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STRUCTURAL, PRODUCTION AND DYNAMIC CHARACTERISTICS OF THE STRICT FOREST RESERVE "RAČANSKA ŠLJIVOVICA" ON MT. TARA

Abstract: Mixed forests of broadleaves and conifers, thanks to their high productivity and high biodiversity, are the most valuable part of the growing stock in Serbia. The aim of this research was to analyse the mixed old-growth forests of fir, spruce and beech in the reserve "Račanska Šljivovica" so as to define the laws which could be applied in the future forest management on Mt. Tara. The research was based on the data of six periodic complete inventories followed by standard dendrometric and statistical processing. Forest structure was similar to the typical selection structure. The recruitment dynamics (except beech) was relatively favourable, with the ratio to dead trees amounting to 1.72. The number of trees and the volume increased constantly, attaining 422.2 $trees \cdot ha^{-1}$, i.e. 800.3 $m^3 \cdot ha^{-1}$, and the volume increment was above 12 $m^3 \cdot ha^{-1}$, despite a slight drop. Silver fir was the protagonist of the selection structure and productivity. It is necessary to stimulate the survival and development of beech at the concrete site, to examine the balanced number of trees and volume, and to investigate the relationship between the number of recruited trees and the stand volume.

Key words: reserve, old-growth forest type, structure, productivity, dynamics

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СТРУКТУРНЕ, ПРОИЗВОДНЕ И ДИНАМИЧКЕ КАРАКТЕРИСТИКЕ СТРОГОГ ШУМСКОГ РЕЗЕРВАТА „РАЧАНСКА ШЉИВОВИЦА“ НА ТАРИ

Извод: Мешовите шуме лишћара и четинара због високе производности и израженог биодиверзитета представљају највреднији део шумског фонда Србије. Циљ истраживања био је да се анализом мешовитих шума јеле, смрче и букве прашумског порекла у резервату „Рачанска Шљивовица“ уоче законитости које би потом имале примену у газдовању шумама Таре. Основ истраживања чине подаци шест периодичних потпуних (тоталних) премера који су подвргнути класичној дендрометријској и статистичкој обради. Структура шума блиска је типичној пребирној структури. Динамика урастања (осим букве) релативно је повољна, са односом према одумрлим стаблима од 1,72. Број стабала и запремина континуирано расту, достижу износ 422,2 $kom \cdot ha^{-1}$, односно 800,3 $m^3 \cdot ha^{-1}$, а запремински прираст је и поред благог пада висок - преко 12 $m^3 \cdot ha^{-1}$. Јела је носилац пребирне структуре и производности, нужно је стимулисати опстанак и развој букве на конкретном станишту, преиспитати уравнотежени броја стабала и запремину и истражити везу између броја ураслих стабала и запремине састојине.

Кључне речи: резерват, прашумски тип, структура, производност, динамика

1. INTRODUCTION

Mixed forests of broadleaves and conifers (in most cases beech and fir, and also beech, fir and spruce) and conifers (most often fir and spruce) occupy 3% of the growing stock area in Serbia, 4.3% of its volume, and 4.8% of its current volume increment (Banković *et al*., 2009). In Serbia, mixed forests are distributed on the mountain massifs - Tara, Zlatibor (Murtenica), Zlatar, Čemerno, Golija, Mokra Gora, Prokletije, Šar Planina, Veliki Jastrebac, Kopaonik and Goč in the west, Stara Planina in the east, and the northernmost sites are on Mts. Rtanj and Malinik. Their small area percentage, exceptionally high productivity at individual sites, ecological diversity (high species diversity, tree sizes and spatial arrangements), higher resistance to adverse effects of different biotic and abiotic factors, and structural complexity, make these forests extremely significant from the protection, social and production aspects, and in this way also very interesting in the scientific sense. For this reason, both in Europe and in Serbia, mixed stands of the above tree species have been selected and protected as strict forest reserves (SFR). Long-term monitoring of SFRs can be a substitute for the research in old-growth forests, which are very rare in Europe. This type of substitution is justified by numerous authors (Prpić, 1972, 1979, Schütz, 1989, Biriş *et al*., 2000, Anić, 2007), taking into account the fact that today all forests are, directly or indirectly, more or less, anthropogenically modified. Consequently, SFRs are reference locations for the research of natural processes and their dynamics (Meyer, 2005). The essence of their selection and conservation, according to Diaci *et al*. (2006), is reflected in the preservation of the original forest composition for future generations, in the conservation of rare and threatened plant and animal species, in

the development of basic and applied natural sciences, conservation of genetic resources, in the promotion of education, recreation and other values of forest ecosystems, etc. The researches in these stands are also the sources of new ideas in silviculture, especially nowadays when new silvicultural models are being developed to imitate natural processes (nature-based silviculture, close-to-nature silviculture). In this sense, the more the ideas on the development of natural forests, first of all SFRs, are widened and deepened, the more forestry practice receives trustworthy incentives and reliable theoretical explanations of the application of management methods and forms classified in the wider concept of close-to-nature management (Korpel, 1996). The study of productivity of permanently protected stands of various tree species makes it possible to study their maximum production potential at the concrete site (Mlinšek, 1968, Tomanić, Jelisavčić, 1997, Tomanić, Malinić, 1997, Stojanović *et al*., 2007, Veen *et al*., 2010). Therefore, the point of the SFR selection and conservation, inter alia, is also to acquire the scientific (theoretical) ideas based on complex and in-depth studies of their dynamics, structure and productivity. The results could be implemented in the regularly managed forests, so that their functionally optimal state can be achieved and maintained.

Systematic and comprehensive research of mixed forests of broadleaves and conifers, and conifers in Serbia started by the middle of 20th century. In this aim, the Strict Forest Reserve "Račanska Šljivovica" was designated and protected on Mt. Tara in mixed forests of fir, spruce and beech by the Institute for Nature Conservation of Serbia. The objective of the research was, based on the data of six periodic complete inventories, to analyse the structural and production characteristics of the forests in the Reserve, as well as their changes (development) in the period from 1960 to 2010. The assessed laws and specificities in the development of these extremely complex forest ecosystems, as well as in the complicated inter-relationships of the component tree species, could be practically implemented in the regular management of the mixed forests of fir, spruce and beech in the wider region of Mt. Tara.

