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THE RATIO BETWEEN THE REAL AND THEORETICALLY NORMAL NUMBER OF TREES IN MIXED FIR, BEECH AND SPRUCE FORESTS IN THE NATIONAL PARK "BIOGRADSKA GORA"

ABSTRACT

In order to select the most favourable method of forest management, and to compile knowledge on the biological-ecological characteristics of tree species and their habitat requirements, good knowledge of the structural elements of stands is of essential importance.

There is no doubt that the forest ecosystems of Biogradska Gora are significant forest objects, due to their exceptional diversity and high level of conservation. Due to the absence of human impact, these ecosystems are especially appreciated as professional and scientific research objects. In order to implement biodiversity management of a sufficiently high level within the forest ecosystems, it is necessary to become familiar with the development processes within the virgin forests.

To identify the differences between the actual status of Biogradska Gora virgin forests and the functional optimal status under the given conditions, normal modes were prepared for mixed forests of spruce, fir and beech (*Piceeto-Abieti-Fagetum*). For the specific research stands in Biogradska Gora, graphic layouts of the ratios between the actual and theoretically normal number of trees, and a review of these ratios was performed.

Keywords: Selection forest, old-growth forest, normal volume, normal number of trees, Biogradska Gora

INTRODUCTION

Due to its low changeability before and after logging and during the rotation period, the selection forest is deemed a permanent forest. The durability of the selection forest is indisputable if the desired optimum model is determined beforehand, and all measures and works are directed to it.

Virgin forests can usefully be taken as a basis for identifying the optimum model because they indicate the dynamic results of natural processes by their spontaneity, and it is accordingly possible, using the initial status, to identify the optimum using already known experiential mathematical forms.

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Mixed spruce, fir and beech forests (*Piceeto-Abieti-Fagetum*) are of huge significance for science and practice. The concern of scientific workers in studying the characteristics of these forest ecosystems, and the numerous scientific papers published locally and globally, stand in favour of this fact.

Studying forest communities of spruce, fir and beech in the area of Montenegro is also of huge significance for science because they are located close to the southern border of their distribution and under certain maritime impact, and are also significant from an economic point of view. At the same time, these are also the most represented species of Montenegrin growing stock (Anđelic et al. 2012). Studies focused on identifying differences between the actual condition of this community within the virgin forests of Biogradska Gora and theoretically normal status as well as the obtained results, can by all means have a practical application.

Selection forest management is often intended to follow theoretical models defining their 'optimal' structure and composition. Dynamics of selected forest stands in South-east Europe were the subject of many studies in recent (Bončina 2011, Čavlović et al 2006, Motta et al 2011). The functional optimum is, connected to the status of forests of forest complex which is, to the highest possible extent, providing the functional durability of the specific objectives of forest management. Prominent differences between the actual condition and the mentioned optimum show the prominence of the forest management problems, which are, as a rule, of a long-term character (Medarević 2006). Under the establishment of normal status, Miletić (1951) calls for reconstruction of selected forests for the purposes of executing permanent management, and calls for the unison of all the structural particularities defining the normal status.

The span within the value of most favourable volume on medium and better site classes is considerably wide, and in these terms, also undefined (Milojković 1976). The normal volume value depends on tree species, the diameter of felling ripeness and forest type, under other favourable elementary conditions (density, mixture, health status, etc.). Generally, identifying the optimal volume is neither simple nor a one-time undertaking, and only temporary solutions can be found within a short period of time.

The most prominent problems of long-term management pertain to the following:

-the need to change the current status to a more optimal one, in relation to the structure as per the number of trees and volume;

-the need to approximate and maintain the optimal admixture rate of the mentioned species, especially by protecting rare and valuable associates (broadleaves) in these forests;

-the need for permanent conservation of selection structure.

MATERIAL AND METHODS

For the purposes of identifying the structural characteristics of mixed forests of beech, fir and spruce in Biogradska Gora, in the strict protection zone (virgin forest reserve), four sample plots were selected and basic information collected. The sample plots (F1-F4) were located two kilometres upstream from the estuary of Biogradska River into Biogradska Lake, at an altitude of around 1200 m (Fig.1).

