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ORIGINAL SCIENTIFIC PAPER

Spatial structure – case study on experimental plots of beech (*Fagus sylvatica* L.) and scots pine (*Pinus sylvestris* L.) in Olovo, Bosnia and Herzegovina

Prostorna struktura sastojine – studij slučaja na eksperimentalnim plohama bukve (*Fagus sylvatica* L) i bijelog bora (*Pinus sylvestris* L.) u Olovu, Bosna i Hercegovina

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ABSTRACT

Spatial structure is the horizontal and vertical arrangement of individual trees. It affects many processes in the stand such as stability, production and regeneration. Stand structure parameters are used to describe spatial structure on experimental plots. The paper presents methods that describe the stand structure through three levels of diversity related to position, species and size. Research has been conducted on two experimental plots from the area of Olovo. Referent trees and their competitors were selected on both experimental plots, and competitors were defined by referent tree distance. The aim of this paper is to describe the spatial structure on experimental plot of European beech (*Fagus sylvatica* L.) and experimental plot of European beech and Scots pine (*Pinus sylvestris* L.). Indicators of spatial diversity, dimensional diversity and diversity of tree species have been determined to achieve that aim. For each experimental plots are described: horizontal tree distribution (Poisson Distribution, Clapham's Variance – Mean Ratio and Morisita's Index of Dispersion), diameter differentiation (Diameter Differentiation by Füldner and Dominance Index by Hui et al.), species diversity and structural diversity (Species Profile Index by Pretzsch) and species intermingling (Species Intermingling Index by Füldner). Obtained results show that the stand structure of both experimental plots deviates from random distribution. Dimensional diversity parameters indicate stronger intensity of competition for beech trees. Analysis of species diversity showed that beech trees occur in groups or patches, and the other represented species mix more intensive.

Key words: *stand structure, dominance, mingling, European beech, Scots pine*

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INTRODUCTION – *Uvod*

Classical describing of growth and stand structure are based on mean and cumulative stand parameters, and simple analysis of frequency distribution different characteristics of individual trees. That way of describing ignores the three-dimensional nature of stand. This understanding is not in line with ecosystem approach to modern forest definition, which means identification of multiple interactions between forest organisms and their inorganic environment, and growth of trees and stands describes like complex consequence of the action different external and internal influences. In purpose to cognition and understanding complicated laws of the process of growth trees and stands and prognosis of their further development, modern researches are focused on exploring growth and conditions for growth for individual trees and their nearest neighbours. In studies which start from individual trees and understand the population as a heterogeneous mosaic of members, focus is on the spatial configuration and diversity of individuals. In structure analyses are determined a lot of spatial structure indicators. They can be used for describing horizontal and vertical stand structure, diversity of species, positions and dimensions on stand level or in the immediate vicinity of the reference trees.

Stand development begins with the interaction of individual trees. Growth of individual trees is influenced by a number of factors: age, size, micro-environment, genetic characteristics and competition (Tomè and Burkhart, 1989). Explaining stand development through the processing of each tree individually, provides new possibilities for understanding and predicting stand growth. Attention is focused on individual trees for insights into basic tree-growth relationships (Bella, 1971).

Spatial structure has a particular influence on stand development. The spatial structure is the horizontal and vertical spatial arrangement of individual trees (Pretzsch, 2009). It is particularly relevant in the transition from homogeneous evenaged stands to structurally rich mixed stands (Pretzsch, 2009). Quantitative data about stand structure are crucial for understanding the functions of ecosystems and sustainable forest management. Stand structure parameters are useful for analysing stand dynamics (Pretzsch, 2009). Stand structure determines the competition between trees in a stand for resources, biomass production and the growing conditions (Pretzsch, 2009). Competition could be defined as an interaction among individuals, brought about leading to a reduction in the survival, growth and reproduction of these individuals (Begon et al, 1986). Competition between trees exists when resource availability falls below the sum requirement of the trees for optimal growth (Brand and Magnussen, 1988). Functions used to quantify competition and stand structure range from simple formulations expressing the hierarchical position of tree within the stand to more complex indices that express the size of, distance to, and number of local neighbours (Burkhart and Tomè, 2012). Parameters such as species, diameter and height indicate on changes in vertical and horizontal stand structure (Staudhammer and LeMay, 2001). Pommerening (2002) worked on the classification of structural indices and examined typical representatives of the classification groups such as the aggregation index of Clark and Evans, the coefficient of segregation of Pielou, the mingling index and many others.

