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ECOLOGICAL AND STRUCTURAL CHARACTERISTICS OF MONODOMINANT MONTANE BEECH FORESTS IN THE NATIONAL PARK BIOGRADSKA GORA, MONTENEGRO

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Abstract - Due to their extraordinary diversity and high level of conservation, the forest ecosystems of Biogradska Gora undoubtedly fall under the most significant forest objects. Owing to the lack of anthropogenic impacts, it is an especially interesting and gratifying research subject for different experts and scientists. In order to implement a sufficiently high biodiversity level management, it is necessary to know the structural characteristics of untouched forests. In this paper we focused our attention on monodominant montane beech forests with their ecological and structural characteristics, as a bioecological basis for environmentally friendly planning and sustainable management of these and similar forest ecosystems.

Key words: Virgin forest, ecology, structure, Nt. Biogradska Gora, Montenegro

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INTRODUCTION

Intensive forest utilization, especially in Western Europe, has resulted in a substantial reduction of areas under virgin forest. Only 1.7% of forest complexes in Europe have an autochthonous structure (Parvainen et al. 2000). This is why examination of the characteristics of untouched forest ecosystems is of increasing interest and significance.

It is thanks to Laibundgut by his actions at IUFRO (International Union of Forest Research Organizations) congresses and his numerous works (Leibundgut 1956, 1978, 1982, 1986, 1989, 1993) that the exploration of virgin forests is undertaken. In his interpretation, virgin forest does not only imply one forest stand, but also the entire forest complex whose habitat, vegetation and mixture of trees is susceptible exceptionally to natural ecological impacts. According to Korpel (1995), a virgin forest is an ecologically stable forest with firm and dynamically balanced relations between the climate, soil and organisms, at the same time conserved from such antropogenous impacts that may change the validity of life processes and stand structure. Indisputable contributions to the investigation of virgin forests within the region have been given by Prpić (1979), Pintarić (1978), Matić (1998), Hartman (1999), Medarević (2001, 2005), Medarević et al. (2002, 2004, 2007), Mayer et al. (2003), Govedar et al. (2006), Dubravac (2006). Kojić and Vilotić (2006), Anić and Mikac (2008) etc.

When speaking about the area of the National Park Biogradska Gora, because of its specific regime of protection, investigations of the forest ecosystems have mainly focused on the diversity of flora (Blečić, 1960; Lakušić, 1966; Blečić and Lakušić, 1970, Lakušić et al. 1991, Stešević and Petrović, 2004, Petrović et al. 2009), fungi (Perić and Perić 1996, 2005, Perić 2001, 2007) and lichens (Bilovitz et al. 2008, 2009, Knežević and Mayrhofer, 2009), while structural characteristics (Tomanić 1991, Medarević et al., 2004), and net primary production and biomass of the most significant ecosystems (Dizdarević et al. 1991) have only occasionally been researched. Because of this, data on virgin forest communities and their production capacities are very scarce.

The protection of this exquisite natural complex dates from 1878 and it belongs to the group of the oldest reserves in the world. The narrower area of the Park extends over the 5450 ha and belongs to the basin of the Biogradska river. Two-level protection (Fig. 1) was setup and two main zones with different regimes established: a zone of strict protection (1600 ha) - virgin forest reserve where all activities that may endanger the spontaneous development and autochthonous nature of this area is forbidden, and the zone of a more liberal regime of protection (3850 ha) with strict selection and control of activities.

The National Park Biogradska Gora, because of the presence of a large number of endangered taxa, floristic richness and presence of the virgin forest reserve (one of the last three in Europe) has been proposed for the site of the national IPA network according to criteria 1 (Petrović, 2009).

The principal objective of our study was to have a better insight into the basic characteristics of the forest ecosystems through defining forest types as an ecological basis for forest management planning in the National Park Biogradska Gora. At the same time, we have started from the aspect that the central position of the administration and management of the forests and environment is taken by investigations directed to define of basic ecological units (Wuest, 2010).

