenije (sliki 2 in 3). Podobnost je posledica razmeroma podobnih mezo-rastiščnih razmer. Pri prvem vpliv toplega mediteranskega podnebja ne prihaja do izraza zaradi razmeroma hladnih in vlažnejših flišnih tal ter zmerne severne ekspozicije. Drugi pa leži na toplih južnih legah v predpanonskem območju. Razlike v floristični sestavi med gradnovima kompleksoma Bojanci in Bukovnica, ki so posledica rastiščno-podnebnih razlik, se pokažejo s tretjo ordinacijsko osjo (slika 3).

Dobov kompleks Polom je bil osnovan na potencialnih rastiščih mešanih gozdov gradna in bukve. Dob so pospeševali zaradi želoda, ki je bil v preteklosti pomemben vir prehrane domačih prašičev (SMOLEJ 1995). Pritalne plasti vegetacije kompleksa Polom kažejo na večjo floristično podobnost z gradnovimi kot dobovimi kompleksi.

Delitev med gradnovimi in dobovimi kompleksi samo na osnovi floristične sestave (prisotnost/odsotnost) pritalnih plasti vegetacije potrjujejo tudi vektorji naraščanja lesne zaloge glavnih dveh drevesnih vrst, doba in gradna. Vegetacija nakazuje specifične razlike v rastiščnih razmerah dobovih in gradnovih gozdov. Podobnost v rastiščnih razmerah ploskev Cigonca in Dobrava se kaže v floristični sestavi. Hkrati pa je podobna sestava vegetacije lahko deloma tudi posledica podobnega načina gospodarjenja v preteklosti, ki je močno pospeševal smreko, kar nakazuje tudi vektor naraščanja lesne zaloge smreke proti tema kompleksoma.

V pritalnih plasteh vegetacije smo našli 256 rastlinskih vrst. Število vrst na ploskev se giblje med 4 in 70 (povprečno 31 vrst/ploskev). V pritalnih plasteh smo na največjem številu ploskev našli navadni gaber *Carpinus betulus* (173 ploskev). Druge pogoste lesnate rastline v pritalnih plasteh so maklen *Acer campestre* (129 ploskev), češnja *Prunus avium* (128), dob *Quercus robur* (113), navadna leska *Corylus avellana* (109) in graden *Quercus petraea* (94).

Zeliščne vrste z veliko frekvenco pojavljanja so podlesna vetrnica *Anemone nemorosa* (124), navadna podborka *Athyrium filix-femina* (116), mnogocvetni salomonov pečat *Polygonatum multiflorum* (111), gozdna vijolica *Viola reichenbachiana* (94), migalični šaš *Carex brizoides* (90), gozdna lakota *Galium sylvaticum* (85) in plazeči skrečnik *Ajuga reptans* (80).

Vektor vrstnega bogastva je usmerjen proti kompleksu Polom, kjer smo v pritalnih plasteh vegetacije povprečno popisali 62 vrst na ploskev. Veliko število vrst smo našli tudi na ploskvah kompleksov Pišece (49 vrst/ploskev) in Krakovski gozd (45 vrst/ploskev). Število vrst je razmeroma majhno na ploskvah kompleksov Cigonca (12 vrst/ploskev) in Dobrava (9 vrst/ploskev).

Glede na veliko število vrst in njihovo medsebojno uravnoteženost smo za ploskve kompleksov Polom, Pišece in Krakovski gozd izračunali tudi velike vrednosti diverzitetnih indeksov (H' in D) ter indeksa poravnanosti (E). Slednji je sicer nekoliko manjši na ploskvah Poloma, kjer v grmovni plasti močno prevladuje leska. Povprečna stopnja zastiranja vrst na ploskev izrazito narašča proti kompleksoma Dobrava in Cigonca z značilnim majhnim številom vrst in močno prevladujočim migaličnim šašem.

V raziskavi smo dali poudarek biodiverziteti in vegetacijski strukturi izbranih hrastovih gozdov, ki sta pomembna elementa trajnostnega razvoja gozdnih ekosistemov.

S pomočjo ordinacijskih tehnik smo nakazali razlike med gozdovi doba in gradna ter nakazali glavne ekološke gradiente. Pestrost pritalne vegetacije v povezavi s sestojnimi parametri (vertikalna struktura) se je pokazala kot dober indikator specifičnih rastiščnih razmer in tudi gospodarjenja z gozdom v preteklosti.

