

**DIAMETER STRUCTURE AND HEIGHT OF TREES DYNAMICS OF FIR
(*Abies alba* Mill.) AND SPRUCE (*Picea abies* Karst.) STANDS IN
MANAGEMENT UNIT „IGMAN“(permanent sample plots 43 and 58)**

**Dinamika debljinske strukture i visine stabala sastojina jele (*Abies alba* Mill.) i
smrče (*Picea abies* Karst.) u GJ „Igman“ (stalne ogledne plohe 43 i 58)**

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Abstract

This paper analyses the dynamics of diameter structure and height curves as the main indicators of a simple stand structure, uneven-aged multi-storied fir and spruce stands in the management unit šIgmanō where selective felling is applied based on the principle of positive selection. The data for analysis was collected by periodical measurement during fifty years on two permanent sample plots, forest sections 43 and 58. It has been determined that during the observation period there had been a change in diameter structure in the sense of increase in the proportion of trees in the lower, and decrease in higher diameter classes as well as the increase of tree height in the complete interval of empirical data. It has been concluded that due to selective felling, with higher diameter classes trees included, conditions have been created for the occurrence of new and the development of the existing young crop; diameter structures of a shape characteristic for even-aged stands have gradually assumed the shape characteristic for selective stands. Thus, due to the increase of competition among the trees of lower diameter classes and the felling of lower height and lower quality trees of higher diameter classes, there has been an increase in the height of trees of the same diameter.

Key words: *fir, spruce, uneven-aged stand, selective structure, diameter structure, height curve*

INTRODUCTION – Uvod

The process of increment and the development of trees and stands is a complex consequence of a number of variables and factors. These factors act in

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synergy, thus making researching and understanding the concept of growth and development extremely complex, especially in mixed uneven-aged stands.

An important segment in the research process of tree and stands increment and development, is analysis of the stand structure, since there is a strong cyclic connection between the tree and stand increment and the structure of the stands. A change in the stand structure modifies the conditions for tree growth and its immediate 'neighbours'; the size and character of increment of individual trees changes and the stand structure as well.

Among the numerous indicators of the so-called simple stand structure, the frequency of tree distribution in diameter classes or the diameter structure and the height of trees are considered as the most important ones, since they are the basis for other structure indicators.

Diameter structure is a direct result of development tendencies and changes which occur in the stand. Different stand development phases can be defined through diameter structure and its changes over time, the dynamics of approaching the normal (optimal) condition, are important parameters for forecasting assortment structure, and are thus the basis for any simulation model of stand development.

Height of trees is a factor important for the wood volume of individual trees and stands and it is an indicator of the production potential of a habitat, while the distribution of tree heights in space determines the vertical structure of a stand. In uneven-aged, i.e. selective stands, consisting of trees of different age and growth, height is associated with a diameter. Mean heights of diameter classes make a series, the so-called height curve, characteristic of every selective stand and every habitat, based on which there are numerous and important conclusions.

MATERIALS AND RESEARCH METHODS - *Materijal i metode istraživanja*

RESEARCH OBJECT - *Objekt istraživanja*

The analysis of the dynamics of diameter structure and height of trees was conducted based on the data accumulated by periodic measurement over fifty years on two permanent sample plots (43 and 58) that are found in fir and spruce forests in management unit 'Igman'.

The management unit 'Igman' encompasses the area of Igman mountain which is a geomorphologic unit together with Bjela-nica mountain, both belonging to the high Dinaric mountains. The climate of this complex is diverse, but generally it is considered mountainous (LU 1, 1966). When considering the flora, Igman and Bjela-nica represent a true image of the flora and vegetation of the continental Dinaric mountains. There are numerous plant species and specific vegetation units as well as their vertical zoning (STEFANOVI 1984).

In the management unit 'Igman', for the purpose of long-term monitoring of the change in sizes of volume increment and other tree and stand taxative elements, there were ten permanent sample plots established in the period between 1954 and 1957. The sample plots are in different altitudes and mainly in different exposures and land inclination in the forests of beech, fir and spruce and forests of fir and spruce, which are the most common and economically the most important in management unit 'Igman'. The selection of these sample plots was not conditioned by pedological, phytocoenological, i.e. typological base since the area had not been subjected to this kind of research at that time. Eventually, Irić, Stefanović and Drinić determined soil types and the affiliation to certain plant community (DRINIĆ, 1974; PAVLIĆ, 1987).

The sample plots in forest sections 43 and 58, which are the object of this research, were founded in 1956. The map of the management unit 'Igman' with the borders of the sections and the location of the sample plots, as well as the satellite images of the specific area of the sample plots and their borders is presented in Figure 1. The scale of the satellite images is different; it has been adapted to the available space.