Fig 1. Position and zone of National Park Biogradska Gora

MATERIALS AND METHODS

The field research included stands within the coeno-ecological group of beech forests types (*Fagion moesiacum*) in eutric and district brown soils. Within the framework of mentioned cenoecological group we have singled out 3 ecological units (sub-associations) such as:

A - typical forest of montane beech *(Fagetum moesiacae montanum typicum)*, on medium deep brown forest soil on eruptive rock;
B - forests of montane beech with fescue (*Fagetum moesiacae montanum drymetosum)* on shallow brown forest soil on eruptive rock;
C - forests of montane beech with woodrush (*Fagetum moesiacae montanum luzuletosum)* on shallow brown forest soil on eruptive rock.

In the zone of strict protection, 9 experimental plots in a monodominant beech forests were chosen; 4 are situated in a typical montane beech forest *(Fagetum moesiacae montanum typicum),* 4 in a montane beech with forest fescue (*Fagetum moesiacae montanum drymetosum),* and only one in a montane beech forests with woodrush (*Fagetum moesiacae montanum luzuletosum*), because it was determined at only one site in the area of the reserve.

The principal research plan was the identification of the pedological, phytocenological and meteorological/climate characteristics of the studied areas by standard methods. After defining the sub-associations we completed a recording, surveying, review and evaluation of the structural forest characteristics (according to typologically methodology). For the identification of primary structural characteristics we completed a total survey of the basic measurement elements (diameters at breast height with accuracy in millimeters, and heights of trees - accuracy in decimeters for all trees with a diameter at breast height (dbh) > 10 cm).

In order to get more precise data about the soils, we took soil samples from each experimental plot. Nine pedological profiles were opened and 19 soil samples processed. According to analysis done in the laboratory of the Centre for Soil Studies of the Biotechnical Faculty in Podgorica, we obtained data on the physical and chemical soil characteristics. Mechanical soil analysis was determined according to the international pipette "b" method. Content of natural-alkali carbonates was done according to Schibler's method, hummus according to Kotzmann's method, and easily accessible phosphorus and potassium by the Al-method according to Egner-Riehm. The hydrolytic acidity of the soil and the sum of absorbed base cations were defined by Kappen's method.

Methodology of phytocoenological studies followed Braun-Blanquet (1964). In total, 11 phytocoenological relevés were taken, 8 in experimental plots, and an additional 3 outside the plot borders, but still in the same sub-association.

Analysis of the structure of these stands showed homogeneity of growth conditions of the present elements of dendroflora and their relation to habitat conditions.

Volume was calculated by the method of direct equalization of volumes, according to Schumacher-Hall's function :

$$V = a\, d^b\, h^c$$

Value of coefficients a, b and c for beech in Montenegro was obtained by computation process from volume tables and they amount to:

a= 0.32037; b= 1.93358; c= 1.026100

Basic statistical indicators for measurement elements are identified with the support of Statgraphics Centurion XV program package.

RESULTS AND DISCUSSION

With reference to the pedological and geological characteristics, we can state that the studied area has a dominant type of soil: brown acid – dystric cambisol on eruptive rock (Fuštić and Djuretic, 2000), and that its geological stratum is made of different eruptive rocks which appeared in this area after the volcanic activities during the Middle Triassic and Jurassic ages (Mihailović et al., 1991). Among them, the most represented are acid equivalents such as keratophyres, quartz keratophyres, rhyolite and their tuffs. Soil in eruptive rocks was found in terrains with a very prominent and dynamic configuration. Three ecological units (sub-associations) were identified within the studied area of a monodominant montane beech: A - *Fagetum montanum typicum*, B - *Fagetum moesiacae montanum drymetosum,* C - *Fagetum moesiacae montanum luzuletosum.*

Compared to the other sub-associations, typical beech forest (*Fagetum moesiacae montanum typicum),* apart from the dominance of beech in the tree layer, is also characterized by poorer floristic composition (Table 2). When speaking about characteristic species of the herb layers which are typical for these forests, the highest abundance is that of *Asperula odorata, Cardamine bulbifera*, *Lamiastrum galeobdolon,* and *Anemone nemorosa.* These stands are characterized by the high cover value of the tree layer (0.9-1.0). The dimensions of the beech trees indicate the high production potential of these forests. The total depth of the profiles of the soil (Table 3) is slightly more than in the other sub-associations and ranges from 40 cm in profiles A1, A2 and A4, to 50 cm depth in A3. In the case of the last soil profile (A3), three layers are distinguished according to the depth.