2. MATERIAL AND METHOD

2.1. Study Area

The study area is located in the Strict Forest Reserve "Račanska Šljivovica", in the Forest Management Unit "Tara", as an integral part of Tara National Park. The FMU "Tara" is located between 43º 51' and 43º 57' north latitude and 17º 03' and 17º 11' east longitude. It mainly covers the limestone plateau of the mountain Tara in the altitudinal belt from 900 to 1,350 *m*. The area of this Management Unit is 3,620.55 *ha*, of which as much as 94.8% accounts for the mixed, selection forests of fir, spruce and beech. The bedrock consists of dense limestones of the Middle and Upper Triassic periods. The soils consist of all soil forms on limestone, with the greatest percentage of well-developed terra fusca. The average annual climate elements for the wider region of Mt. Tara, over the

study period 1975-2005 were: air temperature 7.9ºC, precipitation 977.3 *mm*, relative air humidity 83.4%, sunlight 1,699.5 hours, and the main wind directions were northeast and southwest. The above values indicate the continental mountainous climate, nearing the milder variety of subalpine climate (Medarević, 2005).

The Reserve "Račanska Šljivovica" is a part of the Compartment 156/a of the above Management Unit and it occupies an area of 15.43 *ha*, on moderately steep terrain of balanced slope from 6º to 10º, altitude from 1,160 to 1,200 *m*. Its aspect is east-northeast, occasionally northwest. Bedrock consists of oganogenic dense limestones, and the soil is brown on limestone and dolomite, medium deep (40-80 *cm*), fresh and slightly skeletoid. The dead cover in the Reserve is abundant in medium-thick layer undergoing a favourable process of humification. The species in the tree storey are: *Abies alba*, *Picea abies*, *Fagus moesiaca*, while *Pinus silvestris*, *Pinus nigra* and *Acer pseudoplatanus* occur in very small numbers. In the shrub storey, the most frequent species are: *Rubus hirtus* and *Daphne mezereum*, and in the ground flora layer: *Asperula odorata*, *Cardamine bulbifera*, *Oxalis acetosella*, *Mycelis muralis*, *Viola silvestris*, *Geranium robetianum*, *Cardamine ennaeaphyll*, *Rhamnus fallax*, etc. (Cvjetićanin, Novaković, 2010). The Reserve consists of old-growth forests belonging to the category of high mixed forests of fir, spruce and beech. In the typological sense, they belong to the forest type *Piceo-Abieti-Fagetum typicum* on deep to medium deep brown soils on limestone. The stand in the Reserve "Račanska Šljivovica" is characterised by a complete canopy (0.7) and by mediocre health (Medarević, 2005).

2.2. Data collection and processing

Since 1960, these forests have been managed by the control method - the Goč variety (Milojković, 1962) which, *inter alia*, includes the implementation of a complete inventory providing the information on these complex forest ecosystems. The information periodically collected on the basis of the complete inventory is the most reliable assessment of forest state, of the changes over time, the inventory dynamics and the productivity (Medarević, Obradović, 2007). The data of periodical inventories per management periods from 1960 to 2010, stored in the database of the information system on forests in Serbia, are the foundation of this research. In the above system, the Reserve volume was calculated by the tariff method (Banković, 1991, Banković, Pantić, 2006). The unreliable records on the trees which were in the previous management periods (except the last one) removed from the Reserve, and which in the given case refer only to dead wood, were the main obstacle in the determination of volume increment by the control method, which is, according to Mirković (1959), methodologically the most accurate procedure for the calculation of volume increment. For this reason, it was calculated by the increment percentage method where volume increment percentage was calculated based on regression models (Banković *et al*., 2002).

The statistical data processing consisted of the calculation of the basic measures of variation (arithmetical mean, minimum, maximum, and the coefficient of variation) for

the number of trees and volume per hectare, i.e. parameters α_3 (skewness) and α_4 (kurtosis), as the numerical expressions of the deviation of actual volume distribution per diameter classes from the theoretical form of normal distribution. Skewness was assessed by the following scale: $|\alpha_3| \leq 0.25$ - low skewness, $0.25 < |\alpha_3| \leq 0.50$ - medium skewness and $|\alpha_3| > 0.50$ - high skewness. The above statistical analyses were performed using the software package STATGRAPHICS Centurion XV-Version 15.2.11.

3. RESULTS

In addition to edificator species (fir, spruce and beech), the tree layer in the Reserve "Račanska Šljivovica" also consists of Scots pine, Austrian pine and maple (*A. pseudoplatanus*). The abundance of these species is extremely low and it had a decreasing trend over the study period. In 1960, there were 12.7 trees, and in 2010 5.6 trees per hectare, so their effect on the structure, productivity and dynamics of the Reserve forests was inconsiderable. For that reason, these tree species were not taken into account in the presentation of the study results.

3.1. Number of trees

Distribution of trees by diameter classes as an indicator of forest structure in mixed stands of broadleaves and conifers and conifers in SFR depends on the process of regeneration, recruitment, increment (transition period) and decline. The above processes are conditioned by a complex of ecological and stand factors among which the dominant role is that of the light regime in the stand. In the concrete case of fir, in the first two inventories (1960 and 1970), tree distribution was characterised by a lower, compared to typical selection structure insufficient number of trees in the smallest-diameter degrees and by an excess of trees in the medium-diameter classes (32.5-47.5 *cm*). In general, in

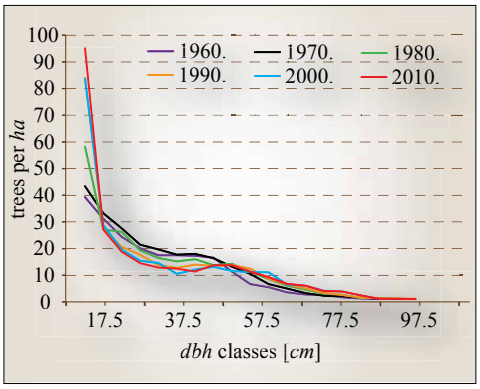

Diagram 1. Diameter structure of fir trees
Графикон 1. Дебљинска структура јеле

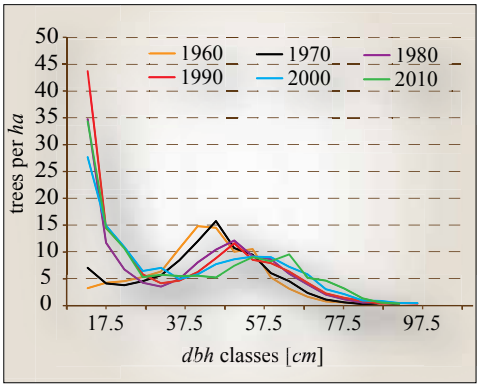

Diagram 2. Diameter structure of spruce trees
Графикон 2. Дебљинска структура смрче