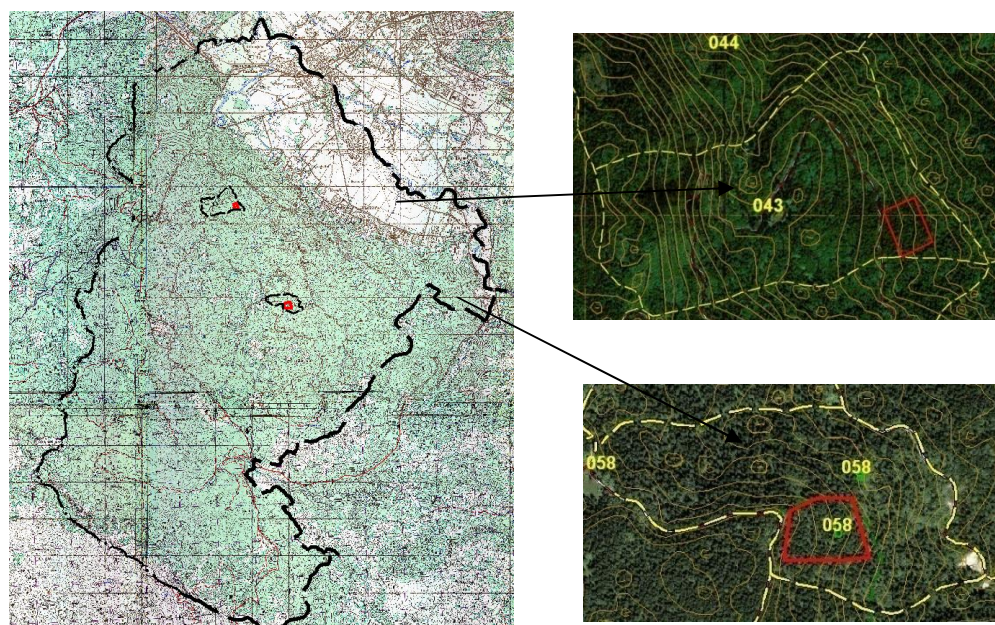


Figure 1. Map of management unit "Igman", borders of the forest sections 43 and 58 with the locations of the sample plots (left), satellite images of the inner areas of sample plots and their borders (right)

Slika 1. Karta GJ „Igman“, granice odjeljenja 43 i 58 sa lokacijama oglednih ploha (lijevo), satelitski snimci užeg područja oglednih ploha i granice ploha (desno)

The basic general and orographic data, vegetation and edaphic characteristics of the researched sample plots are presented in Table 1.

Table 1. Orographic, vegetation and edaphic characteristics of sample plots 43 and 58
Tabela 1. Orografske, vegetacijske i edafske karakteristike oglednih ploha 43 i 58

Sample plot	Altitude (m)	Exposition	Inclination (°)	Area (ha)	Plant Community (Two Relevés)
					Soil
43	1.110	NE	20	1,50	1. <i>Abieti Piceetum illyricum</i> Stef. 2. <i>Abieti Piceetum illyricum</i> Stef.
					Series of soil on limestone. Dominating illimerised soil.
58	1.280	NE	25	2,63	1. <i>Abieti Piceetum illyricum</i> Stef. 2. <i>Abieti Fagetum illyricum</i> Treg.
					The predominant brown soil, mainly shallow, sandy soil on dolomite

The first phytocoenological relevés were made after the foundation of the sample plots and the second ones during the last (fifth) measurement, fifty years later.

During the observation period, there were selective felling on the principle of positive selection made on the sample plots, i.e. trees for felling were selected exclusively from a silviculture point of view.

METHODS OF DATA COLLECTION AND ANALYSIS - *Metode prikupljanja i analize podataka*

Diameters at breast height (*DBH* or $d_{1,3}$) and tree heights (h) above the taxative threshold of 10 cm, were first measured immediately after founding of the sample plots. The measurement was then repeated three times every 10 years, while the fifth measurement, due to the past war events, was conducted 20 years after the fourth one. *DBH* were recorded at every measurement and h during the first, second and fifth one.

DBH were always measured at the same position which had been marked with colour at the first measurement; every following measurement numbered and measured trees that were passed taxative threshold (ingrown trees) and registered a felled trees. Diameter structures were created by distributing trees into diameter classes of 5 cm and summary statistics were determined. During the calculation of this statistics, *DBH* were replaced by average diameter classe to which the trees belong, since the original tree diameters of the first four measurements had been lost during the war, while the diameter classes had been saved (PAVLI , 1987).

Diameter classes of individual measurements were compared to theoretical models often used for presenting diameter frequency distribution. They have been

compared to Normal, Gamma (3 parameters) and Weibull (3 parameters) distribution. The parameter calculation of these functions and the testing of the significance of differences of empirical and theoretical distribution has been carried out using the software STATGRAPHICS CENTURION, option *Distribution Fitting*. The Kolmogorov-Smirnov test (KS) was used for testing the differences.

The changes in the diameter structure in the observation period were analysed by comparing the tree participations in the expanded diameter classes (A: to 30 cm; B: from 30 to 50 cm; C: 50 cm and higher), while the statistical significance of difference between successive diameter structures was tested using the Kolmogorov-Smirnov test (STATGRAPHICS CENTURION, option *Two Sample Comparison*).