The paper presents methods for estimating and describing stand structure through three levels of diversity related on location, species and size. The aim of this research is to describe stand structure of pure stand of European beech (*Fagus sylvatica* L.) and mixed stand of European beech and Scots pine (*Pinus sylvestris* L.). In that purpose it is necessary to determine the indicators of spatial diversity, dimensional diversity and diversity of species.

MATERIAL AND METHODS – *Materijal i metode*

Basic material was gathered on two experimental plots near Olovo in northeast Bosnia (Figure 1). This experimental plots are set in 2014 for the purpose of research within the COST project EuMIXFOR (Pretzsch et al, 2015, 106; Dirnberger et al, 2017; Heym, 2017). One of them is located in the pure stand of beech and the other is located in mixed stand of beech and pine. The measured taxation elements are diameter at breast height (DBH), tree height, crown base height, X and Y coordinates and crown width. For measurements we used *FiledMap*, a new instrument which are first time tested in Bosnia for collection this data (Avdagic et al, 2014). For tree selection we used ArcGIS software.

The main goal of the research is to characterize growing space and competitive situation of individual trees of beech in pure stand and trees of beech and pine in mixed stand. In this chapter are listed methods for describing spatial stand structure:

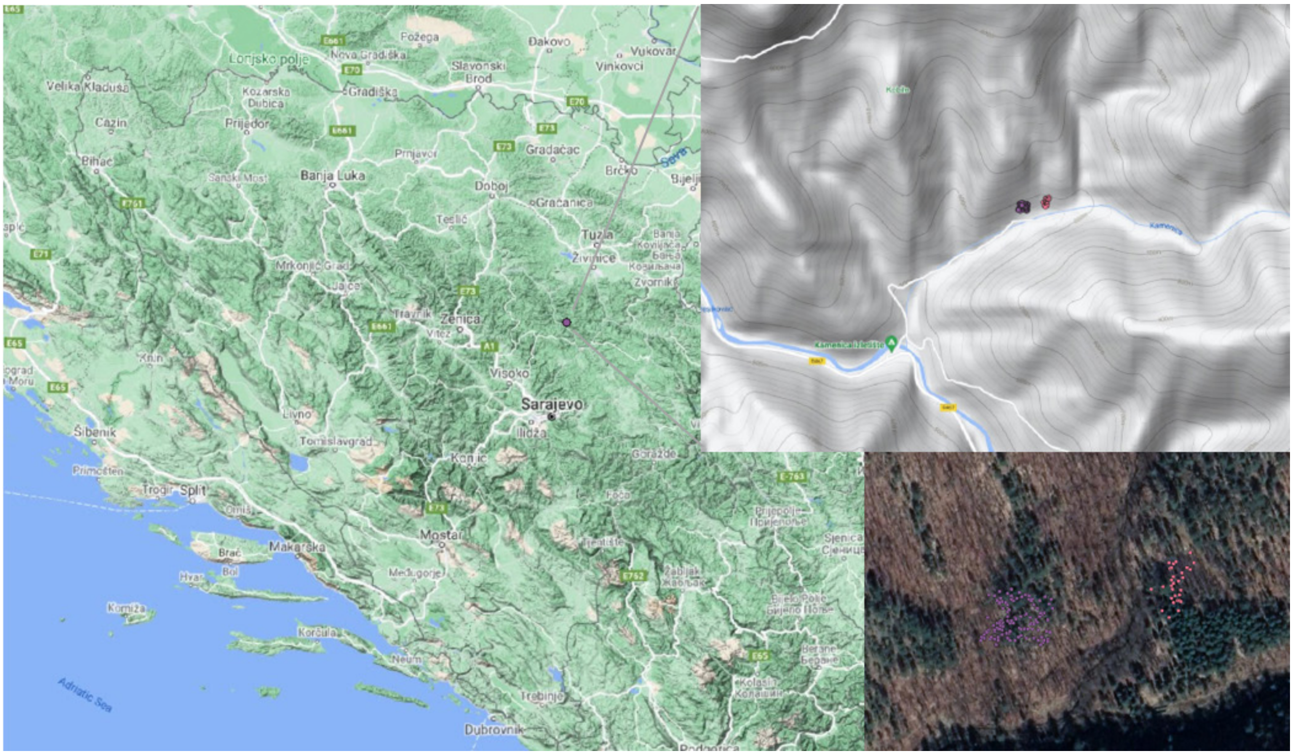


Figure 1. Plots Location

Slika 1. Lokacija ploha

POISSON DISTRIBUTION AS A REFERENCE FOR ANALYSING STAND STRUCTURES – *Poissonova distribucija kao referenca za analizu strukture sastojine*