A particularity of montane beech forests with forest fescue (*Fagetum moesiacae montanum drymetosum)* is a larger number of acidophilic species. Among them, the highest abundance is that of fescue itself (*Festuca drymeia*), followed by *Oxalis acetosella, Lamiastrum galeobdolon* and numerous bryophytes, etc. Concerning the total depth of the soil profiles, it ranges from 25 to 30 cm in B1, B2, B3 and up to the

Table 1. Average values of basic measurement elements.
N- Number of trees; V-Volume; dg, dg_{max}, hg and hg_{max} – average and maximum diameter and high

Ecological unit (subassiciation)	N (Nº/ha)	V (m^3/ha)	dg (cm)	dg_{max} (cm)	hg (m)	hg_{max} (m)
A	396	521.0	38.5	62.8	22.5	29.7
B	426	434.6	35.3	58.8	20.9	27.3
C	483	402.3	33.4	51.0	20.2	23.7

Table 2. Phytocoenological relevés
A- subassociation *Fagetum moesiacae montanum typicum,* B- subassociation *Fagetum moesiacae montanum drymetosum,* C- subassociation *Fagetum moesiacae montanum luzuletosum*.
1-5- number of experimental plots

Phytocoenological relevé	A-1	A-2	A-3	A-4	A-5	B-1	B-2	B-3	B-4	B-5	C
Altitude (m)	1150	1240	1260	1270	1200	1270	1300	1350	1280	1260	
Exposure	W	S	NW	SW	NW	W	NW	S	SW	WN	S
Slope (°)	20	20	25	20	20	17	30	45	25	20	45
Tree layer											
Cover tree layer (%)	100	90	100	100	100	100	90	90	90	100	90
Fagus moesiaca	5.5	5.5	5.5	4.4	5.5	5.5	5.5	5.5	5.5	5.5	5.5
Acer pseudoplatanus		+	1.1	1.1					+		
Fraxinus excelsior		+		+					1.2		
Shrub layer											
Cover shrub layer (%)	30	20	10	20	50	10	20	30	20	50	10
Average height (m)	2	3	5	5	3	2	3	3	3	3	2
Fagus moesiaca	2.3	1.2	+.2	1.2	3.3	1.2	1.2	2.2	1.2	3.3	+.2
Evonymus latifolia							+.2				
Herb layer											
Cover herb layer (%)	80	40	60	80	90	80	90	80	100	100	80
Asperula odorata	3.4	3.3	3.3	3.4	3.4	1.2	+.2	+.2	1.2	+.2	
Lamiastrum galeobdolon	1.2	+.2	1.2	1.2	1.2	1.2	+.2		1.2	1.2	
Cardamine bulbifera	1.2	+.2	+.2	2.3	+.2	+			+.2	+.2	
Festuca drymeia			+.2	+.2		5.5	5.5	3.3	5.5	5.5	
Fagus moesiaca	1.2	+.2	+.2	+.2	+.2	+.2			+.2	+.2	
Dryopteris filix-mas		+	+.2		+.2	+.2	+.2			+	
Abies alba	1.1	+				+	+	+		+	+
Oxalis acetosella					+.2	+	+			+.2	
Prenanthes purpurea	+	+		+		+	+	+			
Mycelis muralis	+		+	+	+	+	+	+			
Mercurialis perennis			+.2	+		+	+				
Geranium robertianum			+		+	+	+				
Fraxinus excelsior			+		+		+		+		
Anemone nemorosa	+.2	+.2	+.2	+.2	+				+		
Viola sylvestris	+	+	+	+	+					+.2	