Height curves for the main species of trees were constructed based on the data of the second and fifth measurement using the method of simple nonlinear regression. Having analysed several different regression models, which are often used to construct sigmoid curves, such as height curves or growth curves of any growth parameter, the Prodans model was chosen:

$$h_{-1,3} = \frac{DBH^2}{(a + b \cdot DBH + c \cdot DBH^2)}$$

in which: h - tree height, DBH - diameter at breast height, a , b and c - function coefficients.

The size of the coefficients and the regression summary statistics were determined using the software STATISTICA 7.0, option *Nonlinear Estimation*.

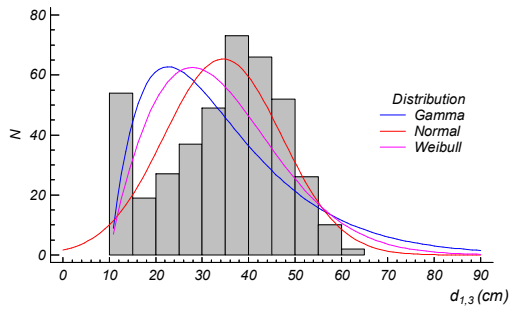
The changes of tree height of a specific DBH in the observation period were analysed by a simple comparison of heights for diameters which represent the limits of expanded diameter classes.

RESULTS - *Rezultati istraživanja*

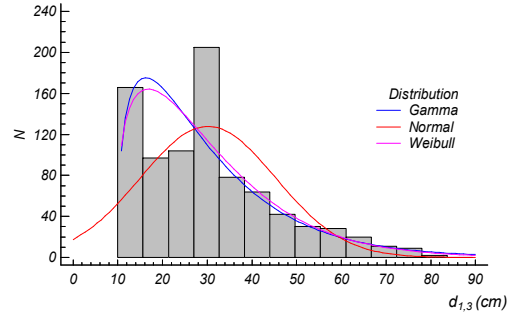
DIAMETER STRUCTURE - *Debljinska struktura*

Graphic presentations of diameter structures of the sample plots for the five conducted measurements and the determined theoretical models are presented in Figure 2 (a-d), and the percentage diameter distributions of the number of ingrown (N_i) and felled (N_f) trees in the periods between measurements in Appendix 2. Beside the diameter structures, there are also data on the number of trees per hectare (N) and the size of average diameter by basal area (Dg).

Diameter structure and height of trees dynamics of Fir (Abies alba mill.) and Spruce (Picea abies Karst.) stands in management unit „Igman“ (permanent sample plots 43 and 58)

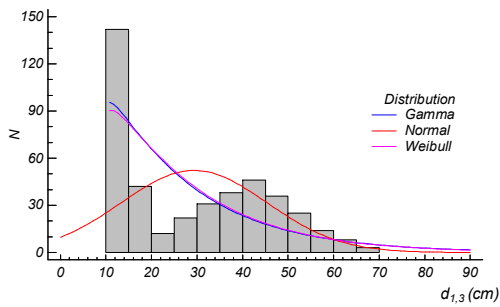


Sample plot 43; $N = 267,7$; $Dg = 36,7$

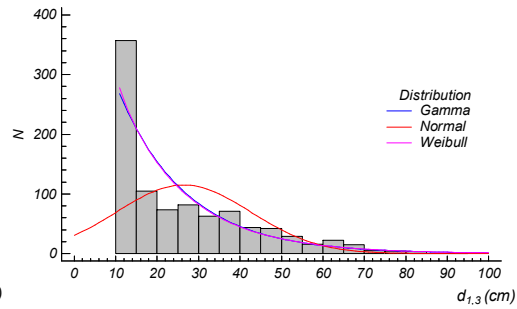


Sample plot 58; $N = 325,5$; $Dg = 33,8$

a) 1. measurement (1956.)

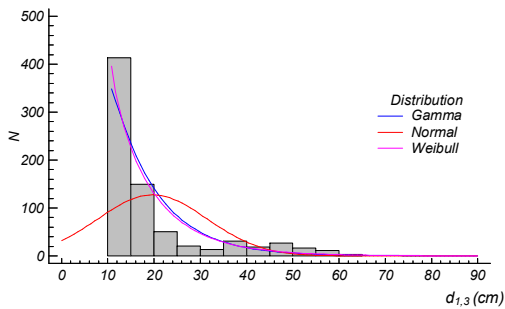


Sample plot 43; $N = 279,3$; $Dg = 33,4$

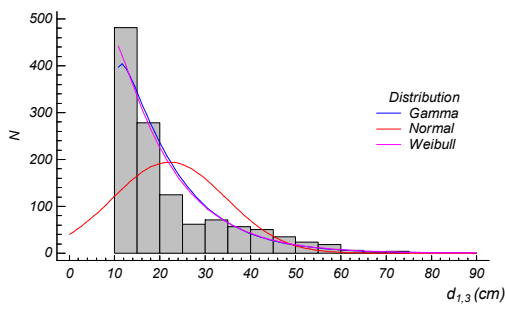


Sample plot 58; $N = 354,4$; $Dg = 31,0$

b) 2. measurement (1966.)