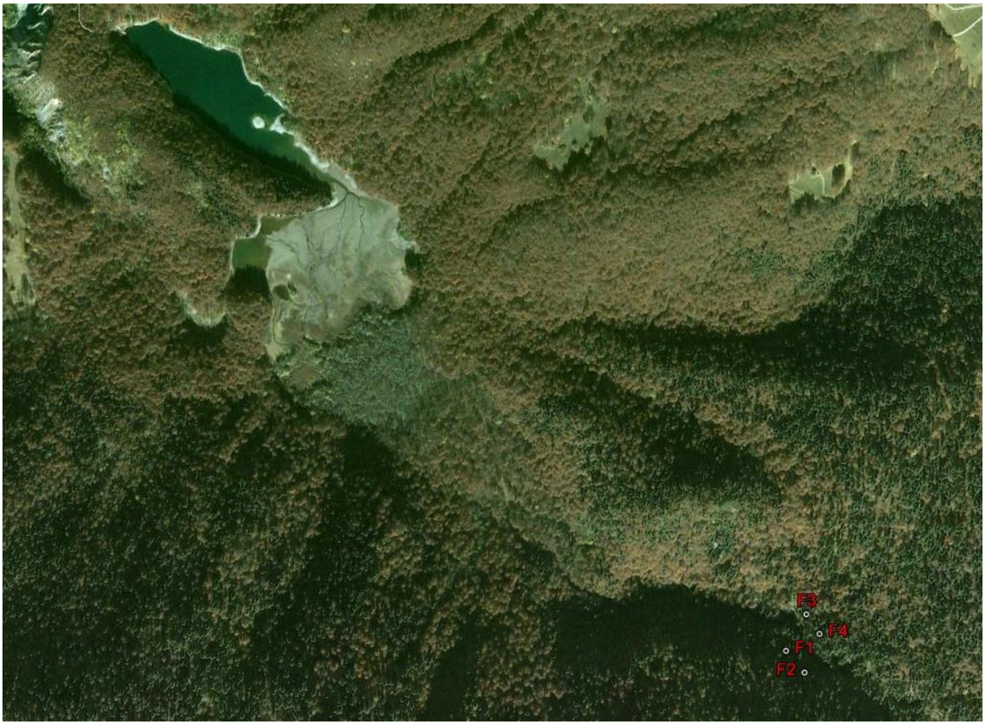

Figure 1. Satellite image of studied area and position of sample plots (Google Earth)

Measurements were taken of all trees having a diameter above the taxation limit (10 cm) at breast height. Diameter measurements were accurate down to the millimetre, and height measurements were accurate to the decimetre.

For the purposes of converting the current status into a more optimal one in relation to the number of trees and their species, and to volume, based on the taxation data, we prepared standards for specific forest complexes based on the number of trees per unit of area (the first and elementary element of structure), that is, based on the number of trees of the adjacent levels. For the preparation of theoretical (inductive) standards we used Liokur's formula, according to which the number of trees and their distribution are presented by geometrical formula.

The number of trees of one diameter degree (i) can be calculated using the following formula:

$$N_i = N_1 \frac{1}{k^{i-1}}$$

When projecting the standards of elements determining the distribution of trees according to their diameter (K, D), and normal volume (Vn), they were calculated (Susmel, according to Kotar 2002.) based on the upper stand height (H_{max}).

For fir and spruce $K=\frac{4.3}{\sqrt[3]{H_{max}}}$, $D = 2.64 \cdot H_{max}$, $V_n=\frac{H^2_{max}}{3}$

For beech $K=\frac{4.54}{\sqrt[3]{H_{max}}}$, $D = 2.33 \cdot H_{max}$, $V_n=\frac{H^2_{max}}{4.23}$

Where K = coefficient of geometric progression; H_{max} = average height of dominant trees; D_{max} = maximum diameter; and, V_n = normal volume.

Normal sequences were established based on such calculated elements of the structure. A normal sequence of trees includes a number of trees per unit of area (ha) which, after the expiry of each rotation period, enables utilization of one mature tree of each represented species and an appropriate number of thinner level trees.