Table 2. Continued

Phytocoenological relevé	A-1	A-2	A-3	A-4	A-5	B-1	B-2	B-3	B-4	B-5	C
Veronica urticifolia						+	+	+			0.2
Acer platanoides						+	+				
Acer pseudoplatanus		+	+	+	+	+					
Evonymus latifolia					+.2		+.2				
Lilium martagon			+						R		
Calamintha officinalis	+	+	+					+			+
Paris quadrifolia			+		+.2						
Polygonatum verticillatum			+.2	+	+						
Sambucus nigra					+						
Prunus avium			+								
Musci ssp.						2.2	2.3				
Galium rotundifolium		1.2				+.2	+.2				+.2
Polypodium vulgare						+	+				
Euonymus latifolia						+.2			+		
Athyrium filix-femina					+	+.2					
Galium sylvaticum						+	+	+			1.2
Neotia nidus-avis		+				+					+
Asplenium trichomanes						+					
Anemone nemorosa						+					
Polygonatum muliflorum						+					
Stellaria holostea						+					
Epilobium montanum			+		+	+					
Hieracium murorum						+					
Hieracium bauhinii											3.2
Luzula luzuloides	+.2						+.2	3.3			4.4
Asarum europaeum							+.2				
Rhamnus fallax							+.2				
Lathyrus vernus							+				
Rubus hirtus							+				
Ribes grossularia							+				
Lonicera xylosteum							+				
Saxifraga rotundifolia							+				
Sorbus aucuparia							+				
Tilia grandifolia									+		
Lonicera nigra					+.2				+		
Sorbus aucuparis										+	
Luzula sylvatica								1.2			
Symphytum tuberosum			+		+						
Melitis melisophyllum				+	+						
Geum urbanum					+						
Sanicula europaea			+.2								
Arum maculatum			+								
Melica uniflora		+.2									

Table 3. Physical and chemical properties of soil in experimental plots

sample	profile	horizon	depth	2-0.25	0.25-0.02	0.02-0.002	<0.002	total sand	total clay	% skeletor	humus (%)	pH in KCl	pH in H_2O	mg P_2O_5/ 100 g	mg K_2O/ 100 g
1	**B1**	**1**	**0-10**	21.40	37.90	20.78	19.92	59.30	40.70	49.931	11.1	3.88	4.75	**2.9**	**24.7**
2		2	10-25	28.10	39.80	16.57	15.53	67.90	32.10	51.669	2.8	4.06	4.75	1.2	15.2
3	**B2**	**1**	**0-12**	32.75	30.87	17.57	18.80	63.63	36.37	59.24	9.8	3.77	4.84	**2.1**	**21.5**
4		2	12-30	16.71	32.82	22.55	27.92	49.53	50.47	59.981	5.1	3.6	4.53	1.0	32.5
5	**B3**	**1**	**0-7**	21.28	30.82	24.82	23.08	52.10	47.90	24.54	4.6	3.51	4.79	**1.4**	**13.7**
6		2	7-30	21.92	26.73	24.95	26.40	48.65	51.35	31.756	2.6	3.47	4.21	0.7	12.1
7	B4	1	0-8	8.17	48.13	24.00	19.70	56.30	43.70	28.494	9.1	3.45	4.3	**2.8**	**29.4**
8		2	8-35	12.03	47.89	17.73	22.35	59.93	40.07	53.665	5.0	4.05	4.61	1.9	10.5
9	**C1**	**1**	**0-10**	8.95	43.10	23.68	24.27	52.05	47.95	30.125	5.2	3.25	4.14	**2.2**	**13.7**
10		2	10-35	14.45	35.80	20.67	29.08	50.25	49.75	23.313	2.7	3.8	4.44	0.6	5.8
11	**A1**	**1**	**0-10**	10.39	42.06	19.73	27.83	52.45	47.55	45.043	9.0	3.65	4.41	**2.0**	**16.8**
12		2	10-40	23.81	49.84	15.58	10.77	73.65	26.35	28.001	5.3	4.33	4.81	1.5	5.0
13	**A2**	**1**	**0-10**	25.74	34.06	19.37	20.83	59.80	40.20	39.967	6.4	3.47	4.55	**2.2**	**27.8**
14		2	10-40	24.01	35.12	15.32	25.55	59.13	40.87	43.032	3.3	3.98	4.72	0.8	8.9
15	**A3**	**1**	**0-8**	16.69	46.18	21.05	16.07	62.87	37.13	38.358	11.0	3.66	4.51	**2.7**	**16.8**
16		2	8-20	12.86	34.84	25.90	26.40	47.70	52.30	46.332	4.7	3.7	4.49	1.0	5.8
17		3	20-50	16.12	36.86	21.73	25.30	52.98	47.02	45.757	4.2	4	4.71	1.0	5.8
18	**A4**	**1**	**0-12**	0.45	56.78	21.43	21.35	57.22	42.78	29.832	10.9	3.24	4.17	**2.1**	**13.7**
19		2	12-40	7.21	30.39	25.80	36.60	37.60	62.40	37.312	4.8	3.51	4.34	1.6	7.4