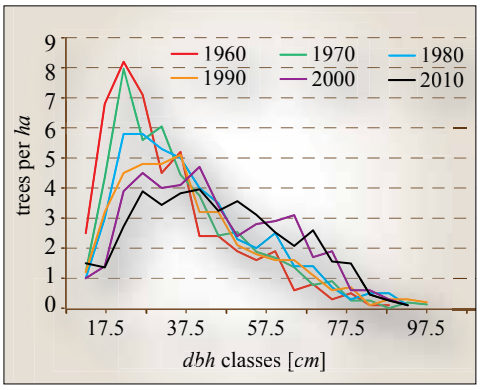

Diagram 3. Diameter structure of beech trees
Графикон 3. Дебљинска структура букве

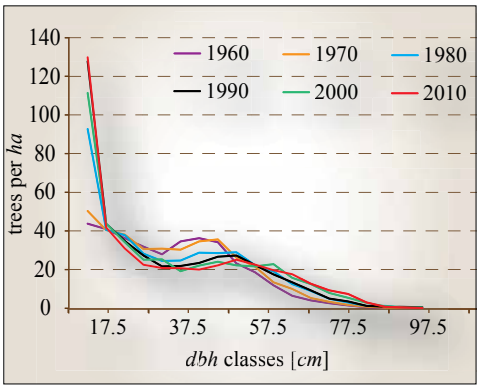

Diagram 4. Diameter structure - total
Графикон 4. Дебљинска структура - укупно

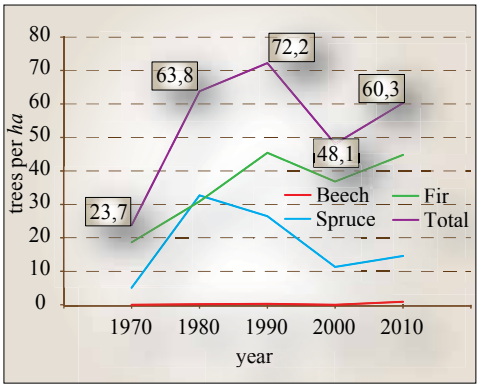

Diagram 5. Recruited trees
Графикон 5. Урасла стабла

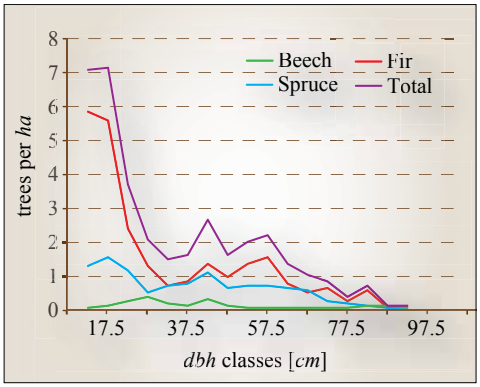

Diagram 6. Dead wood (№ of trees) in 2010
Графикон 6. Мртво дрво (бр. ст.) у 2010. год.

this period tree distribution indicated an atypical selection structure (Diagram 1). By the development of the more favourable light regime in the Reserve in the period 1980-2010, the recruitment of fir trees was intensified (Diagram 5), and the part of the distribution curve representing the smallest-diameter trees was prolonged and asymptotically approached to the ordinate, while the number of trees in medium-diameter classes decreased sharply. The consequence of these processes over the given period was the fir tree distribution, similar to the typical selection structure. The asymmetric and excessive bell distribution with the maximum number of trees in diameter classes 42.5 *cm*, i.e. 47.5 *cm* respectively, characterised the spruce tree distribution during the first two inventories (Diagram 2). The recruitment of spruce trees (especially in the period 1970-1990) led to the increase in the number of trees in the thinnest-diameter degrees and in this sense, to the prolongation of the left tail of the distribution curve, but in contrast to fir, the number of trees in medium classes (in absolute amounts) remained high. Because of that, spruce

tree distribution in the period after 1980 had the characteristics of the hidden binomial distribution. Insufficient regeneration, minimal recruitment, poorer shade tolerance and greater inferiority of beech in the struggle for life space, compared to the competitive species (fir and spruce), resulted in the fact that spruce structure was very distant from the typical selection structure throughout the study period (Diagram 3). Under the effect of the domination of fir trees in the Reserve, the percentage of which in the total number of trees per individual periods ranged from 57.5% to 62.1%, the distribution of the total number of trees (Diagram 4) had for the most part the characteristics of fir distribution. Some differences, as the consequence of the effect of spruce diameter structure, were reflected in the higher percentage of trees in the diameter classes 32.5-52.5 *cm*, because of which the distribution of the total number of trees was somewhat more distant from the typical selection structure than it was the case with fir diameter structure. By all means, this was also caused by the great deviation of beech diameter structure from the selection structure.

In SFR "Račanska Šljivovica" beech recruitment (Diagram 5) was absent in some management periods of the study period (1960-1970 and 1990-2000), and in other periods it amounted to 0.2-0.9 trees per hectare. During the last management period, the ratio between the recruited and dead trees was 0.75. This means that dead beech trees were compensated by recruitment to the main stand by only 75%. Spruce recruitment ranged from 5.1 tree per hectare in the period 1960-1970 to the maximum values of 32.7 trees per hectare in the period 1970-1980, after which it had a decreasing trend. During the last management period, it amounted to 14.6 trees per hectare, with the ratio to dead trees of 1.45. The number of recruited fir trees ranged from 18.7 in the first management period to 44.8 trees per hectare in the last period during which the ratio to dead trees was 1.88. Total number of recruited trees varied from 23.7 to 72.2 per hectare, but during the last management period (2000-2010) it was 60.3 trees per hectare, with the ratio to dead trees in the period amounting to 1.72.