With regard to the identified balanced volume and optimal admixture rate, we come to the optimal number of sequences and therefore to a number of trees per unit of area of all the represented tree species on a specific site

RESULTS AND DISCUSSION

Following the measurements of the sample plots, we perceived a small number of trees per unit of area, ranging from 297 to 398 (on average 347 trees/ha), with the presence of trees of huge dimensions. The share of the thinner trees (diameter up to 30 cm at breast height) was 47.7% of the total number of trees. The thick trees (diameter above 50 cm at breast height) set up a continuous overstorey cover, characterised by a small number of trees per area. Understory trees appear locally, while the lowest storey is also visible, made of suppressed trees and their progeny established at short-term compound interruptions. Beech and fir share is higher in thinner-diameter degrees.

The ratio of beech and fir with regard to their representation at individual levels is more or less equal, and spruce are of far lower numbers and equally dispersed according to the diameter degrees, with prominent presence of large-dimensioned trees.

By using Susmel's formulae we have identified the elements of structure determining the distribution of trees according to diameter (K, D), as well as normal volumes (Vn) based on the upper stand height (H_{max}) (Tab 1.), and based on such obtained values we have established normal tree mode sequences for all three species individually (Tab. 2)

Table 1. Amounts of H_{max}, K, D and V

Ecological unit F	H_{max}	K	V	D
Fir	36.20	1.30	436.81	96
Beech	27.70	1.50	181.39	65
Spruce	40.00	1.26	533.33	105

Table 2. Normal mode sequences of trees

Diameter degree (cm)	Beech			Fir			Spruce		
	Sequence pieces	Vs.st (m^3)	V sequence (m^3)	Sequence pieces	Vs.st (m^3)	V sequence (m^3)	Sequence pieces	Vs.st (m^3)	V sequence (m^3)
12.5	57.67	0.08	4.613	86.50	0.07	6.055	61.38	0.07	4.297
17.5	38.44	0.18	6.920	66.54	0.16	10.647	48.83	0.16	7.813
22.5	25.63	0.33	8.458	51.19	0.33	16.891	38.85	0.3	11.654
27.5	17.09	0.58	9.910	39.37	0.57	22.443	30.91	0.63	19.470
32.5	11.39	0.82	9.340	30.29	0.96	29.076	24.59	0.97	23.849
37.5	7.59	1.17	8.885	23.30	1.25	29.123	19.56	1.66	32.469
42.5	5.06	1.66	8.404	17.92	1.71	30.646	15.56	1.93	30.032
47.5	3.38	2.19	7.391	13.79	2.27	31.294	12.38	2.49	30.824
52.5	2.25	3.09	6.953	10.60	3.12	33.086	9.85	3.43	33.779
57.5	1.50	3.53	5.295	8.16	3.78	30.835	7.83	3.93	30.790
62.5	1.00	4.4	4.400	6.27	4.69	29.429	6.23	4.5	28.048
67.5				4.83	5.89	28.430	4.96	5.74	28.462
72.5				3.71	6.54	24.283	3.94	6.93	27.337
77.5				2.86	7.92	22.620	3.14	8.89	27.898
82.5				2.20	8.88	19.509	2.50	9.56	23.867
87.5				1.69	9.75	16.478	1.99	10.02	19.894
92.5				1.30	13.214	17.178	1.58	11.42	18.044
97.5				1.00	14.863	14.863	1.26	12.94	16.265
>100							1.00	14.38	14.380
Total			**80.568**			**412.885**			**429.171**

According to a typological study of forests in Croatia (Cestar et al. 1986) for the selected ecological unit I-C-10 (*Abieti-Fagetum illyricum* on brown soil), which, according to their characteristics, are the most similar to the studied stands of Biogradska Gora, it is recommended to have a beech share of 30% of total, with a higher share of fir. When creating the standards for mixed forests of beech, fir and spruce, the designed ratio of dominant species was 30:40:30%. On the basis of such a designed ratio of species, we have calculated the number of normal sequences for each one of them:

$$\text{Number of normal beech sequences/ha} = \frac{181.39m^3 \bullet 0.3}{80.568m^3} = 0.68$$

$$\text{Number of normal sequences for fir/ha} = \frac{436.81m^3 \bullet 0.4}{412.885m^3} = 0.42$$

$$\text{Number of normal sequences for spruce/ha} = \frac{533.33m^3 \bullet 0.3}{429.171m^3} = 0.37$$