Kljub močnim antropogenim pritiskom na hrastove gozdove v preteklosti in sedanjosti lahko pri nas še vedno najdemo razmeroma pestre gozdove doba in gradna z razgibano vegetacijsko strukturo. Zanje je na splošno značilno veliko število drevesnih vrst in veliko bogastvo vrst v pritalnih plasteh vegetacije.

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Appendix 1: Species of understorey vegetation (shrub, herb and moss layer) - presence per complexes (in the table only 163 species with presence on 10 or more research plots are shown; the total number of plant species is 256).

Priloga 1: Vrste pritalnih plasti vegetacije (grmovna, zeliščna in mahovna plast) - pojavljanje vrste po kompleksih (v preglednici je samo 163 vrst, ki se pojavljajo na 10 ali več raziskovalnih ploskvah; celotno število vrst je 256).

Legend: *Q. robur* complexes: PO-Polom (I), KG-Krakovski gozd (II), DO-Dobrava (III), CI-Cigonca (IV), HR-Hraščica (V); *Q. petraea* complexes: PA-Panovec (1), BO-Bojanci (2), PI-Pišece (3), BU-Bukovnica (4).

Legenda: komplex doba *Q. robur*: PO-Polom (I), KG-Krakovski gozd (II), DO-Dobrava (III), CI-Cigonca (IV), HR-Hraščica (V); komplex gradna *Q. petraea* complexes: PA-Panovec (1), BO-Bojanci (2), PI-Pišece (3), BU-Bukovnica (4).

		PO	KG	DO	CI	HR	PA	BO	PI	BU	sum	sum	sum
		I	II	III	IV	V	1	2	3	4	I-V	1-4	ALL
		N=25	N=25	N=25	N=25	N=25	N=25	N=25	N=25	N=25	N=125	N=100	N=225
1	Carpinus betulus L.	25	22	2	22	25	24	12	22	19	**96**	**77**	**173**
2	Acer campestre L.	24	24	0	0	25	24	7	25	0	**73**	**56**	**129**
3	Prunus avium L.	18	11	1	0	16	24	25	25	8	**46**	**82**	**128**
4	Anemone nemorosa L.	16	25	1	10	25	17	17	1	12	**77**	**47**	**124**
5	Athyrium filix-femina (L.) Roth	19	25	15	23	11	0	17	0	6	**93**	**23**	**116**
6	Quercus robur L.	25	22	16	25	25	0	0	0	0	**113**	**0**	**113**
7	Polygonatum multiflorum (L.) All.	25	25	1	7	17	2	14	0	20	**75**	**36**	**111**
8	Corylus avellana L.	25	25	5	0	13	2	25	14	0	**68**	**41**	**109**
9	Quercus petraea (Matt.) Liebl.	0	0	0	0	0	25	25	21	23	**0**	**94**	**94**
10	Viola reichenbachiana Jordan ex Boreau	21	12	3	0	24	20	2	10	2	**60**	**34**	**94**
11	Carex brizoides L.	0	25	25	25	15	0	0	0	0	**90**	**0**	**90**
12	Ligustrum vulgare L.	25	0	0	0	18	13	8	25	1	**43**	**47**	**90**
13	Crataegus monogyna Jacq.	25	0	0	0	0	25	11	25	0	**25**	**61**	**86**
14	Galium sylvaticum L.	11	0	0	0	0	25	25	21	3	**11**	**74**	**85**
15	Euonymus europaea L.	25	20	1	0	23	8	0	6	0	**69**	**14**	**83**
16	Ajuga reptans L.	22	10	5	0	22	8	1	6	6	**59**	**21**	**80**
17	Polytrichum formosum Hedw.	13	0	8	11	0	6	6	7	22	**32**	**41**	**73**
18	Sorbus torminalis (L.) Crantz	12	0	0	0	0	19	17	25	0	**12**	**61**	**73**
19	Fagus sylvatica L.	9	0	1	0	0	1	12	24	25	**10**	**62**	**72**
20	Rosa arvensis Huds.	19	4	0	0	0	24	0	25	0	**23**	**49**	**72**
21	Brachypodium sylvaticum (Huds.) P.Beauv.	13	6	0	0	0	21	5	25	0	**19**	**51**	**70**
22	Pulmonaria officinalis L.	21	0	0	0	24	3	0	22	0	**45**	**25**	**70**
23	Hieracium umbellatum L.	17	0	0	0	1	18	0	16	17	**18**	**51**	**69**
24	Galium odoratum (L.) Scop.	0	21	0	0	0	0	9	19	17	**21**	**45**	**66**
25	Carex sylvatica Huds.	11	9	0	0	14	9	7	11	4	**34**	**31**	**65**
26	Sanicula europaea L.	25	0	0	0	5	1	9	24	1	**30**	**35**	**65**
27	Cruciata glabra (L.) Ehrend.	25	3	0	0	0	15	11	10	0	**28**	**36**	**64**
28	Fraxinus ornus L.	0	0	0	0	0	25	13	25	0	**0**	**63**	**63**
29	Galeopsis speciosa Mill.	1	1	9	12	21	0	17	0	2	**44**	**19**	**63**
30	Cornus mas L.	21	22	0	0	0	0	19	0	0	**43**	**19**	**62**
31	Euphorbia dulcis L.	9	11	0	0	0	21	0	20	0	**20**	**41**	**61**
32	Viburnum opulus L.	21	8	0	0	3	5	13	11	0	**32**	**29**	**61**
33	Dryopteris carthusiana (Vill.) H.P.Fuchs	2	3	24	23	1	1	0	0	6	**53**	**7**	**60**
34	Rubus hirtus W. & K.	0	0	0	1	3	14	25	17	0	**4**	**56**	**60**