The Poisson distribution describes the probability of n trees in a randomly selected sample plot by covering the plot with a square grid and record the frequency of trees present in each square (Pretzsch, 2009). This distribution comprises the parameter λ which represents the mean number of stems in the square and equals the mean, and the constant e is Euler's number (e = 2,718282) (Pretzsch, 2009):

$$p_n = \frac{\lambda^n}{n!} \times e^{-\lambda}.$$

CLAPHAM'S VARIANCE – MEAN RATIO – *Clapham-ov odnos varijansa – sredina*

The relative variance I_c is based on the number of plants in sample squares (Pretzsch, 2009).The variance – mean ratio can calculate with formula:

$$I_c = \frac{s_n^2}{\bar{n}}$$

$\bar{n}$ – mean plant number per square

s_n^2 – variance in plant number per quadrat (Pretzsch, 2009).

The following three cases can be distinguished:

- $s_n^2 = \bar{n}$, $I_c = 1.0$ indicating a purely random distribution;

- $s_n^2 = \bar{n}$, $I_c > 1.0$ indicating clumping and

- $s_n^2 = \bar{n}$, $I_c < 1.0$ indicating a regular distributions occurs (Pretzsch, 2009).

MORISITA'S INDEX OF DISPERSION – *Morisitin indeks disperzije*

The index of dispersion from Morisita is calculated from the number of squares q, the occupancy of the squares n_q and the total number of objects n (Pretzsch, 2009):

$$I_\sigma = \frac{q\sum_{i=1}^{q} n_i \times (n_i - 1)}{n \times (n-1)}$$

If the observed probability is equal to the expected probability for a Poisson distribution, then $I_\square = 1$ and the distribution is random; if the observed probability is greater than the expected probability, then $I_\square > 1$, which indicates clumping and if the observed probability is less than expected then $I_\square < 1$ and distributions is regular (Pretzsch, 2009).

DIAMETER DIFFERENTIATION BY FÜLDNER – *Diferencijacija prečnika (Ti) prema Füldneru*

The diameter differentiation quantifies diameter heterogeneity in the immediate neighbourhood of a central tree (Füldner 1995, 1996; Gadow 1993, according to Pretzsch 2009). For a central tree (i) and its nearest neighbour (j) the diameter differentiation is defined as:

$$T_i = \frac{1}{m} \times \sum_{j=1}^{m} r_{ij}$$

$$r_{ij} = 1 - \frac{min(d_i, d_j)}{max(d_i, d_j)}$$

n – number of central tree

d_i, d_j – diameters of central tree and its neighbour (Pretzsch, 2009).

The T_i values can may range from 0 to 1. If the T_i values are equal 0 then neighbour trees have the same size diameters (Gadow and Hui, 1998). The mean diameter differentiation within a stand can be calculated as (Pretzsch, 2009):

$$\bar{T} = \frac{1}{n} \times \sum_{i=1}^{n} T_i$$

T values show how diameters of randomly selected tree are different from its nearest neighbour trees (Pretzsch, 2009).

DOMINANCE INDEX BY HUI ET AL. – *Indeks dominantnosti prema Hui i dr.*

Forest growth and yield modelling research has focused on intra-specific competition (Liu and Burkhart, 1994). However, understanding of inter-specific competition becoming more important because of an emphasis on mixed stand management (Weiskittel et al., 2011). Competition between plants is summarized as the action on, and reaction to their living environment (Ford and Sorrensen, 1992). Dominance index reflects the relationship between the size of a reference tree and its nearest neighbours (Li et al, 2017). Dominance index is defined as the proportion of the n nearest neighbour of a given reference tree which are bigger than the reference tree (Gadow and Hui, 2001):

$$U_i = \frac{\sum_{j=1}^{m} k_{ij}}{m}$$

i – reference tree, j – neighbour tree, m – number of neighbour trees

$k_{ij} = 0$ – reference tree is bigger than neighbour tree

$k_{ij} = 1$ – otherwise.