This is how we came to the normal number of trees per ha (Tab. 3), and also to the possibility of comparing the actual and constructed theoretically normal structure. The normal number of trees is 382, which is more than the 347 found. The lack of a number of trees compared to the designed standard is, at all three species and in total, stated in the thinnest diameter degrees (Fig. 2–5). For spruce, the total number of trees is lower than the designed standard.

Based on the calculated parameters we came to the balanced volumes for this ecological unit, amounting to 389.14 m^3/ha.

Table 3 Comparison of actual and constructed theoretically normal structure.

Diameter degree (cm)	Beech			Fir			Spruce			Total		
	Status pieces /ha	Normal pieces /ha	Diffe rence	Status pieces /ha	Normal Pieces /ha	Diffe rence	Status pieces /ha	Normal Pieces /ha	Diffe rence	Status piece s/ha	Norma. Pieces /ha	Diffe rence
12.5	21.9	39.2	-17.3	24.1	36.3	-12.2	3.4	22.7	-19.3	49.4	98.3	-48.9
17.5	19.8	26.1	-6.3	17.8	28.0	-10.2	4.1	18.1	-14.0	41.7	72.2	-30.5
22.5	17.5	17.4	0.1	15.0	21.5	-6.5	3.8	14.4	-10.6	36.3	53.3	-17.0
27.5	14.5	11.6	2.9	20.1	16.5	3.6	3.5	11.4	-7.9	38.1	39.6	-1.5
32.5	13.9	7.8	6.2	13.7	12.7	1.0	3.4	9.1	-5.7	31.0	29.6	1.4
37.5	12.3	5.2	7.1	11.8	9.8	2.0	1.0	7.2	-6.2	25.1	22.2	2.9
42.5	5.9	3.4	2.5	5.5	7.5	-2.0	2.7	5.8	-3.1	14.1	16.7	-2.6
47.5	10.7	2.3	8.4	7.1	5.8	1.3	5.5	4.6	0.9	23.3	12.7	10.6
52.5	2.5	1.5	1.0	5.7	4.5	1.3	6.8	3.6	3.2	15.0	9.6	5.4
57.5	4.6	1.0	3.6	5.9	3.4	2.5	1.7	2.9	-1.2	12.2	7.4	4.9
62.5	2.0	0.7	1.3	6.7	2.6	4.1	0.0	2.3	-2.3	8.7	5.6	3.1
67.5	4.0		4.0	5.2	2.0	3.2	0.7	1.8	-1.1	9.9	3.9	6.0
72.5	2.5		2.5	3.9	1.6	2.3	3.1	1.5	1.6	9.5	3.0	6.5
77.5	1.0		1.0	4.5	1.2	3.3	3.1	1.2	1.9	8.6	2.4	6.2
82.5	2.0		2.0	6.3	0.9	5.4	0.7	0.9	-0.2	9.0	1.8	7.2
87.5				0.0	0.7	-0.7	0.0	0.7	-0.7	0.0	1.4	-1.4
92.5				0.5	0.6	-0.1	0.0	0.6	-0.6	0.5	1.1	-0.6
>95				4.1	0.4	3.7	10.3	0.5	9.8	14.4	0.9	13.5
Total	135.10	116.28	18.82	157.90	156.06	1.84	53.80	109.26	-55.46	346.80	381.60	-34.80

In old growth forest communities of spruce, fir and beech in Biogradska Gora it was perceived that, although there is a lower number of trees per unit of area (on average 349 trees/ha) compared to the theoretically normal number of trees, the presence of large dimensioned-trees (especially fir and spruce) will result in a higher wood volume than the normal range from 646 m^3/ha to 983 m^3/ha. On average, wood volume in the sample plots of this ecological unit was 796.8 m^3/ha. It correspond with old-growth spruce-fir stands in the eastern Carpathian mountains (Keeton et al 2010) where the two old growth sites had significantly lower live tree densities, and significantly greater mean stand diameters.