		PO	KG	DO	CI	HR	PA	BO	PI	BU	sum	sum	sum
		I	II	III	IV	V	1	2	3	4	I-V	1-4	ALL
		N=25	N=25	N=25	N=25	N=25	N=25	N=25	N=25	N=25	**N=125**	**N=100**	**N=225**
35	Symphytum tuberosum L.	15	17	0	0	0	3	9	14	2	**32**	**28**	**60**
36	Fragaria moschata (Duchesne) Weston	25	0	0	0	0	10	0	23	0	**25**	**33**	**58**
37	Lonicera caprifolium L.	0	0	2	0	20	25	0	11	0	**22**	**36**	**58**
38	Primula vulgaris Huds.	25	0	0	0	0	6	6	21	0	**25**	**33**	**58**
39	Tilia cordata Mill.	25	0	0	0	0	1	24	7	0	**25**	**32**	**57**
40	Pyrus pyraster (L.) Burgsd.	21	2	0	0	1	5	2	25	0	**24**	**32**	**56**
41	Serratula tinctoria L.	0	0	0	0	1	25	5	25	0	**1**	**55**	**56**
42	Acer pseudoplatanus L.	8	0	0	0	5	3	14	25	0	**13**	**42**	**55**
43	Deschampsia cespitosa (L.) P.Beauv.	0	3	22	19	9	1	0	0	1	**53**	**2**	**55**
44	Salvia glutinosa L.	25	0	0	0	0	4	2	24	0	**25**	**30**	**55**
45	Solidago virgaurea L.	24	0	0	0	0	10	0	21	0	**24**	**31**	**55**
46	Galeobdolon montanum (Pers.) Pers. ex Rchb.	21	25	0	0	8	0	0	0	0	**54**	**0**	**54**
47	Festuca heterophylla Lam.	24	0	1	0	0	10	1	17	0	**25**	**28**	**53**
48	Pteridium aquilinum (L.) Kuhn	8	4	0	0	0	2	25	0	14	**12**	**41**	**53**
49	Circaea lutetiana L.	0	25	0	0	20	0	7	0	0	**45**	**7**	**52**
50	Anemone ranuculoides L.	2	18	0	0	25	1	4	0	0	**45**	**5**	**50**
51	Carex flacca Schreber	12	0	0	0	0	13	0	25	0	**12**	**38**	**50**
52	Scrophularia nodosa L.	10	1	7	2	0	0	21	0	7	**20**	**28**	**48**
53	Frangula alnus Mill.	4	0	10	14	0	3	9	0	7	**28**	**19**	**47**
54	Gentiana asclepiadea L.	15	6	3	0	0	0	23	0	0	**24**	**23**	**47**
55	Picea abies (L.) Karsten	1	0	25	21	0	0	0	0	0	**47**	**0**	**47**
56	Ranunculus ficaria L.	0	21	0	0	25	0	0	0	0	**46**	**0**	**46**
57	Prunus spinosa L.	14	0	0	0	0	7	4	21	0	**14**	**32**	**46**
58	Hedera helix L.	0	0	0	0	0	24	0	21	0	**0**	**45**	**45**
59	Lamium orvala L.	18	0	0	0	0	0	18	8	0	**18**	**26**	**44**