The last inventory (2010) in the Reserve showed that 35.1 trees were killed (dead and decayed) per hectare, of which 23.8 trees were fir, 10.1 spruce and 1.2 beech. Although these are exceptionally shade tolerant tree species, due to a long-lasting and deep shade, the greatest number of dead trees (50.4%) were in the category of small-diameter trees within the diameter classes of 12.5-22.5 *cm* (Diagram 6).

The number of beech trees in the study period varied minimally (c_N=5.71%), between 40.4 and 46.9 *trees*·ha^{-1} and decreased by 11.1%

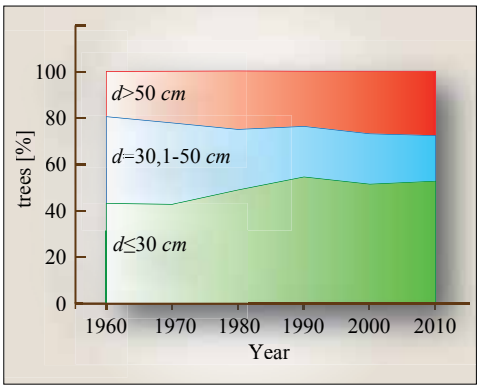

Diagram 7. Tree distribution per diameter classes

Графикон 7. Дистрибуција стабала по дебљинским класама

(Table 1). The last inventory showed the increase in the number of spruce trees by 43.4% compared to 1960. The number of spruce trees over the study period was mainly characterised by an increasing trend, with high variability per individual management periods (c_N=20.4%) and it ranged from 92.2 to 138.6 *trees·ha*$^{-1}$. In contrast to spruce, the variability in the number of fir trees, as the dominant tree species in the Reserve, per individual management periods, was substantially lower (c_N=6.91%). The number of fir trees ranged from 203.6 to 248.3 *trees·ha*$^{-1}$ and, compared to the beginning of the study period, it increased by 22.0%. The total number of trees and its trend are the consequences of the percentage of individual tree species in the Reserve and the range of the number of trees over the study period. In this sense, the total number of trees generally increased continually, with a moderate variability (c_N=8.32%) and it ranged from 342.7 to 422.2 *trees·ha*$^{-1}$. According to the inventory in 2010, there was an increase by 23.2% in the total number of trees compared to 1960.

Table 1. Changes in the total number of trees and its distribution per diameter classes
Табела 1. Промене укупног броја стабала и његове дистрибуције по дебљинским класама

Tree species/ Врста дрвећа	Inventory year / Година премера						*N* arit.	*min*	*max*	c_N
	1960	1970	1980	1990	2000	2010				
	trees·ha^{-1} / *kom·ha*$^{-1}$									%
Beech / Буква	46.9	45.8	45.1	40.4	43.4	41.7	43.9	40.4	46.9	5.71
Spruce / Смрча	92.2	92.9	124.7	138.6	128.8	132.2	118.2	92.2	138.6	20.4
Fir / Јела	203.6	226.8	229.4	243.0	239.5	248.3	231.7	203.6	248.3	6.91
Total / Укупно	342.7	365.5	399.2	422.0	411.7	422.2	393.9	342.7	422.2	8.32
Diameter class Класа дебљине	%									
d≤30 *cm*	43.0	42.6	48.7	54.4	51.3	52.6				
d=30.1–50 *cm*	37.4	35.1	26.1	21.8	21.7	19.6				
d>50 *cm*	19.6	22.3	25.2	23.8	27.0	27.8				

Legend / Легенда: *N* arit. - arithmetic mean of tree number / аритметичка средина броја стабала, *min* - minimum number of trees / минимални број стабала, *max* - maximum number of trees / максимални број стабла, c_N [%] - coefficient of variation of tree number / варијациони коефицијент броја стабала, *d* - diameter at breast height / прсни пречник стабла

Grouping of trees in diameter classes enables a better insight into the inventory dynamics over a time period. In the concrete conditions, the percentage of small-diameter (*d*≤30 *cm*) and large-diameter trees (*d*>50 *cm*) had an increasing trend, as opposed to the category of medium-diameter trees (*d*=30.1–50 *cm*), whose percentage in the total number of trees decreased continually (Diagram 7). Precisely, the percentage of small-diameter trees increased in the relative sense by 22.3%, large-diameter trees by 41.8%, and the percentage of medium-diameter trees, compared to 1960, decreased by 47.6% (Table 1).

3.2. Volume

Volume distribution per diameter classes is directly dependent on the distribution of the number of trees, site quality, characteristics of tree species, etc. Fir volume structure in SFR "Račanska Šljivovica" was characterised by positive and high skewness (α_3=0.640-1.094) in all management periods, except in 2010, when it was also positive (Table 2), but medium skewed (α_3=0.268). Taking into account the structure of these forests and the fact that fir is the protagonist of the structure, during the study period the kurtosis (α_4) of its volume structure increased, and variation width per individual management periods amounted to 85-95 *cm* (Diagram 8). Spruce volume per diameter classes (Diagram 9) was characterised by high and positive skewness (α_3=0.955-1.289), high kurtosis and variation width from 80 to 95 *cm*. Beech volume structure was highly variable and it ranged from low and positive skewness (α_3=0.167) in 1960, via high and negative