Sample plot 43; $N = 502,3$; $Dg = 22,9$



Sample plot 58; $N = 462,4$; $Dg = 25,4$

c) 3. measurement (1976.)

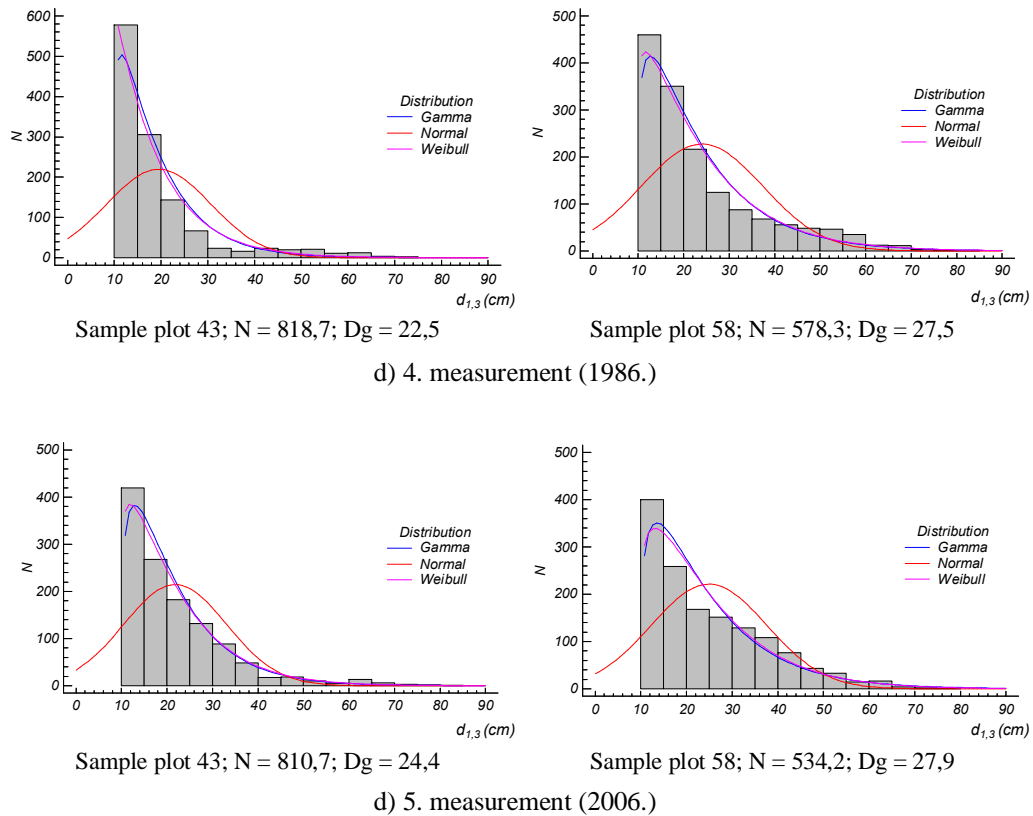


Figure 2. Frequency distributions of DBH for each measurement
 Grafikon 2. Distribucije frekvencija prsnih prečnika stabala za pojedine premjere

According to the graphic presentations and statistical parameters for frequency distributions (appendix 1) the diameter structures of the first measurement is characterized by a rather small proportion in thin diameter class (A) and a large proportion of the middle class trees (B). During the time diameter structures have changed in the sense of increasing proportion of trees in the lower diameter classes and decreasing in the middle and higher ones, or increase of positive skewness and kurtosis. The exception is the fifth measurement in which determined reduced proportion of trees in the lower and higher diameter classes, and increased in the class of middle diameter, Table 2.

Diameter structure and height of trees dynamics of Fir (Abies alba mill.) and Spruce (Picea abies Karst.) stands in management unit „Igman“ (permanent sample plots 43 and 58)

Table 2. Percentage distributions of the number of trees per expanded diameter classes
Tabela 2. Procentualne raspodjele broja stabala po proširenim debljinskim klasama

Sample plot	Diameter classes	Measurement				
		1	2	3	4	5
43	A	33,0	52,1	84,1	89,0	82,4
	B	57,9	36,0	12,0	6,8	14,3
	C	9,1	11,9	4,0	4,2	3,3
58	A	56,7	66,2	77,8	75,7	69,7
	B	31,6	23,6	17,6	17,1	25,3
	C	11,7	10,2	4,6	7,2	5,0

The largest changes in diameter structures have appeared in the period between the second and the third measurement.

According to the results of the KS test diameter structures of successive measurements, there are significant statistical differences on the confidence level of the 95 % ($p < 0.05$), Table 3.