60	Mercurialis perennis L.	23	20	0	0	0	0	0	0	0	**43**	**0**	**43**
61	Molinia arundinacea Schrank	0	0	0	4	0	18	18	1	0	**4**	**37**	**41**
62	Cardamine bulbifera (L.) Crantz	0	25	0	0	0	0	2	13	0	**25**	**15**	**40**
63	Melampyrum pratense L.	0	0	0	0	0	2	23	15	0	**0**	**40**	**40**
64	Viburnum lantana L.	15	0	0	0	0	2	0	22	0	**15**	**24**	**39**
65	Crataegus laevigata (Poir.) DC.	0	25	0	0	13	0	0	0	0	**38**	**0**	**38**
66	Lathyrus niger (L.) Bernh.	0	0	0	0	0	21	0	17	0	**0**	**38**	**38**
67	Aegopodium podagraria L.	3	24	0	0	6	0	4	0	0	**33**	**4**	**37**
68	Tamus communis L.	0	0	0	0	0	1	12	24	0	**0**	**37**	**37**
69	Luzula pilosa (L.) Willd.	10	0	1	0	0	18	4	0	3	**11**	**25**	**36**
70	Clematis vitalba L.	7	0	0	0	0	0	3	25	0	**7**	**28**	**35**
71	Heracleum sphondylium L.	21	4	0	0	6	1	0	3	0	**31**	**4**	**35**
72	Hieracium sylvaticum (L.) L.	5	0	0	0	4	9	1	13	3	**9**	**26**	**35**
73	Rubus caesius L.	19	16	0	0	0	0	0	0	0	**35**	**0**	**35**
74	Aposeris foetida (L.) Less.	0	10	0	0	0	0	0	24	0	**10**	**24**	**34**
75	Calamagrostis arundinacea (L.) Roth	0	0	0	0	0	25	0	9	0	**0**	**34**	**34**
76	Daphne mezereum L.	23	10	0	0	0	0	0	0	1	**33**	**1**	**34**
77	Dryopteris filix-mas (L.) Schott	9	8	0	0	0	1	12	1	3	**17**	**17**	**34**
78	Melittis melissophyllum L.	0	0	0	0	0	8	5	21	0	**0**	**34**	**34**
79	Paris quadrifolia L.	22	12	0	0	0	0	0	0	0	**34**	**0**	**34**
80	Aruncus dioicus (Walter) Fernald	25	0	0	0	0	0	7	0	0	**25**	**7**	**32**
81	Cornus sanguinea L.	0	0	0	0	0	7	0	25	0	**0**	**32**	**32**
82	Cyclamen purpurascens Mill.	25	0	0	0	0	0	0	6	0	**25**	**6**	**31**
83	Campanula trachelium L.	24	0	0	0	0	0	0	6	0	**24**	**6**	**30**
84	Cephalanthera longifolia (L.) Fritsch	6	0	0	0	0	11	0	2	11	**6**	**24**	**30**
85	Convallaria majalis L.	4	0	0	0	0	0	21	5	0	**4**	**26**	**30**
86	Dactylis glomerata L.	1	0	0	0	5	13	0	10	0	**6**	**23**	**29**
87	Melampyrum nemorosum L.	24	5	0	0	0	0	0	0	0	**29**	**0**	**29**