35 cm in B4. The deeper profile soil is characterized by an extremely high content of potassium. Usually it is lower than in a hummus horizon and it rarely exceeds 10 mg to 100 g of soil.

The stand of montane beech with woodrush (*Luzula luzuloides*) as the differential species of ground flora is characterized by the dominance of slightly shorter beech trees in the tree layer. As far as the herb layer is concerned, there are *Hieracium bauhini*, *Galium silvaticum* etc. This site is characterized by its extremely steep terrain with shallower and skeleton soil of acid reactions. The sample of soil from this plot had the highest level of acidity compared to all the other tested ones (pH in H_2O is 4.14).

Considering the selection of the most favorable method of forest management in general, it is of extreme importance that in addition to knowledge of the biological-ecological characteristics there is good insight into the structural elements of stands.

The structure of the virgin monodominant beech forest of Biogradska Gora is close to even-aged forests. At first sight the presence of giant trees can easily be perceived. In addition, the number of trees per area and in a total cover is rather small. Taking into account that the forest is of a virgin type, its present structure is the result of spontaneous development processes over a long time period.

In general, the control of the number of trees points to the required management procedures which can change the number and distribution of trees in the stand (Medarevic *et al.*, 2010). The number of trees in sub-association A ranges from 276.7 to 583.3, on average 396. In sub-association B the number of trees ranges from 354.9 to 515.3, on average 426.2, while in sub-association C we recorded 483 trees per ha.

With regard to the structure it can be said that the researched stands of sub-associations A, B and C have a structure close to even-aged stands. This is indicated by appearance of one maximum in the diameter structure, and a more or less prominent left asymmetry (Figs. 2-4). It is obvious that here we have virgin forest communities of extremely weak regeneration. The number of trees whose diameters at breast height are less than 30 cm ranges from 42.4 % in series A to 53.2% of total number of trees in series C.

The line of distributing trees per diameter degrees of series A assumes a Gaussian curve with left asymmetry. Wide dispersion is a characteristic for virgin forest communities. This type of structure indicates the stable development phase of a virgin forest. The structural characteristics of the stands of sub-association B are similar to the one of sub-association A, whereas a slightly wider frequency is notable here. In sub-association C we come to a slightly narrower frequency of trees per diameter. Here we also come