It has four possible values: 0.0, 0.33, 0.67 and 1.0. A higher value implies that the reference tree is dominant than all three neighbours.

The U index for stand is calculated like average for all reference trees:

$$\bar{U} = \frac{1}{N} \times \sum_{i=1}^{n} U_i$$

N – number of reference trees in the stand (Pretzsch, 2009).

Relative dimensional dominance of individual species in stand could be estimated with dominance index.

SPECIES PROFILE INDEX BY PRETZSCH – *Pretzsch-ov indeks profila vrsta*

Index A for species profiles is based on the diversity index H by Shannon (1948, according to Pretzsch, 2009). Index A takes into account the presence of species in different height zones (Pretzsch, 2009). Index A equals:

$$A = -\sum_{i=1}^{s}\sum_{j=1}^{z} p_{ij} \times \ln p_{ij}$$

S – number of species, Z – number of height zones

n_{ij} – number of individuals of the species

p_{ij} – proportion of species in the height zone (Pretzsch, 2009).

The maximum value of the index A for given number of species and zones is

$$A_{max} = \ln(S \times Z)$$

then index A can be standardized according to

$$A_{rel} = \frac{A}{\ln(S \times Z)} \times 100 \text{ (Pretzsch, 2009).}$$

SPECIES INTERMINGLING INDEX BY FÜLDNER (1996) – *Indeks miješanja vrsta po Füldner-u (1996)*

Index M_i describes the spatial structure of the species mixture in a stand, and its defined as the proportion of the nearest neighbours of another species (Gadow and Füldner, 1992, according to Gadow and Hui, 2001):

$$M_i = \frac{1}{n} \times \sum_{j=1}^{n} v_{ij}$$

i – reference tree, j – neighbouring trees, n – number of neighbour trees

$v_{ij} = 0$ – if neighbour belongs to the same species as reference tree

$v_{ij} = 1$ – if neighbour belongs to a species different from reference tree (Pretzsch, 2009).

For a structural quartet index M_i has four possible values. When all trees in the quartet belong to the same species M_i is equal 0, when one neighbour belongs to another species M_i index is 0.33, M_i is equal 0.67 when two neighbour trees belongs to a different species and M_i has a higher value (1.0) when all neighbours belong to another species (Füldner, 1996, according to Pretzsch, 2009). The index M for stand is calculated as average for all reference trees:

$$\bar{M} = \frac{1}{N} \times \sum_{i=1}^{N} M_i$$

N – number of reference trees in the stand (Pretzsch, 2009).

The larger value of index M indicate that individual trees of that species intermingle more intensive with the other species, and the lower values indicate appearance of species in groups or patches (Pretzsch, 2009).

RESULTS AND DISCUSSION – *Rezultati i diskusija*

Reference trees has selected after setting the systematic square grid (5 x 5 m). For selection competitive trees used the principle of the structural quartet. The structural quartet comprises a central tree and its three nearest neighbours. On the first experimental plot are selected 29 reference trees, and on the second are selected 85 reference trees.

POISSON DISTRIBUTION AS A REFERENCE FOR ANALYSING STAND STRUCTURES – *Poissonova distribucija kao referenca za analizu strukture sastojine*

In case of first experimental plot, in a sample squares occur two trees or less. Graph 1 (a and b) shows differences between observed and expected frequencies. These differences suggest on exception from the Poisson distribution. In the sample squares of the second experimental plot occur five trees, but some of squares are empty. Graph 2 (a and b) shows frequencies for experimental plot 2.