		PO	KG	DO	CI	HR	PA	BO	PI	BU	sum	sum	sum
		I	II	III	IV	V	1	2	3	4	I-V	1-4	ALL
		N=25	N=25	N=25	N=25	N=25	N=25	N=25	N=25	N=25	N=125	N=100	N=225
88	Oxalis acetosella L.	11	3	4	8	3	0	0	0	0	**29**	**0**	**29**
89	Aremonia agrimonoides (L.) DC.	20	0	0	0	0	0	8	0	0	**20**	**8**	**28**
90	Rubus fruticosus agg.	0	20	0	0	0	0	0	0	8	**20**	**8**	**28**
91	Carex montana L.	25	0	0	0	0	0	0	2	0	**25**	**2**	**27**
92	Gagea lutea (L.) Ker-Gawl.	0	21	0	0	6	0	0	0	0	**27**	**0**	**27**
93	Scilla bifolia L.	0	21	0	0	6	0	0	0	0	**27**	**0**	**27**
94	Vicia oroboides Wulf.	0	0	0	0	0	3	0	21	3	**0**	**27**	**27**
95	Betonica officinalis L.	25	0	1	0	0	0	0	0	0	**26**	**0**	**26**
96	Ilex aquifolium L.	0	0	0	0	1	25	0	0	0	**1**	**25**	**26**
97	Luzula luzuloides (Lam.) Dandy & Wilm.	0	0	0	0	0	24	0	1	1	**0**	**26**	**26**
98	Vinca minor L.	0	0	0	0	0	25	0	0	1	**0**	**26**	**26**
99	Dryopteris dilatata (Hoffm.) A.Gray	0	0	0	25	0	0	0	0	0	**25**	**0**	**25**
100	Epimedium alpinum L.	0	0	0	0	0	0	25	0	0	**0**	**25**	**25**
101	Omphalodes verna Moench	25	0	0	0	0	0	0	0	0	**25**	**0**	**25**
102	Ruscus aculeatus L.	0	0	0	0	0	25	0	0	0	**0**	**25**	**25**
103	Sesleria autumnalis (Scop.) F.W.Schultz	0	0	0	0	0	25	0	0	0	**0**	**25**	**25**
104	Asarum europaeum L.	0	12	0	0	0	0	0	12	0	**12**	**12**	**24**
105	Berberis vulgaris L.	24	0	0	0	0	0	0	0	0	**24**	**0**	**24**
106	Crocus napolitanus Mord. & Loisel.	0	20	1	3	0	0	0	0	0	**24**	**0**	**24**
107	Impatiens noli-tangere L.	0	24	0	0	0	0	0	0	0	**24**	**0**	**24**
108	Leucojum vernum L.	0	22	0	0	2	0	0	0	0	**24**	**0**	**24**
109	Pulmonaria dacica Simonk.	0	24	0	0	0	0	0	0	0	**24**	**0**	**24**
110	Carex pilosa Scop.	0	11	0	0	0	12	0	0	0	**11**	**12**	**23**
111	Glechoma hederacea L.	0	17	0	0	6	0	0	0	0	**23**	**0**	**23**
112	Brachypodium rupestre (Host) Roem. & Schult.	22	0	0	0	0	0	0	0	0	**22**	**0**	**22**
113	Carex digitata L.	0	0	0	0	0	20	0	0	2	**0**	**22**	**22**
114	Lonicera xylosteum L.	22	0	0	0	0	0	0	0	0	**22**	**0**	**22**
115	Ulmus glabra Huds.	0	0	0	0	0	0	0	22	0	**0**	**22**	**22**
116	Cardamine trifolia L.	0	21	0	0	0	0	0	0	0	**21**	**0**	**21**
117	Lamium maculatum L.	0	19	0	0	1	0	1	0	0	**20**	**1**	**21**
118	Alliaria petiolata (MB.) Cav. & Grande	0	20	0	0	0	0	0	0	0	**20**	**0**	**20**
119	Mycelis muralis (L.) Dum.	8	0	0	0	1	0	5	0	6	**9**	**11**	**20**
120	Asplenium trichomanes L.	17	0	0	0	0	0	0	2	0	**17**	**2**	**19**
121	Stellaria holostea L.	0	7	0	5	6	0	0	0	1	**18**	**1**	**19**
122	Festuca gigantea (L.) Vill.	4	2	0	0	0	0	12	0	0	**6**	**12**	**18**
123	Peucedanum venetum (Sprengel) Koch	18	0	0	0	0	0	0	0	0	**18**	**0**	**18**
124	Ranunculus nemorosus DC.	18	0	0	0	0	0	0	0	0	**18**	**0**	**18**
125	Arum maculatum L.	0	17	0	0	0	0	0	0	0	**17**	**0**	**17**
126	Cardamine impatiens L.	0	17	0	0	0	0	0	0	0	**17**	**0**	**17**
127	Galium aparine L.	0	14	0	0	3	0	0	0	0	**17**	**0**	**17**
128	Inula spiraeifolia L.	17	0	0	0	0	0	0	0	0	**17**	**0**	**17**
129	Pulmonaria mollissima Kerner	0	0	4	0	0	0	0	13	0	**4**	**13**	**17**
130	Veronica hederifolia L.	0	9	0	0	8	0	0	0	0	**17**	**0**	**17**
131	Cardamine amara L.	0	16	0	0	0	0	0	0	0	**16**	**0**	**16**
132	Fragaria vesca L.	0	0	0	0	0	0	16	0	0	**0**	**16**	**16**
133	Geum urbanum L.	0	16	0	0	0	0	0	0	0	**16**	**0**	**16**
134	Isopyrum thalictroides L.	1	15	0	0	0	0	0	0	0	**16**	**0**	**16**
135	Melica uniflora Retz.	7	1	0	0	0	5	3	0	0	**8**	**8**	**16**
136	Peucedanum oreoselinum (L.) Moench	15	0	0	0	0	0	0	1	0	**15**	**1**	**16**
137	Senecio fuchsii C.C.Gmelin	12	0	0	0	0	0	0	4	0	**12**	**4**	**16**
138	Solanum dulcamara L.	14	0	0	2	0	0	0	0	0	**16**	**0**	**16**
139	Urtica dioica L.	0	13	0	0	3	0	0	0	0	**16**	**0**	**16**
140	Veronica persica Poir.	0	8	0	0	8	0	0	0	0	**16**	**0**	**16**