Table 3. Comparison of the diameter structures of successive measurements
Tabela 3.: Poređenje debljinskih struktura uzastopnih premjera

Sample plot	KS test	Between Measurements			
		1 and 2	2 and 3	3 and 4	4 and 5
43	Estimated overall statistic DN	0,339	0,548	0,548	0,471
	Approximate P-value	0,000	0,000	0,000	0,000
58	Estimated overall statistic DN	0,383	0,396	0,396	0,302
	Approximate P-value	0,000	0,000	0,000	0,000

The determined diameter structures statistically differ ($p < 0.05$) from the applied theoretical models of frequency distribution (Normal, Gamma - 3 parameters and Weibull - 3 parameters). Parameter sizes and the KS test results on the confidence level of the 95 % are presented in Appendix 3.

HEIGHT OF TREES - *Visine stabala*

Height curves of the second and fifth measurements (*HC_2* and *HC_5*) separated by tree species are presented in Figure 3, while the size of coefficients and statistic summary of the chosen regression models are presented in appendix 2. In the graphs are given and the average heights of diameter classes (*h_avg_2* and *h_avg_5*).

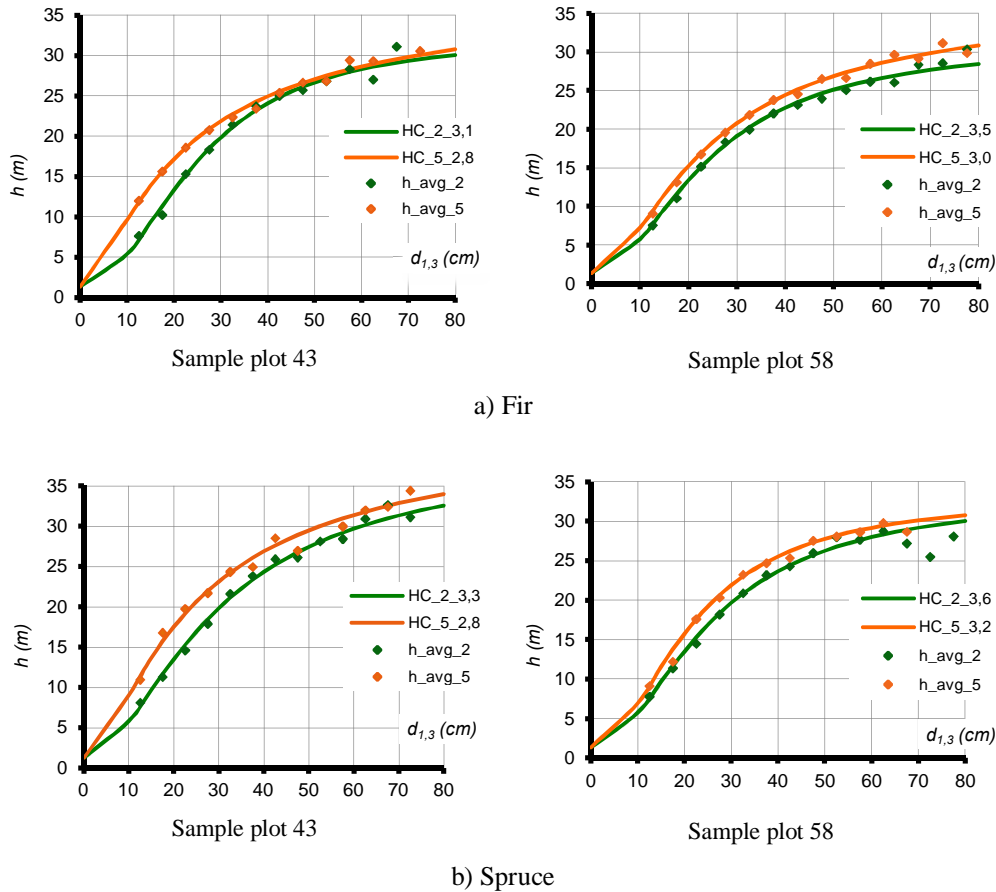


Figure 3. Height curves and average diameter classes heights
 Grafikon 3. Visinske krive i prosječne visine debljinskih klasa

Height curves for various measurements are not identical, but in each of the cases they are of a sigmoid shape with significantly longer, less and more expressed, part of degressive increase of trees height with the increase of their diameter.

Trees height in the fifth measurement is, on average, larger that the trees height of the second measurement comparing trees of the same diameter. The differences in height of trees in an absolute and percentage amount in relation to the height at the second measurement for diameters of expanded diameter classes (A, B and C) are presented in Table 4.