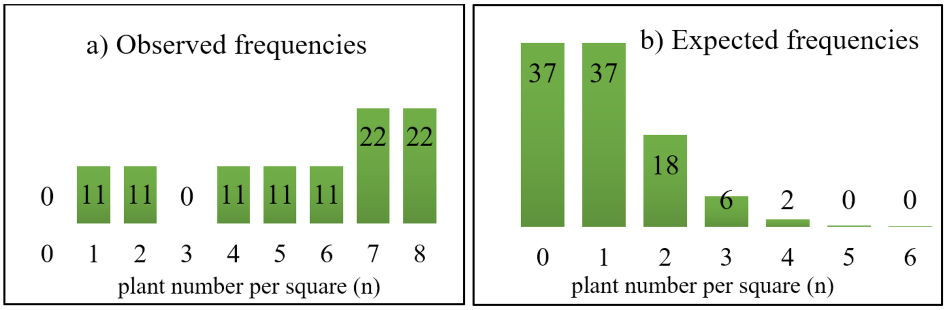
CLAPHAM'S VARIANCE – MEAN RATIO – *Clapham-ov odnos varijansa – sredina*

Research results of variance – mean ratio are shown in Table 1. Value of the Clapham's variance – mean ratio on the first experimental plot amount 0.5. In this case, variance is less then mean tree number per square sample. That indicating a regular distribution. Index I_c on the second experimental plot is 1.18. It can be assumed that this value indicating clumping.

Table 1. Clapham's variance – mean ratio

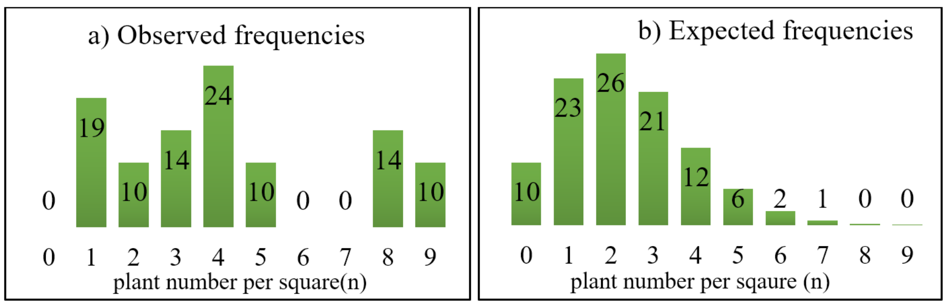
Tabela 1. Clapham-ov odnos varijansa – sredina

Index	Experimental plot 1	Experimental plot 2
$\bar{n}$	1,0	2,3
s_n^2	0,5	2,75
I_c	0,5	1,18



Graph 1. Comparison of observed (a) and expected (b) frequencies on the experimental plot 1

Grafikon 1. Poređenje posmatranih (a) i očekivanih (b) frekvencija ogledne plohe 1



Graph 2. Comparison of observed (a) and expected (b) frequencies on the experimental plot 2

Grafikon 2. Poređenje posmatranih (a) i očekivanih (b) frekvencija ogledne plohe 2

MORISITA'S INDEX OF DISPERSION – *Morisitin indeks disperzije*

Morisita's index tests whether the distribution pattern is significantly different from a random distribution (Pretzsch, 2009). Table 2 shows the results for both experimental plots. Value of Morisita's index in the first plot amount 0.5. That value indicating a regular distribution. In the second plot index is 1.07, which indicates clumping or aggregation.

Table 2. Morisita's index of dispersion

Tabela 2. Morisitin indeks disperzije

Index	Experimental plot 1	Experimental plot 2
$\bar{n}$	9	21
I_σ	0,5	1,07
σ	0,056	0,12
E (σ)	0,5	1,07

DIAMETER DIFFERENTIATION BY FÜLDNER – *Diferencijacija prečnika (T_i) prema Füldneru*

The diameter differentiation is determined based on diameters of the central tree and its three nearest neighbours in the pure and mixed stand. The values of T_i may range from 0 to 1.0 (Pretzsch, 2009). If diameter differentiation is low then the T_i values approach 0, but the maximum diameter differentiation produces T_i values close to 1.0 (Pretzsch, 2009). Table 3 shows the results of diameter differentiation for both experimental plots. The values for first plot range from 0.29 to 0.41, and for second plot values varies from 0.28 to 0.32. Based on these values can be determine the differences between diameters of reference tree and its neighbours. The diameter differentiation for the pure stand is 0.35, and for mixed stand is 0.30. The results show that trees on experimental plot 2 have more dimensional differences than trees on plot 2. In the pure stand smaller diameters amount about 60-70% of larger diameter, and in the mixed stand smaller diameter is about 70% of larger diameter.