		PO I	**KG** II	**DO III**	**CI IV**	**HR V**	**PA 1**	**BO 2**	**PI 3**	**BU 4**	**sum I-V**	**sum 1-4**	**sum ALL**
		N=25	N=25	N=25	N=25	N=25	N=25	N=25	N=25	N=25	**N=125**	**N=100**	**N=225**
141	Abies alba Mill.	1	0	2	0	0	12	0	0	0	**3**	**12**	**15**
142	Actaea spicata L.	8	0	0	0	0	0	7	0	0	**8**	**7**	**15**
143	Buglossoides purpurocaerulea (L.) I.M.Johnston	0	0	0	0	0	0	0	15	0	**0**	**15**	**15**
144	Carex umbrosa Host	0	0	0	0	0	0	0	0	15	**0**	**15**	**15**
145	Hacquetia epipactis (Scop.) DC.	3	11	0	0	0	0	0	1	0	**14**	**1**	**15**
146	Knautia drymeia Heuff.	3	0	0	0	11	0	0	1	0	**14**	**1**	**15**
147	Moehringia trinervia (L.) Clairv.	0	0	0	0	11	0	4	0	0	**11**	**4**	**15**
148	Potentilla erecta (L.) Räuschel	13	0	0	0	0	2	0	0	0	**13**	**2**	**15**
149	Pseudostellaria europaea Schaeftlein	0	14	0	1	0	0	0	0	0	**15**	**0**	**15**
150	Ranunculus lanuginosus L.	7	7	0	0	0	0	0	0	0	**14**	**0**	**14**
151	Campanula persicifolia L.	12	0	0	0	0	0	0	1	0	**12**	**1**	**13**
152	Sorbus aria (L.) Crantz	0	0	0	0	0	1	0	12	0	**0**	**13**	**13**
153	Taraxacum officinale F.Weber in Wiggers	9	0	0	0	0	0	0	2	2	**9**	**4**	**13**
154	Carex pendula Huds.	0	12	0	0	0	0	0	0	0	**12**	**0**	**12**
155	Juniperus communis L.	0	0	0	0	0	6	0	5	1	**0**	**12**	**12**
156	Angelica sylvestris L.	8	2	0	1	0	0	0	0	0	**11**	**0**	**11**
157	Chamaecytisus hirsutus (L.) Link	1	0	0	0	0	2	1	7	0	**1**	**10**	**11**
158	Chrysosplenium alternifolium L.	0	11	0	0	0	0	0	0	0	**11**	**0**	**11**
159	Iris graminea L.	0	0	0	0	0	0	0	11	0	**0**	**11**	**11**
160	Agrostis canina L.	0	0	0	10	0	0	0	0	0	**10**	**0**	**10**
161	Clinopodium vulgare L.	0	0	0	0	0	0	0	10	0	**0**	**10**	**10**
162	Platanthera bifolia (L.) L.C.Rich.	1	0	0	0	0	1	2	4	2	**1**	**9**	**10**
163	Ranunculus auricomus L.	0	9	0	0	1	0	0	0	0	**10**	**0**	**10**