Table 4. The differences of the estimated tree heights between the fifth and second measurement for limits of the extended diameter classes

Tabela 4. Razlike procijenjenih visina stabala petog i drugog premjera za granice proširenih debljinskih klasa

Sample plot	Species of trees	The differences in absolute amount (m)				The differences in percentages (%)			
		10	30	50	70	10	30	50	70
43	JL	4,24	2,00	0,39	0,47	44,18	9,16	1,44	1,59
	SM	3,27	3,29	2,03	1,53	35,85	14,21	6,87	4,65
58	JL	1,47	1,70	1,79	2,22	20,39	8,18	6,67	7,42
	SM	1,18	2,24	1,48	0,90	17,08	10,24	5,33	3,01

Heights of spruce trees on both sample plots have been changed in the same way. The greatest increase in the absolute amount was determined for trees in medium diameter class, and the smallest for thin trees. In percentage, the largest increase is the height of thin trees, while the height increase of thick trees is the smallest in this case as well. The largest increase in fir trees height in the absolute amount, was determined for thin trees on the sample plot 43, and for thick trees on sample plot 58. The situation is reversed for the smallest increase of fir trees height. Fir trees height increase, if presented in percentage, as for spruce, is the largest for thin and smallest for thick trees.

DISCUSSION AND CONCLUSIONS – *Diskusija i zaključci*

DIAMETER STRUCTURE - *Debljinska struktura*

Diameter structures of the first measurement are not of a falling curve shape which is a characteristic of selective stands. These structures, due to a large participation of medium thick trees, remind of diameter structures of even-aged stands and thus imply the remaining virgin forest features (MATI 1980). This was specific of most beech, fir and spruce forests in Bosnia at the time of founding the sample plots, and it is directly connected to the fairly short amount of time since virgin forest began to be transformed into economical forests.

An increase in the participation of thin trees has been ascertained as well as the decrease of the participation of medium thick trees, which is a direct consequence of the felling in the period between individual measurements and tree increments, entry trees in the inventory part of the stand (ingrown trees) and the next higher or even greater diameter degrees.

Stronger intensity felling, which had been undertaken on both sample plots immediately prior to the second and third measurements, including medium thick trees to the greatest extent, influenced a more significant change in diameter structures. Due to more free space and larger quantities of light in the stands, these felling have

resulted in a greater intensity of ingrown trees and an increase in the participation of thin trees, thus forming diameter structures of a falling curve form. Minor differences in diameter structure forms in the following periods, between the third and fourth, and the fourth and fifth measurements, are connected to lower intensity felling which mostly included thin trees of which an important part is mortality due to competition. This relates to the period between the fourth and fifth measurements which is twice longer than other periods, due to war, and without regular felling.

Based on the shape of diameter structures and their changes, regardless of the aberrations from the regular models, it can be stated that by using selective felling on the principle of positive selection, a selective structure, or one similar to it, has been created.

Based on the values of homogeneity index (H), determined for diameter classes of 5 cm (IBRAHIMSPAHIĆ, 2012), a selective structure was achieved at the second, third and fourth measurement on the sample plot 43 (H: 2,58; 2,18 and 2,63), and in the third measurement on sample plot 58 (H: 2,79). Aberrations from selective structure are a consequence of a larger participation of medium thick and thick trees. Aberrations of diameter structure from a regular falling curve diameter structure, due to the 'lack' or 'surplus' of trees in individual diameter levels, according to MATIĆ (1980) are a common appearance. Achieving an ideal diameter structure in a specific stand and with rational management is rarely possible, and if it does happen it is difficult to be maintained.

The determined changes of diameter structures are in accordance with the results of selective forest structure research according to which a diameter structure in the form of falling curve is formed if selective felling is carried out over a longer period of time (LIOCOURT, 1899 according to SCHÜTZ, 1989; MEYER, 1933 according to KOTAR 2005).

It is important to notice the research results of BONINA and DEVJAK (2002) and KOTAR (2003) according to which the functioning of forests, as selective ones and fulfilling goals over decades, is possible even in case of deflection of the diameter structure from the regular shape. KOTAR (2003) came to the conclusion that the calculated theoretical frequencies according to the Liocourt formula are not the necessary condition for a balanced state, and that there is not a completely balanced state and thus it is more appropriate to use the term 'state of dynamic balance'.

The determined 'loss' of selective structure, after it has been achieved according to the homogeneity index size, is in accord with the already known notion that selective forests are biologically stable and structurally unstable (AMON, 1944; FLURY, 1933 and LEIBUNDGUT, 1945, according to MILETIĆ, 1950; MATIĆ, S., et al., 2001) and that the manner of management demands long-term consistent work and ample knowledge and experience at the selection of trees for felling (BONINA, 2011).

HEIGHT OF TREES - *Visina stabala*

Different shapes of height curves imply the variety of stand structure, site conditions, height and diameter increment flow and the foundation of selective structure.

According to the determined height curve forms, an increased diameter increment and decreased height increment, trees of 25-40 cm diameters can be characterized, while the diameter increment for trees over 40 cm is even larger with a lower height increment.

These results are in accordance with MILETI (1950), since one can notice the appearance of a period of large increment in lower diameter classes based on height curve forms. These results are also in accordance with BURGER (1941 according MILETI, 1950) who also notices that an abrupt decrease in height increment sets in at diameters 20-40 cm, when trees are in a more open space and cross from the lower into the higher layer.