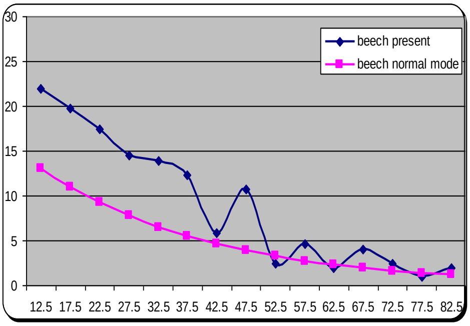

Figure 2. Ratio between the actual and theoretically normal number of beech trees.

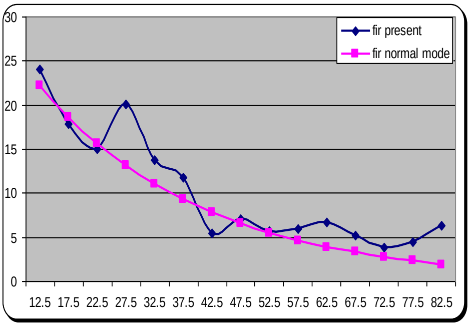

Figure 3. Ratio between the actual and theoretically normal number of fir trees.

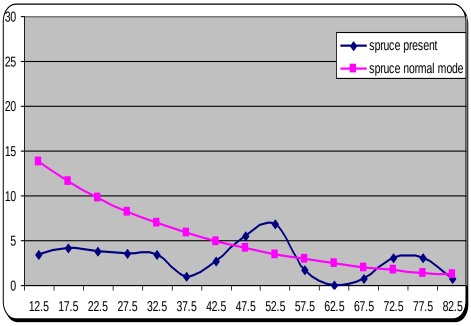

Figure 4. Ratio between the actual and theoretically normal number of spruce trees.

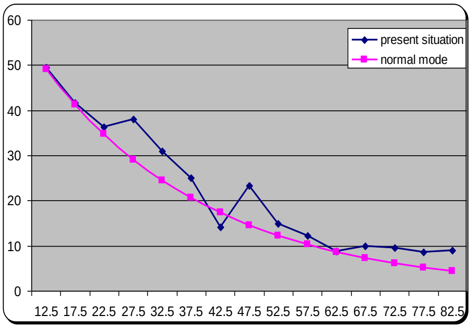

Figure 5. Ratio between the actual and theoretically normal number of trees.

In Serbia the total area of the protected areas is 5.89% of the whole territory (Djordjevic et al 2011). Values of the volume in stands of the mixed forests of spruce, fir and beech on National park Tara (Serbia), according to Medarević et al. (2007), range, within a wide area, from 562 m^3/ha in selection structure stands to 990 m^3/ha in the stands of rainforest character.

By utilising the results of the studies on mixed beech, fir and spruce forests in the Tara and Goc mountains, at a broadleaf-to-conifer ratio of 20:80%, a balanced volume of 410 m^3/ha was identified. In the most wide-spread management class of mixed beech, fir and spruce forest selection structures of the national park Tara (management class 12 – production-protection forests), on deep and medium-deep acid brown soil on limestone, the average inventory height was 462.84 m^3/ha (Medarević et al. 2002). Matović (2005) and Vamović (2005) studying Zlatar and Golija indicated normal volume of 510 m^3/ha and 500 m^3/ha, respectively.

Govedar et al. (2006), studying the rainforest Lom in the Bosnia and Herzegovina, recorded a volume from 600 to 1343 m^3/ha.

An optimal inventory height for Montenegrin conditions between 320 and 430 m^3/ha, depending on habitat conditions, has been accepted as axiom in the forestry science and practice (Jović et al. 1991), which also corresponds to the identified balanced volume amounting to 389.14 m^3/ha. In preserved stands in Ljubisnja, we have identified volumes of 348 to 404 m^3/ha on limestone, and from 452 to 772 m^3/ha on erruptive rock (Čurović et al. 2011).