Table 3. The values of diameter differentiation (T_i) for both experimental plots

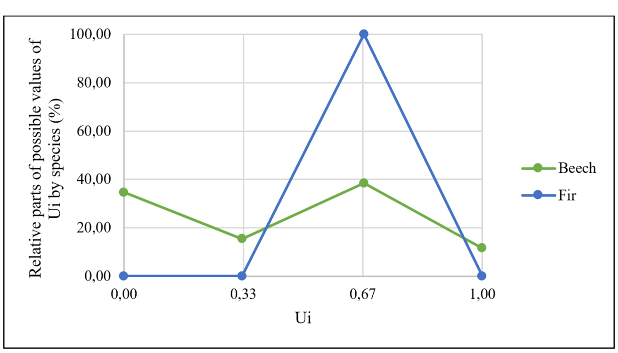
Tabela 3. Veličine indeksa prosečnog diferenciranja prečnika (T_i) za obje plohe

Index	Experimental plot 1	Experimental plot 2
$\overline{T}_i$	0,35	0,30
$\overline{T}_1$	0,41	0,28
$\overline{T}_2$	0,29	0,32
$\overline{T}_3$	0,35	0,30

DOMINANCE INDEX BY HUI ET AL. – *Indeks dominantnosti prema Hui i dr.*

The dominance index is used to quantify the number of neighbour trees that have larger diameters than reference tree (Gadow and Hui, 1998). Based on U_i value can be evaluate level of relative dimensional dominance for each species in the stand. A lower values implies on deficiency of competition, because reference tree is larger than its three nearest neighbours. A higher value implies on presence of distinct competition because the reference tree is smaller than all three neighbours. Graphs of relative part of possible values of dominance index (0.0, 0.33, 0.67, 1.0) are made for better understanding stand structure and dimensional diversity.

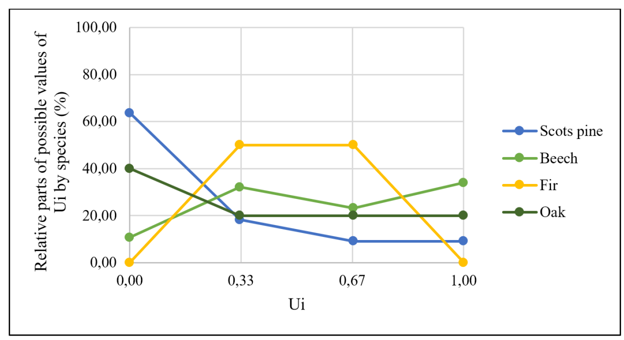
On the first experimental plot are most reference beech tree which are larger than all of three neighbours (34.6%), and those trees who are thinner than its two neighbours (38.5%). In these case it is pure stand with one fir tree. Dominance index for fir tree is 0.67. This means that fir tree is larger from just one neighbour. These results indicate on low competition.



Graph 3. Relative parts of possible values of dominance index by species on experimental plot 1

Grafikon 3. Relativni udio mogućih veličina indeksa dominantnosti po vrstama drveća na oglednoj plohi 1

On the second experimental plot most represented species is European beech (65.8%), then Scots pine (25.9%), fir (2.4%) and oak (5.9%). Reference beech trees grow in conditions of distinct competition, because the results show that 32.1% of beech trees are thinner than one neighbour (U_i = 0.33), 23.21% are thinner than two neighbours (U_i = 0.67) and 33.9% of beech trees are thinner than all of three neighbours (U_i = 1.0). Reference pine trees grow in conditions of low competition because the results indicate that 63.6% of pine trees are larger than all of three neighbours (U_i = 0.0), and 9% are pine trees who are thinner than two or three neighbours (U_i = 0.33 and 0.67). On this plot are two reference fir trees, one of them is larger than one neighbour (0.33), and the second one is dimensional more dominant than two neighbours (0.67). Five oak trees grow in conditions of low competition.



Graph 4. Relative parts of possible values of dominance index by species on experimental plot 2

Grafikon 4. Relativni udio mogućih veličina indeksa dominantnosti po vrstama drveća na oglednoj plohi 2

SPECIES PROFILE INDEX BY PRETZSCH – *Pretzsch-ov indeks profila vrsta*

To calculate index A the stand is divided into three height zones, which constitute 0-50%, 50-80% and 80-100% of the maximum stand height (Pretzsch, 2009). The species proportions are calculated for the three zone and two (plot 1) or four (plot 2) species. Any deviation from the single layered pure stand is recognized by increase in the species profile index (Pretzsch, 2009). The results for species profile index are shown in table 4.