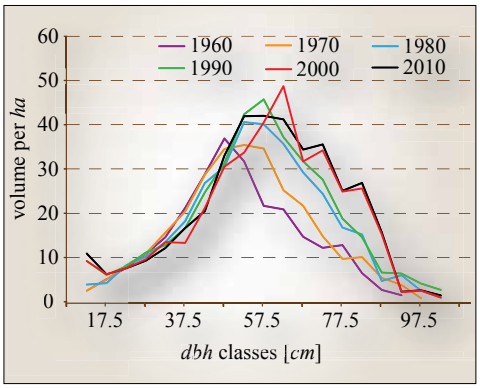

Diagram 8. Volume structure of fir
График 8. Запреминска структура јеле

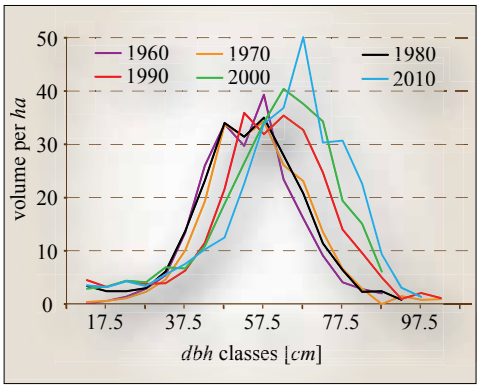

Diagram 9. Volume structure of spruce
График 9. Запреминска структура смрче

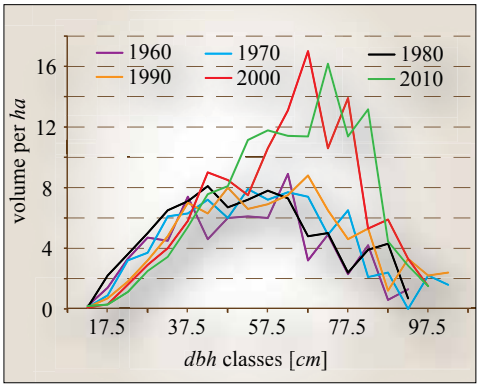

Diagram 10. Volume structure of beech
График 10. Запреминска структура букве

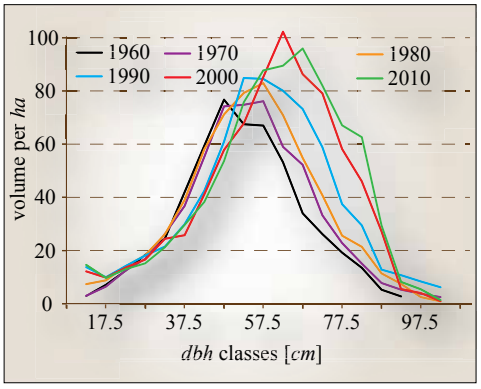

Diagram 11. Volume structure - total
График 11. Запреминска структура (ук.)

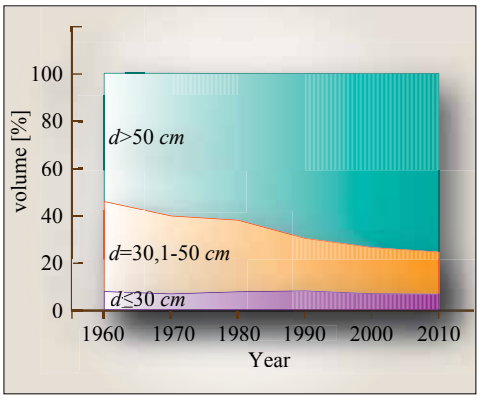

Diagram 12. Distribution of volume per Biolley diameter classes

Графикон 12. Дистрибуција запремине по класама дебљине Biolley-а

skewness [α_3=(–0.747)-(–0.901)] over 1970-1990, to high (α_3=0.702) and low (α_3=0.145) positive skewness in the period 1990 - 2010. During the entire study period the distribution was kurtic, and the variation width ranged between 85 and 95 *cm* (Diagram 10). Total volume structure sublimed the characteristics of the structure of individual tree species, especially fir as the dominant species in the Reserve. For that reason, the total volume structure was characterised by high and positive skewness (α_3=0.418-0.964) with the mitigating trend towards the end of the analysed period. Kurtosis was high, it had an increasing trend, and variation width of the distribution ranged from 85 to 95 *cm* (Diagram 11).

Table 2. Skewness and kurtosis of volume distribution in the study period

Табела 2. Симетричност и спљоштеност дистрибуција запремине у истраживаном периоду

Inventory year Година премера	Fir / Јела		Spruce / Смрча		Beech / Буква		Total / Укупно	
	α_3	α_4	α_3	α_4	α_3	α_4	α_3	α_4
1960	1.094	–0.360	1.289	–0.672	0.167	–0.404	0.964	–0.940
1970	0.804	–0.987	0.955	–1.071	–0.901	–1.013	0.818	–1.076
1980	0.640	–1.007	0.988	–1.093	–0.865	–0.609	0.816	–1.107
1990	1.022	–0.790	1.022	–1.121	–0.747	–0.875	0.901	–1.114
2000	0.652	–0.678	0.991	–1.007	0.702	–0.464	0.717	–0.983
2010	0.268	–1.225	1.263	–0.373	0.145	–1.106	0.418	–1.361
Variation width Варијац. ширина	85-95 *cm*		80-95 *cm*		85-95 *cm*		85-95 *cm*	

Legend / Легенда: α_3 - measure of skewness / мера асиметрије, α_4 - measure of kurtosis (excess) / мера спљоштености (ексцес)

Beech volume per hectare in the period 1960-2010 permanently increased between 69.6 and 123.9 $m^3 \cdot ha^{-1}$, with high variability (c_V=23.62%) and an increase of 78.0%, compared to the beginning of the above period. The increasing volume trend was also found in spruce. It ranged between 210.2 and 291.1 $m^3 \cdot ha^{-1}$, and the coefficient of variation was c_V=13.50%. In 2010, spruce volume increased by 38.5% compared to the beginning of the study period. The volume of fir, as the dominant tree species in the Reserve, increased constantly per individual management periods, from 252.3 $m^3 \cdot ha^{-1}$ in 1960 to

385.3 $m^3 \cdot ha^{-1}$ in 2010, with the coefficient of variation c_V=15.64%. Percentage increase in fir volume accounted for 52.7% (Table 3). The logical consequence of the increase in volume of tree species in the Reserve was also the increase in total volume per hectare. It ranged from 532.1 to 800.3 $m^3 \cdot ha^{-1}$, and at the end of the fifty-year period the percentage amounted to 50.4%.