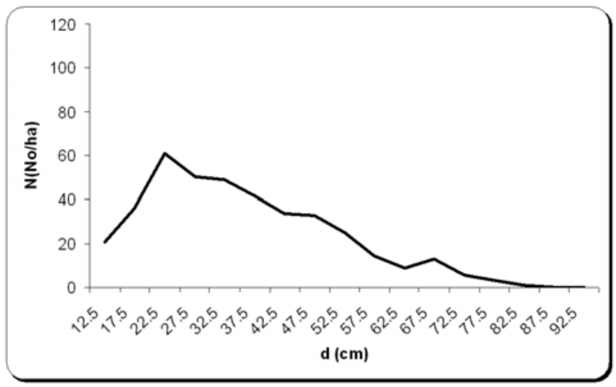

Fig. 2. Diameter structure of sub-association A

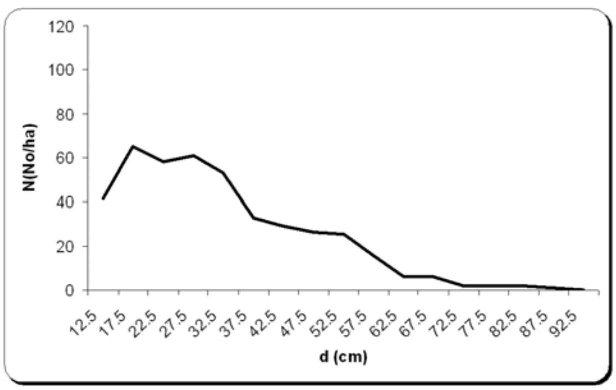

Fig. 3. Diameter structure of sub-association B

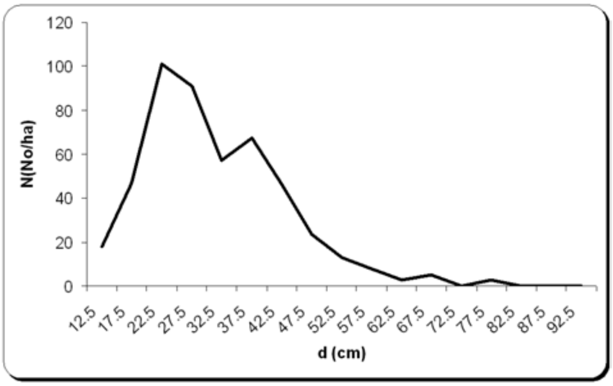

Fig. 4. Diameter structure of sub-association C

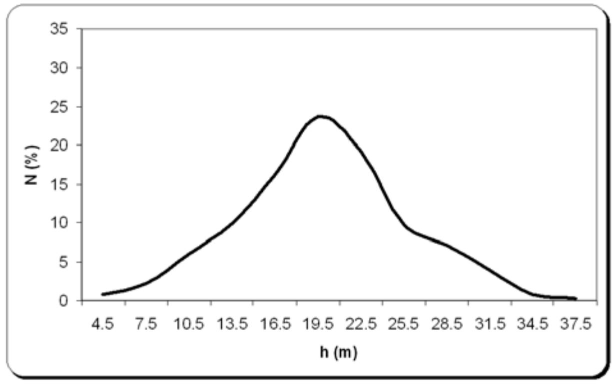

Fig. 5. Height structure of sub-association A

to the prominent left asymmetry of the tree distribution line per diameter degrees, and a stable phase of virgin forest development.

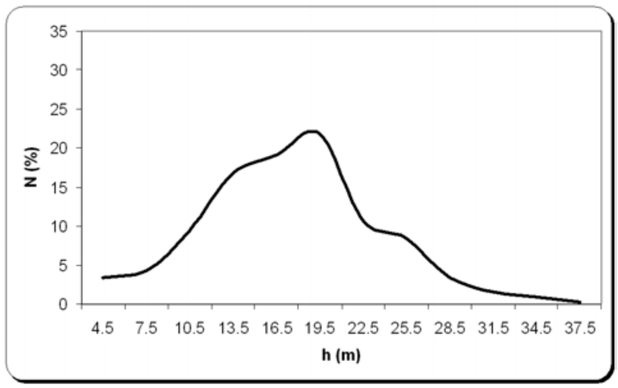

Fig. 6. Height structure of sub-association B

A more thorough evaluation of the structural characteristics of the stands can only be provided by a simultaneous analysis of structure per diameter and height (Medarević, 2006.). Tree height is a structural element that enables us to more realistically consider the vertical structure of stands.