Table 4. The values for species profile index by both experimental plots

Tabela 4. Veličina indeksa profila vrsta A po oglednim plohama

Index	Experimental plot 1	Experimental plot 2
A	1,11	1,71
Number of species	2	4

Table 5 shows the maximum values of A index for three height zones and two species for experimental plot 1 and four species for plot 2, and relative species profile index A_{rel}.

Table 5. The maximum values of index A and the standardized species profile index A_{rel} for both experimental plots

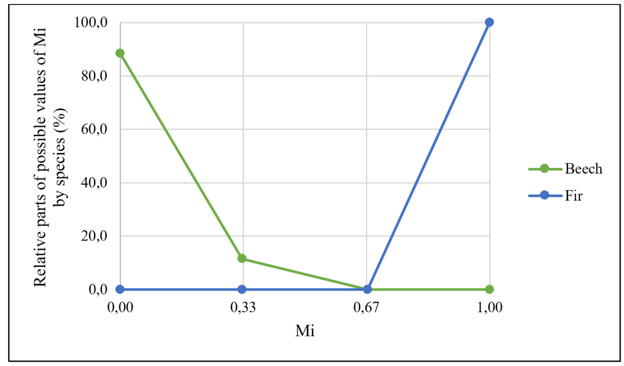
Tabela 5. Maksimalne vrijednosti indeksa A i relativni indeks profila vrsta za obje eksperimentalne plohe

Index	Experimental plot 1	Experimental plot 1
A_{max}	1,79	2,48
A_{rel}	61,70%	68,73%

Index A quantifies the stand structure diversity (Pretzsch, 2009). On experimental plot 1 index A amount 1.11, and on the plot 2 is 1.71. Reason for that is increase values of A index in mixed and highly structured mixed stands. The A_{rel} index quantifies the relative degree of structural diversity, in fact, that is the observed diversity in relation to the maximum structural diversity for the given number of species and number of zones (Pretzsch, 2009). On the first plot A_{rel} is 61.7% and on the second plot is 68.3%.

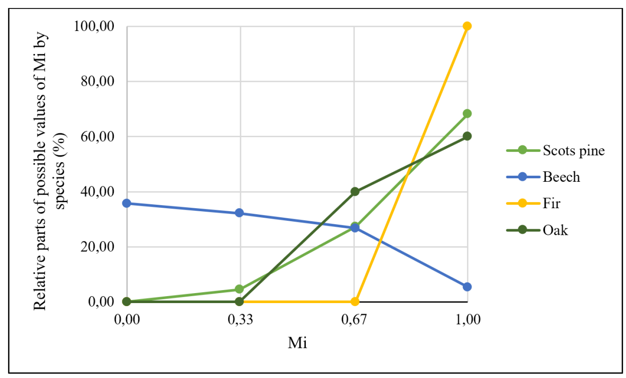
SPECIES INTERMINGLING INDEX BY FÜLDNER (1996) – *Indeks miješanja vrsta po Füldner-u (1996)*

For mingling species analysis is used index M_i. This index is based on information about whether a reference tree is surrounded by trees of another species. A higher value indicates that individual trees mix more intensively with other species, and if the values are lower that indicate the occurrence of species in groups (Pretzsch, 2009). Graphs 5 and 6 show relative part of possible values of index M_i by species.



Graph 5. Relative parts of possible values of index M by species on experimental plot 1

Grafikon 5. Relativni udio mogućih veličina indeksa M po vrstama drveća na oglednoj plohi 1



Graph 6. Relative parts of possible values of index M by species on experimental plot 2

Grafikon 6. Relativni udio mogućih veličina indeksa M po vrstama drveća na oglednoj plohi 2

Considering that experimental plot 1 is in pure beech stand, about 88% of reference trees for neighbours have beech trees. Exception of that is one fir tree surrounded by beech tree, which is neighbour for three reference trees. Graph 6 shows that 35.7% of reference beech trees for three nearest neighbours have beech trees, 32.14% of them have one neighbour of another species, about 26.8% have two neighbours of different species, and just 5% of reference trees have all of three neighbours of another species. Data show that individual pine trees are mingling most intense with other species, because 68% of reference trees of this species for neighbours have the other species.