The changes in tree height, i.e. the difference in height curves, is a consequence of the difference in stand structure due to the application of different intensity felling and the change in wood volume and diameter and height structure of the stands (FLURY, 1933 and LEIBUNDGUT, 1945 according MILETI, 1950; MITSCHERLICH, 1952 according KOTAR, 2005; KLÄDTKE, YUE, 2003; KOTAR, 2005).

The determined tree height increase in the entire interval of empirical data, during the period the height curve changes were analysed (40 years), is in accordance with diameter structures of the stands. This period saw an increase in the number of trees, mostly thin trees (10-30 cm); the participation of medium thick trees (30-50 cm) was decreased, while the participation of thick trees was increased. In some cases, we saw the increase in the diameters of the thickest trees. In such conditions, there is serious competition between trees, especially between thin and medium thick trees; trees maintain a strong height increment at the cost of diameter increment and thus achieve a larger level of slenderness in all diameter classes. This so-called survival strategy (PRETZSCH, 2009) results in shifting height curves to bigger heights. The increase of tree height of specific diameter structures is also based on computation, i.e. it is the consequence of felling shorter trees due to positive selection. This is especially true for thick fir trees on the sample plot 58, with the largest increase in height.

This shift in height curves is not specific for stands with long-term selective manner of management. A long-term consistent application of selective manner of managing stand structures does not change significantly and related to it neither do tree heights of specific diameters. Medium heights of diameter classes in a selective stand tend to achieve a certain state of balance, while achieving possible tree heights for specific stands, which is a suitable measure for stand quality (FLURY, 1929 according MILETI, 1950). In the case of increased target diameter level there can be an

increase in tree height in higher diameter classes with the decrease or stagnation for tree height of lower diameter classes (FLURY, 1932 according MILETIĆ, 1950).

The changes determined in this paper are changes which occur in the process of creating a selective structure of the stand. In the upcoming period, by creating a selective stand structure and decreasing competition between medium thick and thick trees, height and slenderness level of trees of the same diameter will decrease to a certain extent due to the increase of diameter increment; while the thin tree heights should not experience significant change.

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APPENDICES - Prilozi

Appendix 1. Summary Statistics for *DBH* of trees
 Prilog 1. Deskriptivna statistika prsnih prečnika stabala

Summary Statistics	Sample plot									
	43					58				
	Measurement									
	1	2	3	4	5	1	2	3	4	5
Count	415	419	754	1228	1216	856	932	1216	1521	1405
Average (cm)	34,5	29,4	19,7	19,5	21,8	30,2	26,4	22,1	24,0	24,9
Median (cm)	37,5	27,5	12,5	17,5	17,5	27,5	22,5	17,5	17,5	22,5
Mode (cm)	37,5	12,5	12,5	12,5	12,5	12,5	12,5	12,5	12,5	12,5
Std. dev. (cm)	12,7	16,0	11,8	11,2	11,3	15,1	16,2	12,5	13,3	12,7
Coeff. of var. (%)	36,8	54,5	60,0	57,2	51,9	50,2	61,3	56,4	55,5	50,8
Standard error	0,6	0,8	0,4	0,3	0,3	0,5	0,5	0,4	0,3	0,3
Minimum (cm)	12,5	12,5	12,5	12,5	12,5	12,5	12,5	12,5	12,5	12,5
Maximum (cm)	62,5	67,5	62,5	72,5	82,5	82,5	92,5	72,5	82,5	77,5
Range (cm)	50,0	55,0	50,0	60,0	70,0	70,0	80,0	60,0	70,0	65,0
Skewness	-0,3	0,4	1,8	2,3	1,9	0,8	1,2	1,5	1,4	1,1
Std. skewness	-2,5	3,3	20,6	33,5	27,3	9,6	14,4	21,4	22,3	16,1
Kurtosis	-0,8	-1,2	2,3	5,4	4,6	0,1	0,7	1,6	1,3	0,6
Std. kurtosis	-3,3	-5,0	13,0	39,0	32,8	0,5	4,2	11,7	10,7	4,6

Appendix 2. Percentage diameter distributions of the number of ingrown (*Ni*) and felled (*Nf*) trees

Prilog 2. Procentualna debljinska raspodjela broja uraslih (*Ni*) i posječenih stabala (*Nf*)

	Diameter classes	Sample plot							
		43				58			
		Between Measurements							
		1 and 2	2 and 3	3 and 4	4 and 5	1 and 2	2 and 3	3 and 4	4 and 5
<i>Ni</i>	A	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0
<i>Nf</i>	A	20,4	15,7	65,6	81,8	33,5	32,4	80,3	74,0
	B	71,0	55,1	27,1	12,2	32,1	32,5	13,1	14,8
	C	8,6	29,2	7,3	6,0	34,4	35,1	6,6	11,2

Diameter structure and height of trees dynamics of Fir (Abies alba mill.) and Spruce (Picea abies Karst.) stands in management unit „Igman“ (permanent sample plots 43 and 58)

Appendix 3. Coefficients of theoretical models of frequency distributions and results KS tests differences empirical and theoretical frequency (DN and p; probability 95%)