After gaining an insight into the height structure of pure beech forests, we obtained confirmation for one layer of these stands since there is a maximum of representation of the number of trees appearing with a height level of 19.5 m. We can therefore classify the studied beech stands as structurally even-aged. At the same time, according to graphic layouts (Figs. 5-7), we can perceive the relationship of beech towards light. Beech as a type preferring semi-shade still streams towards an even-aged nature, with wide distribution per diameter and height. Thus, we should have in mind the virgin forest character of the researched object.

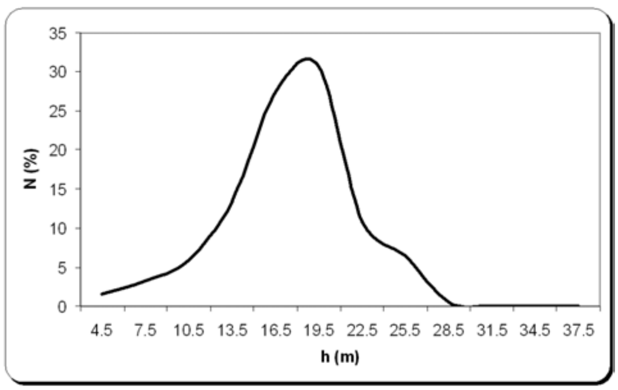

Fig. 7. Height structure of sub-association C

Indicators of wood volume quantity have significant values. Volume share from the lower to higher diameter degrees grows with minor oscillations and reaches a maximum at a certain diameter degrees; it then falls, which is one of the features of virgin forest type stands.

The same is in the sub-associations where beech is the dominant species. In sub-association A, apart from the maximum in diameter degree of 47.5cm, a prominent growth of volume at diameter degree of 67.5 occurs. In sub-association B the maximum value occurs at diameter degree 52.5cm, while in sub-association C the maximum wood volume stock occurs a little earlier in a diameter degree of 37.5cm.

The distribution lines of wood volumes per diameter degrees (Figs. 8-10) in series A and B have a bump shape and are relatively symmetrical, while in sub-association C left asymmetry is pronounced.

In the experimental plots of sub-association A, wood volumes range from 406.7 to 773.9m^3/ha, on average 521 m^3/ha. In sub-association B, the wood volumes are from 363 to 487.6 m^3/ha, on average 434.6 m^3/ha, and in sub-association C the average wood volume is 402.33 m^3/ha. In the National Park Đerdap, within the stands of a montane beech type we have identified volumes between 524 and 634 m^3/ha (Medarević, 2005). In stands with woodrush (*Luzulo-Fagetum moesiacae montanum*) in Đerdap, as in Biogradska Gora, we have identified the lowest volumes, below 300 m^3/ha. Since according to Medarević et al. (2003), the average volume in high beech forests of Serbia, regardless to their structural form, ranges from 197 to 333m^3/ha; the volume of these forests within the studied area indicate an extraordinary production potential. In virgin forest communities of beech forests in Albania (Mirdita, Puka and Rajca) we recorded a volume of 559.3, that is 780.7 and 807.4 m^3/ha (Meyer et al. 2003).

Although the average values of pre-existing conditions of the stands within the sub-associations have limited application, in the most cases these data can be used as an indicator for production differentiation (Jović et al. 1991), especially when referring to stands that have been spontaneously developing, which is the case with the forests of Biogradska Gora. Average values of basic measurement elements – number of trees (N), wood volume(V), average stand tree per diameter (d_g), average diameter 20% of the thickest trees (d_{gmax}), and corresponding heights (h_g, h_{gmax}) according to all sub-associations, are given in Table 1.