Appendix 2: Mean values per plot of nine oak dominated forest complexes in Slovenia

Priloga 2: Povprečne vrednosti po devetih kompleksih hrasta v Sloveniji

	POLOM	KRAKOVSKI GOZD	DOBRAVA	CIGONCA	HRAŠČICA	PANOVEC	BOJANCI	PIŠECE	BUKOVNICA
LABEL OF COMPLEX / *OZNAKA KOMPLEKSA*	I	II	III	IV	**V**	**1**	**2**	**3**	**4**
ABBREVIATION / *OKRAJŠAVA*	**PO**	**KG**	**DO**	**CI**	**HR**	**PA**	**BO**	**PI**	**BU**
NUMBER OF PLOTS / *ŠTEVILO PLOSKEV*	N=25	N=25	N=25	N=25	**N=25**	**N=25**	**N=25**	**N=25**	**N=25**
ELEVATION (m) / *NADMORSKA VIŠINA (m)*	370	150	160	260	180	140	280	470	230
INCLINATION (°) / *POVP. NAKLON(°)*	10	0	0	0	0	5	15	25	10
LONGITUDE / *GEOG. DOLŽINA*	5489640	5532690	5550925	5545165	5598240	5397650	5521290	5551040	5601740
LATITUDE / *GEOG. ŠIRINA*	5067090	5082090	5088981	5135670	5167490	5090244	5038915	5096765	5173740
TREE LAYER / *DREVESNA PLAST*									
NUMBER OF TREES (STEMS) / *ŠTEVILO DREVES*	17	12	25	14	17	26	12	21	17
NUMBER OF TREE SPECIES / *ŠTEVILO DREVESNIH VRST*	3.2	2.9	2.0	2.8	2.4	2.0	1.6	3.8	2.4
TOTAL GROWING STOCK (in m^3) / *CELOTNA LESNA ZALOGA (LZ)*	12	22	27	23	22	12	19	24	16
GROWING STOCK (in m^3) OF / *LESNA ZALOGA (LZ)***:**									
Quercus robur	9.3	16.4	23.8	18.3	18.5	/	/	/	/
Quercus petraea	/	/	/	/	/	11.7	18.9	18.3	13.5
Quercus cerris	/	/	/	/	/	/	/	3.9	/
Carpinus betulus	0.8	4.4	/	0.6	3.4	/	/	/	0.1
Acer campestre	/	0.4	/	/	0.1	/	/	0.1	/
Alnus glutinosa	/	0.6	/	0.2	/	/	/	/	/
Fagus sylvatica	/	/	/	/	/	/	0.2	1.1	2.3
Picea abies	/	/	3.4	3.4	/	/	/	/	/
Tilia cordata	1.5	/	/	/	/	/	0.1	/	/
UNDERSTOREY VEGETATION LAYERS / *PRITALNE PLASTI VEGETACIJE*									
SPECIES RICHNESS / *VRSTNA PESTROST (BOGASTVO)*	62	45	9	12	23	37	31	49	12
SUM OF SPECIES COVER (%) / *SEŠTEVEK ZASTIRANJA VSEH VRST*	182	178	74	105	114	130	154	124	27
MEAN SPECIES COVER (%) / *POVPREČNA STOPNJA ZASTIRANJA NA VRSTO*	3	4	10	9	5	4	5	3	3
EVENNESS(E) / *INDEKS PORAVNANOSTI*	0.79	0.81	0.46	0.37	0.70	0.80	0.72	0.82	0.77
SHANNON (H') / *SHANNONOV INDEKS PESTROSTI*	3.26	3.07	0.99	0.94	2.17	2.89	2.47	3.18	1.89
SIMPSON (D) / *SIMPSONOV INDEKS PESTROSTI*	0.92	0.92	0.43	0.37	0.79	0.90	0.84	0.92	0.72