Prilog 3. Koeficijenti teoretskih modela distribucija frekvencija i rezultati KS testa razlika empirijskih i teoretskih frekvencija (DN i p; vjerovatnoća 95 %)

Sample plot	Measurement	Theoretical models								
		Normal		Gamma (3-parameter)			Weibull (3-parameter)			
		mean	standard deviation	shape	scale	lower threshold (specified)	shape	scale	lower threshold (specified)	
43	1	parameters	34,464	12,672	2,068	0,085	10,000	1,853	27,183	10,000
		DN	0,187		0,216			0,192		
		p	0,000		0,000			0,000		
	2	parameters	29,362	16,011	1,051	0,054	10,000	1,057	19,770	10,000
		DN	0,210		0,227			0,233		
		p	0,000		0,000			0,000		
	3	parameters	19,668	11,805	1,029	0,106	10,000	0,943	9,363	10,000
		DN	0,318		0,326			0,298		
		p	0,000		0,000			0,000		
	4	parameters	19,516	11,153	1,183	0,124	10,000	1,017	9,595	10,000
		DN	0,291		0,276			0,246		
		p	0,000		0,000			0,000		
	5	parameters	21,801	11,310	1,326	0,112	10,000	1,131	12,392	10,000
		DN	0,214		0,212			0,195		
		p	0,000		0,000			0,000		
58	1	parameters	30,175	15,140	1,445	0,072	10,000	1,289	21,777	10,000
		DN	0,137		0,135			0,134		
		p	0,000		0,000			0,000		
	2	parameters	26,411	16,183	0,997	0,061	10,000	0,980	16,262	10,000
		DN	0,205		0,241			0,236		
		p	0,000		0,000			0,000		
	3	parameters	22,114	12,478	1,136	0,094	10,000	1,030	12,279	10,000
		DN	0,268		0,236			0,219		
		p	0,000		0,000			0,000		
	4	parameters	24,039	13,344	1,232	0,088	10,000	1,096	14,571	10,000
		DN	0,221		0,180			0,168		
		p	0,000		0,000			0,000		
	5	parameters	24,938	12,659	1,310	0,088	10,000	1,172	15,805	10,000
		DN	0,191		0,181			0,176		
		p	0,000		0,000			0,000		

Appendix 4. The values of coefficients and statistical parameters for the selected regression models of height curves

Prilog 4. Veličine koeficijenata i statističkih pokazatelja odabranih regresionih modela visinskih krivih

Sample plot	Species	Measurement	Coefficients of functions			R	R ²	S _{ey} ²	N
			a	b	c				
43	JL	2	0,033	-0,112	22,525	0,998	0,996	0,255	612
		5	0,027	0,514	4,239	0,942	0,887	3,844	141
	SM	2	0,026	0,300	16,410	0,995	0,989	0,440	147
		5	0,024	0,467	5,733	0,970	0,940	3,860	70
58	JL	2	0,033	0,097	18,239	0,998	0,997	1,311	555
		5	0,028	0,361	10,517	0,976	0,953	3,813	114
	SM	2	0,031	0,097	18,595	0,998	0,996	0,879	344
		5	0,031	0,051	14,250	0,960	0,922	8,439	131

R - coefficient of correlation; R² - coefficient of determination;
S_{ey}² - standard error of estimate; N - number of tree heights

SAŽETAK

U radu je analizirana dinamika debljinskih struktura i visinskih krivih, kao osnovnih pokazatelja jednostavne strukture sastojina, raznodobnih vi-espratnih sastojina jele i smr e u GJ šIgmanõ u kojim se provode preborne sje e bazirane na principu pozitivne selekcije. Pri tome su kori-teni podaci koji su prikupljeni periodi nim premjerima tokom 50 godina na dvije stalne ogledne plohe u -umskim odjeljenjima 43 i 58.

Utvr eno je da debljinske strukture prvog premjera, zbog zna ajnog udjela srednje debelih stabala, odstupaju od oblika koji je karakteristi an za preborne sastojine i podsje aju na debljinsku strukturu jednodobnih sastojina. Ove debljinske strukture su vremenom uz sje e debelih i srednje debelih stabala, razvoj novog i postoje eg podmlatka, te prirast stabala i prelazak u naredni vi-i ili vi-e debljinske stepene postepeno prevedene u debljinske strukture oblika karakteristi nog za preborne sastojine. Uz to je, zbog pove anja konkurencije izme u stabala nifih debljinskih klasa i sje e nifih i nekvalitenijih stabala vi-ih debljinskih klasa, do-õo do pove anja visina stabala u cijelom intervalu empirijskih podataka, odnosno pomjeranja visinskih krivih prema ve im visinama stabala.

Zaklju eno je da se primjenom prebornih sje a na principu pozitivne selekcije vremenom postepeno formira debljinska struktura uz koju je obezbije eno funkcionisanje sastojine kao preborne, a visine stabala se mijenjaju prema visinama koje su realno mogu e na datom stani-tu i tek tada se mogu koristiti kao pogodan indikator proizvodnog potencijala stani-ta.