According to Miletic's normal modes (1952, 1953, 1957), the number of trees per unit of area with diameter degrees up to 30 cm should be 70.6% of the total number and 27.9% of the total volume. Within the studied stands in Biogradska Gora, the number of trees of a diameter degree up to 30cm was 47.7% of the total number, with a 5.57% share in total volume. This is confirmed by the rainforest character of the studied stands, and the exclusive impact of large-dimensioned trees on all of the structural elements, especially on wood volume (which, in the sample plots of Biogradska Gora, amounts to 796.8 m^3/ha) and on the distribution of this volume. The right asymmetry of the volume structure differentiates this forest from the regular selection forest types and confirms the rainforest character of the studied stands.

CONCLUSIONS

Forests of beech, fir and spruce within the reserve of the nation park Biogradska Gora are characterized by an irregular selection structure with an excess of large trees, and a partial and insufficient number of younger trees, which reflects the rainforest character of the studied stands. From the current irregular selection structure it is clear that it is supported by fir and beech and that spruce enables a more rational utilization of production (spatial) habitat potential by its presence.

Although the number of trees per unit of area is smaller compared to the theoretically normal number, the presence of trees of huge dimensions (especially fir and spruce) results in extraordinary values of standing wood volume.

With regard to this basic material (actual data obtained in the rainforest of Biogradska Gora), the status relating to number of trees and their volume is different from normal. The normal number of trees is 381 pieces/ha and normal volume (Vn) is 389 m3/ha. At the same time, the structure is hyperbolic and mildly descending compared to the progressive decrease of trees by calculation using coefficient K, which is different for all three species and amounts to: 1.3 for fir, 1.26 for spruce and 1.5 for beech.

Difference in structure first of all indicates the need for steadiness and a long period of duration, and potential conversion of old growth into commercial types of selection forests.

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ODNOS STVARNOG I TEORIJSKI NORMALNOG BROJA STABALA U MJEŠOVITIM ŠUMAMA JELE, BUKVE I SMRČE U NACIONALNOM PARKU "BIOGRADSKA GORA"

SAŽETAK

Za sagledavanje izbora najpovoljnijeg načina gazdovanja šumama uopšte od posebnog značaja je, pored poznavanja biološko-ekoloških karakteristika vrsta drveća i uslova staništa, dobro poznavanje strukturnih elemenata sastojina. Trajnost prebirne šume je neospornija ako se prethodno utvrdi željeni optimum-model prema kojem se usmjeravaju sve aktivnosti.

Kao osnov za utvrđivanje optimuma mogu korisno poslužiti prašume jer svojom spontanošću ukazuju na dinamičke rezultate prirodnih procesa, te u skladu s tim je moguće kao polaznim stanjem-osnovicom moguće utvrđivati optimum poznatim iskustvenim matematičkim obrascima.

Šumski ekosistemi Biogradske gore bez sumnje spadaju među najznačajnije šumske objekte, zbog izuzetne raznolikosti i visokog stepena očuvanosti. Ovi ekosistemi su usled izostanka uticaja ljudskog faktora, stručno i naučno posebno interesantni i zahvalni istraživački objekti. Da bi se gazdovanje sprovodilo na dovoljno visokom biodiverzitetskom nivou u okviru šumskih ekosistema potrebno je upoznati se sa razvojnim procesom u netaknutim šumama

Šume bukve, jele i smrče u strogom rezervatu NP "Biogradska gora" karakteriše nepravilna prebirna struktura sa viškom stabala najjačih dimenzija, djelimičnim i nedovoljno brojnim mlađim stablima, čime se odslikava prašumski karakter proučavanih sastojina

Za potrebe utvrđivanja razlika stvarnog stanja i funkcionalno optimalnog stanja u datim uslovima, u Nacionalnom parku "Biogradska gora" izrađene su normale za mješovite šume smrče, jele i bukve (*Piceeto-Abieti fagetum*).

Ključne riječi: prebirna šuma, prašuma, normalna zapremina, normalni broj stabala, Biogradska gora