CONCLUSIONS – *Zaključci*

The paper presented methods which describe the stand structure through three levels of diversity related to position, species and size. On the basis of conducted researches, following conclusions can be made.

The use of Poisson distribution indicates on exception from random distribution in pure and mixed stands. Results obtained by use distribution indices based on sample quadrats indicate on regular distribution in pure stand, and on clumping in mixed stand.

For dimensional diversity analysis were used diameter differentiation by Füldner and dominance index by Hui et al. The results show that dimensional diversity is larger in pure stand, that is, the trees of structural quartet is more different in terms of diameter size in pure stand. Competition is stronger in mixed stand, it can be conclude that between trees in mixed stand dominate stronger competition terms than in pure stand. Observation all of species individually shows that reference beech trees are more competitive in compare with other species.

Species profile index by Pretzsch and methodological principles were used for species diversity analysis. Value of index A in pure stand is 1.17 and in mixed stand is 1.71. Pure stand has lower value, and reason for that is one tree of different species and unequable vertical distribution. Index M_i in pure stand is 0.07 and in mixed stand is 0.53. Low value of this index on experimental plot 1 is expected because that is pure beech stand with one fir tree. In the mixed stand species are mingling more intensively. The results show that beech trees occur in groups and in patches, but fir, pine and oak trees occur like single trees, what mean that they mingling more intense with other species.

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SAŽETAK

Razvoj sastojine počinje interakcijom pojedinačnih stabala i postoji niz metoda koje se mogu koristiti za proučavanje odnosa među stablima. Poseban uticaj na rast i razvoj sastojina ima prostorna struktura. Struktura sastojine se može definirati kao prostorna raspodjela stabala, određenim uzorcima miješanja različitih vrsta drveća i prostornim rasporedom njihovih dimenzija. Strukturu sastojine čine sva stabla, njihova raspodjela i međusobni odnosi i zahtjevi. Ona utiče na mnoge procese u sastojini kao što su stabilnost, produkcija i podmlađivanje. Od strukture sastojine u najvećoj mjeri zavisi mogućnosti zadovoljenja potreba okoliša i društva za općekorisnim i prozvodnim funkcijama šuma.

U radu su predstavljene metode koje opisuju strukturu sastojine kroz tri nivoa raznolikosti koji se odnose na položaj, vrstu i veličinu. Istraživanje je izvršeno na osnovu podataka prikupljenih sa dvije ogledne plohe sa područja Olova. Na obje plohe su odabrana referentna stabla i njihovi konkurenti, koji su definirani udaljenošću od referentnog stabla. Cilj je bio opisati prostorne strukture na eksperimentalim plohama koje se nalaze u čistoj sastojini bukve i mješovitoj sastojini bukve i bijelog bora. Za postizanje postavljenog cilja utvrđeni su pokazatelji prostornog diverziteta, dimenzionog diverziteta i diverziteta vrsta drveća. Za opisivanje horizontalne raspodjele stabala korištena je Poissonova distribucija, Clapham-ov odnos varijansa – sredina i Morisitin indeks disperzije. Rezultati ukazuju na to da se u čistoj sastojini radi o pravilnoj distribuciji, a u mješovitoj dolazi do grupisanja. Za analizu raznolikosti veličina stabala korišteni su indeks diferencijacije prečnika prema Füldneru i indeks dominantnosti prema Hui-u i dr. Rezultati pokazuju da je dimenziona diferencijacija veća u čistoj sastojini, odnosno da se stabla strukturnog kvarteta više razlikuju u čistim sastojinama u pogledu veličine prečnika. Istraživanje je pokazalo da među stablima mješovite sastojine vladaju jači konkurentski odnosi naspram stabala čiste sastojine. Posmatranjem svih vrsta pojedinačno dolazi se do zaključka da referentna stabla bukve pokazuju jaču konkurenciju u odnosu na druge prisutne vrste. Raznolikost vrsta i raznolikost strukture su opisani uz pomoć Pretzsch-ovog indeksa profila vrsta, a način prostornog miješanja vrsta utvrđen je kroz indeks miješanja vrsta po Füldner-u. Rezultati su pokazali da se stabla bukve javljaju u skupinama i manjim grupama, dok se stabla ostalih zastupljenih vrsta intenzivnije miješaju.