Table 3. Changes in total volume and its distribution per Biolley diameter classes
Табела 3. Промене укупне запремине и њене дистрибуције по класама дебљине Biolley-a

Tree species/ Врста дрвећа	Inventory year / Година премера						V arit.	*min.*	*max.*	c_V
	1960	1970	1980	1990	2000	2010				
	$m^3 \cdot ha^{-1}$									%
Beech / Буква	69.6	83.4	82.7	87.2	120.9	123.9	94.6	69.6	123.9	23.62
Spruce / Смрча	210.2	213.3	226.6	252.6	271.5	291.1	244.2	210.2	291.1	13.50
Fir / Јела	252.3	287.3	331.6	357.6	371.3	385.3	330.9	252.3	385.3	15.64
Total / Укупно	532.1	584.0	640.9	697.4	763.7	800.3	669.8	532.1	800.3	15.48
Diameter class Класа дебљине	%									
d≤30 *cm*	7.7	6.7	7.6	8.0	6.8	6.6				
d=30.1–50 *cm*	38.1	33.0	30.3	22.2	19.5	17.8				
d>50 *cm*	54.2	60.3	62.1	69.8	73.7	75.6				

Legend / Легенда: *V* arit. - arithmetic mean of volume/аритметичка средина запремине, *min* - minimum volume/минимална запремина, *max* - maximum volume/максимална запремина, c_V [%] - coefficient of variation of volume/варијациони коефицијент запремине, *d* - diameter at breast height/прсни пречник стабла

In the study period, the share of volume of small-diameter trees (*d*≤30 *cm*) in the total volume per hectare decreased relatively by 14.3%, volume of medium-diameter trees (*d*=30.1-50 *cm*) by 53.3%, and the percentage of volume of large-diameter trees (*d*>50 *cm*) increased by 39.5% (Diagram 12).

3.3. Volume increment

The volume increment, as one of the most reliable indicators of stand vitality and productivity and the site production potential over the study period and per tree species in SRŠ "Račanska Šljivovica" is presented in Table 4.

In beech, the current volume increment ranged from 1.10 to 2.38 $m^3 \cdot ha^{-1}$, with high variability per individual management periods (c_{Iv}=30.08%). Maximum value of beech increment was recorded by the inventory in 2000, after which its increment dropped. Spruce increment is also characterised by high variability (c_{Iv}=24.82%), which ranged from 2.90 to 5.18 $m^3 \cdot ha^{-1}$, with a constant decrease after 1980. Compared to the above tree species, the variability of fir volume increment in the study period was lower

(c_{Iv}=14.48%), its increment ranged within 4.87-7.12 $m^3 \cdot ha^{-1}$, reaching the maximum in 2000 after which it declined. On the whole, the current volume increment in the period 1960-2010 amounted to 8.87-13.40 $m^3 \cdot ha^{-1}$. The maximum value was attained in 1990, and in the last two management periods there was a mild decrease by 4-8% compared to the maximum value.

Table 4. Changes in current volume increment
Табела 4. Промене текућег запреминског прираста

Tree species Врста дрвећа	Inventory year / Година премера						I_v arit.	*min.*	*max.*	c_{Iv}
	1960	1970	1980	1990	2000	2010				
	$m^3 \cdot ha^{-1}$									%
Beech / Буква	1.10	1.38	1.42	1.30	2.38	1.93	1.59	1.10	2.38	30.08
Spruce / Смрча	2.90	3.28	5.18	5.03	3.37	3.60	3.89	2.90	5.18	24.82
Fir / Јела	4.87	5.60	6.72	7.07	7.12	6.86	6.37	4.87	7.12	14.48
Total / Укупно	8.87	10.26	13.32	13.40	12.87	12.39	11.85	8.87	13.40	15.70

Legend / Легенда: I_v arit. - arithmetic mean of current volume increment / аритметичка средина текућег запреминског прираста, *min* - minimum current volume increment / минимални текући запремински прираст, *max* - maximum current volume increment / максимални текући запремински прираст, c_{Iv} [%] - coefficient of variation of current volume increment / варијациони коефицијент текућег запреминског прираста

4. DISCUSSION

Tree distribution per diameter classes is a characteristic parameter used by many authors (Korpel, 1995, Peterken, 1996, Goodburn, Lormier, 1999, Altay *et al.*, 2005, Govedar, 2005, Anić *et al.*, 2006, Westphal *et al.*, 2006) in the structural definition of old-growth forests, i.e. SFRs. Based on this parameter, it was concluded that forests in the Reserve "Račanska Šljivovica", in general and at the development stage after 1980, were structurally similar to typical selection forests, and that fir is the protagonist of such structure. The significance of fir for the development and maintenance of the sustainable selection forest structure at the local level (area of Mt. Tara) is reported by Milojković and Mirković (1955), Tomanić (1996/1997), and Medarević *et al.* (2007). At the regional level, this significance is explicitly pointed out by Korpel (1996), who states that without a significant percentage of fir in the 5th and 6th vegetation degrees (5th - forest of beech and fir, 6th - forest of beech, fir and spruce) in European countries, it is not possible to count on a stable and functional selection forest. The absence of sufficient and continued regeneration and recruitment, unfavourable ratio of recruitment to tree decline with the implication of extremely irregular diameter structure, decrease in the total number of trees in the study period by 11.1% and greater demands for light, point to the unfavourable conditions in SFR for beech development and to its inferior position compared to spruce and fir. This can be the confirmation of the studies reported

by Milojković and Mirković (1955) and Tomanić (1996/1997) regarding the unfavourable position of beech in mixed stands with spruce and fir in the area of Tara. To prevent further disturbance of forest composition from the aspect of the percentage of individual tree species, and soil degradation (acidification), suitable management measures (primarily more favourable light regime) should be applied to stimulate regeneration, recruitment and survival, to increase the percentage of beech trees in the mixture of the stands which belong to the same forest type. In this sense, selection felling is required as the main tool for the sustainable regulation of structural relations in selection forests and their conversion to a balanced state (Medarević, 2005). High and positive skewness, high kurtosis with continual increase and significant variation width in volume structure are the signs of volume accumulation in larger diameter classes and significant tree sizes attained at this site, first of all by fir. This should be taken into account in the definition of felling maturity diameter in regularly managed forests.