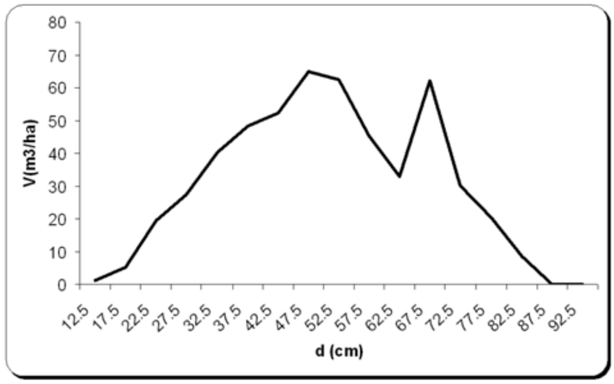

Fig. 8. Volume structure of sub-association A

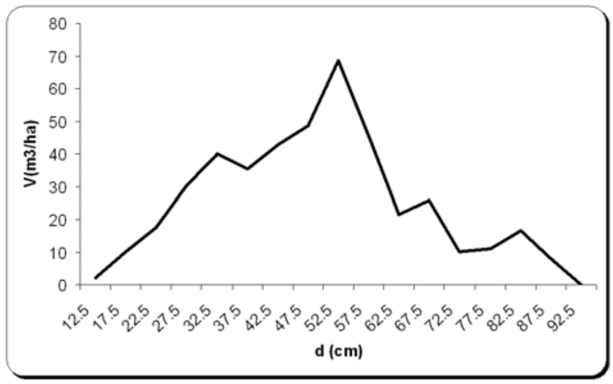

Fig. 9. Volume structure of sub-association B

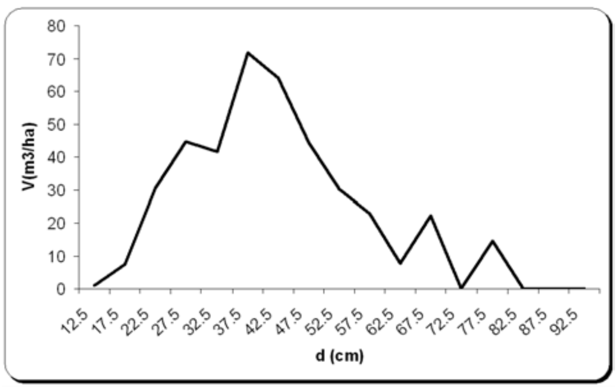

Fig. 10. Volume structure of sub-association C

The pre-existing condition of beech-forest thickness confirms the classical axiom that the number of trees grows when going from better to poorer habitats. Comparing the production indicators of monodominant beech forests it can be concluded that in sub-association A these parameters have larger values than in sub-association B, while the values of the reviewed measurement indicators are the lowest in sub-association C. the obtained values of the basic production indicators already indicate a logical production differentiation within the range of pure beech forests, i.e. a decrease in production capacity from sub-association A – typical beech forests (*Fagetum moesiacae montanum typicum*) to sub-association C – beech forests with woodrush (*Fagetum moesiacae montanum luzuletosum*). Similar results (concurrent) were obtained in studies of other authors in Željin (Jović et al. 1991) and Veliki Jastrebac (Milošević, 2006) in forests of production character.

CONCLUSION

According to the reviewed characteristics and values of all the elements of structure in general, it can be concluded that the studied stands of separated sub-associations of monodominant montane beech, according to almost all analyzed ecological and production indicators differ enough for them to be singled out into special forest types, such as:

Type A – typical montane beech forest *(Fagetum moesiacae montanum typicum)* on brown forest soil, medium deep on base eruptive rock;

Type B - montane beech forest with forest fescue (*Fagetum moesiacae montanum drymetosum)* on brown shallow soil on base eruptive rock;

Type C - montane beech forest with woodrush (*Fagetum moesiacae montanum luzuletosum*) on brown forest soil, shallow on basic eruptive rock.

This research, according to scientific and empirical indicators connected to the primary characteristics of habitats and stands within the specific complex (according to the data about virgin forests of Biogradska Gora), has determined the forest types in monodominant forests of montane beech which require a different planning procedure according to the defined types of these forests.

The presented results provide a clear framework for the design goals of management of the forests that belong to defined types of forests not only in Montenegro, but also beyond. The results of this study can be applied in practice, both in the planning of the objectives and measures in the studied forest ecosystems, as well as within the process of defining forest types on a regional level.

Finally, we wish to stress that this work represents the beginning of comprehensive multidisciplinary studies that will be the basis for modern and ecologically grounded planning in the forest ecosystems in the National Park Biogradska Gora. This was the main objective of the present paper.

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