The sustainability of selection management (selection structure), inter alia, also depends on the volume of regeneration, recruitment, and the ratio between the number of recruited and dead trees in the stand (Mayer, 1976, Leibundgut, 1978, Altay *et al*., 2005). The magnitude of recruitment depends on numerous factors, such as: tree species, site quality, regeneration success, stocking, stand volume and cycle period (Medarević, Obradović, 2007, Medarević *et al*., 2010). Taking into account the high significance of recruitment, it is logical that it was dealt with by many authors. They determined primarily the minimum number of recruited trees from the aspect of achievement and sustainable maintenance of selection structure. Thus Miletić (1959), based on several methods, found the number of 5.9 to 9.2 of recruited trees annually per hectare. In the area of Tara, Tomanić and Malinić (1997) define 7.8 trees and point out that the recruitment dynamics of tree species is such that it leads to a permanent increase in the percentage of fir in mixed stands with beech and spruce. In the management class of selection forests of fir, spruce and beech at the better sites of Mt. Tara, Medarević and Obradović (2007) recorded the average 7.7 recruited trees per hectare annually in the period 1970-2000. The annual recruitment of 7 trees per hectare is considered as the minimum for the sustainability of selection structure (Medarević *et al*., 2010). However, the above studies disregard a very important and, with regard to recruitment, more reliable indicator of dynamic processes in forests, and that is the ratio of the number of recruited trees to the number of dead trees. In SFR "Račanska Šljivovica" there were on average 5.4 recruited trees per hectare per year during the entire study period. Based on the above criteria, this number of recruited trees is insufficient and it points to the deterioration of the relevant conditions, and also to a serious disturbance of the forest reserve viability and structure. However, if we consider the ratio of recruited trees and dead trees during the last management period with the reliable data on dead trees, then this conclusion refers only to beech for which the ratio was 0.75. For spruce it was 1.45, for fir 1.88, total 1.72. Therefore, even with the exceptionally high volume in the last management period, it indicates a good inventory regeneration and relatively favourable dynamic processes in the Reserve. Regarding the recruitment dynamics, an interesting subject for future research

is to study the nature and to model the relationship between the number of recruited trees and the size of volume per hectare. The point at which further increase in volume causes the drop in the number of recruited trees below the critical minimum for the desired ratio to dead trees, could represent a criterion for the determination of the balanced volume.

According to the criteria of Helsinki Conference (2003), dead wood is considered a key indicator of forest ecosystem biodiversity and sustainable management. Consequently, the recording of dead trees in regular inventories is increasingly practiced in European forestry. During the last inventory, the presence of dead trees in different phases of degradation was recorded throughout the area of SFR "Račanska Šljivovica". More than a half of the recorded number of dead trees was in the thinnest-diameter classes (12.5-22.5 *cm*). Similar distribution of dead trees was also observed by Anić and Mikac (2008) in the study on old-growth stands of fir, spruce and beech (with a minimum percentage of other hard broadleaves) in "Čorkova Uvala" in Plitvicka Jezera national park. They ascribed such distribution of dead wood to the extreme suppression of the trees in the thinnest-diameter categories, which is survived by the majority of trees by entering the stagnation stage, while a lower percentage of trees die. Thanks to the mixture, all-agedness in the widest sense, and a series of other parameters, forests in the entire area of Mt. Tara, not only of the analysed Reserve, are characterised by high biodiversity.

The Reserve "Račanska Šljivovica" was characterised by a steady increase in the number of trees per hectare over the study period, in the end amounting to 422.2 $trees \cdot ha^{-1}$, with the following percentage of tree species (beech:spruce:fir) 9.9:31.3:58.8%. This number of trees attained the volume of 800.3 $m^3 \cdot ha^{-1}$ with the mixture proportion (beech:spruce:fir) which amounted to 15.5:36.4:48.1% in 2010. An intensive drop in the percentage of medium-diameter trees, protagonists of increment power in selection stands, in the total number of trees and the accumulation of volume in the largest-diameter categories, resulted in the drop in volume increment and (logically) in the drop in increment percentage in the last two management periods. However, the volume increment is still maintained at a rather high level - above 12 $m^3 \cdot ha^{-1}$, and the percentage increment accounts for 1.55%, and for that reason the above drop cannot be qualified as a sign of serious forest devitalisation in the Reserve. The high productivity of old-growth forests of fir, spruce and beech in SFRs was also reported by other authors. In the study of inventory elements of natural (old-growth) mixed stands of the above tree species in Bosnia and Herzegovina, Drinić (1956) reports the volume of 600-1,343 $m^3 \cdot ha^{-1}$ and the current volume increment of 4.19-8.82 $m^3 \cdot ha^{-1}$. In the case of beech percentage of above 40%, Korpel (1996) reports the volume of 450 to 900 $m^3 \cdot ha^{-1}$ in Slovakian old-growth forests, and in the case of a higher percentage of conifers (especially fir) - 500-1.100 $m^3 \cdot ha^{-1}$, which clearly indicates that conifers (fir and spruce) are the protagonists of high productivity in these mixed forests. A similar conclusion can be made based on the data reported for old-growth forest "Lom" (Republic of Srpska) by Govedar *et al.* (2006). These authors found that under the conditions of the mixture proportion beech:spruce:fir=29:29:42%, the volume in old-growth forest amounted to 1.216 $m^3 \cdot ha^{-1}$ and the number of trees was 966 $trees \cdot ha^{-1}$. In the old-growth forest "Čorkova Uvala"in

Plitvička Jezera National Park, Anić and Mikac (2008) found 440 trees per hectare and the volume of 671.2 $m^3 \cdot ha^{-1}$, under the conditions of the mixture proportion beech: spruce: fir=42:6:52%. Based on the presented values, obviously the increase in beech percentage in the mixture leads to the lower volume per hectare. On the sample plots established in the stands of *Piceeto-Abieti-Fagetum typicum* on brown soil on eruptives, in SFR in the National Park Biogradska Gora, Čurović (2011) found that the average number of trees was 347 $trees \cdot ha^{-1}$ and that the average volume was 797 $m^3 \cdot ha^{-1}$, with mixture proportion beech:spruce:fir=20.5:33.8:45.7%. Forest productivity in regularly managed forests of fir, spruce and beech was investigated by several authors in the area of Tara. Milojković and Mirković (1955) recorded the volume of 342 to 587 $m^3 \cdot ha^{-1}$ on sample plots, the current volume increment of 5.1 to 8.9 $m^3 \cdot ha^{-1}$ and the increment percentage of 0.90-2.32%. According to Milojković (1962, 1986), the average number of trees in sustainable selection structure in these forests should be 450 to 480 $trees \cdot ha^{-1}$, and balanced volume should be 410 $m^3 \cdot ha^{-1}$, under the percentage of 80% of conifers and 20% of broadleaves. Tomanić (1996/1997) considered that, in these forests, the optimal number of trees should be 660 $trees \cdot ha^{-1}$ and the optimal volume 600 $m^3 \cdot ha^{-1}$. In all management classes covering the high selection forests of fir, spruce and beech in the forest *Piceo-Abieti-Fagetum typicum* on deep to medium deep soils on limestone, in the area of entire Mt. Tara, Medarević (2005) found the average volume of 543 $m^3 \cdot ha^{-1}$, the volume increment of 9.8 $m^3 \cdot ha^{-1}$ and the increment percentage of 1.82%. In the study of structural and production characteristics of forest types in Tara National Park, Medarević *et al*. (2007) found the volume of 990 $m^3 \cdot ha^{-1}$ in the old-growth stands of the above forest type, and in other stands, where the average number of trees was 456 $trees \cdot ha^{-1}$, the average volume was 709 $m^3 \cdot ha^{-1}$, the average current volume increment was 15.9 $m^3 \cdot ha^{-1}$ and the average volume increment percentage was 2.24%. The analysis and the comparison of the presented data on the productivity in the Reserve and in the regularly managed forests, makes it necessary to re-evaluate the balanced number of trees, and especially the balanced volume in mixed forests of fir, spruce and beech in *Piceo-Abieti-Fagetum typicum* on deep to medium deep brown soils on limestone in the area of Tara. In the case of the balanced number of trees, we are closer to the conclusion reported by Milojković (1962, 1986) that it should range from 450 to 480 $trees \cdot ha^{-1}$ than to Tomanić's (1996/1997) conclusion of 660 $trees \cdot ha^{-1}$. However, because of the exceptionally high volume, relatively high volume increment and also continual and sufficient regeneration (except for beech) and recruitment, with a favourable ratio of dead trees, we are more inclined to accept Tomanić's statement (1996/1997) that the balanced volume should amount to about 600 $m^3 \cdot ha^{-1}$ is more acceptable. By all means, these values should be confirmed or corrected by additional research, which should also include the qualitative analysis of volume, the analysis of dominant trees development and increment, transition times, etc.

5. CONCLUSIONS

The essence of this research was not to assess the state of the forest Reserve "Račanska Šljivovica"from different aspect of being able to intervene, in the sense of improvement, by different management measures, because the strictest regime of protection excludes such an option. The objective was to observe some laws related to the spontaneous development, structure and productivity in mixed forests of fir, spruce and beech at the given site, which could then be implemented in the regularly managed forests in this area. In this sense, regardless of a series of limitations in this research resulting from the Reserve regime of protection, it is possible to make the following conclusions:

1. In the mixture with beech and spruce, fir is a tree species which forms and ensures the structure and production sustainability of these forests;
2. At the concrete site, as regards the spontaneous development of the inventory, beech is an inferior species compared to conifers. For this reason, managed forests have to be supported by some management measures (improvement of light regime in the stand) in the regeneration, recruitment, survival and increase in the mixture percentage;
3. The number of trees of the main tree species (edificators) in the study period was uniform in beech (entire period), quite increased in spruce (in the period 1970-1980) and increased in fir (in the period 1960-1970). The period 1980-2010 was characterised by the stability (uniformity) of the number of trees in the Reserve;
4. At the same time, the stand volume increased continuously and stably from 1960 to 2010. Under the increase of the total number of trees in the study period by 23.2%, the volume accumulated and increased by 50.4%. The disproportion of the previous ratio was caused by the change in the percentage of the main diameter categories in the total volume over time. The percentage of volume of small-diameter trees in the study period (50 years) decreased by 14.3%, medium-diameter trees by 53.3%, and the percentage of volume of large-diameter trees increased by 39.5%. This points to the present processes of stand "layering" in the structural sense, but also to the "phase of stability" in the life cycle of old-growth forests. The movement of the first layer towards the larger categories and the physiological maturity of tree dying leads to the "phase of degradation" in due time and to the structure more or less close to selection structure. Production stability, measured by the continuity of increment and production, especially in the last 40 years, also points to the "phase of stability"in old-growth forests from the development aspect;
5. The specificity and spontaneousness of productivity in old-growth forests requires an additional and more complex research and continuous monitoring of the inventory, to create a real base for the definition of management normatives and directives in managed forests;
6. The quantity of stand volume which is followed by the drop in the number of recruited trees below the critical minimum which provides a favourable approach

to tree dying should be researched and possibly implemented as one of the indicators for the assessment of balanced volume.

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REFERENCES

Altay U.G., Misir M., Misir N., Hakki Y. (2005): *Calculation of uneven-aged stand structure with the negative exponential diameter distribution and Sterba's modified competition density rule*, Forest Ecology and Management 214 (212–220)

Anić I., Mikac S., Oršanić M., Drvodelić D. (2006): *Structural relations between virgin and management beech-fir stands (Omphalodo-Fagetum Marinček et al., 1992) in forests of the Croatian Dinaric Karst*, Periodicum Biologorum 108 (663–669)

Anić I. (2007): *Utjecaj strukture i pomladivanja na potrajnost šuma bukve i jele te šuma bukve nacionalnog parka plitvicka jezera*, Završno izvješce, Sveucilište u Zgrebu, Šumarski fakultet, Zagreb (1-62)

Anić I., Mikac S. (2008): *Struktura, tekstura i podmlađivanje dinarske bukovo-jelove prašume Čorkova uvala*, Šumarski list CXXXII, 11-12 (505-515)

Banković S. (1991): *Zapreminske tablice za jelu (Abies alba Mill.) i smrču (Picea excelsa Link.) u šumamam nacionalnog parka Tara*, Univerzitet u Beogradu-Šumarski fakultet, Nacionalni park Tara, Bajina Bašta (1-106)

Banković S., Medarević M., Pantić D. (2002): *Regresioni modeli procenta zapreminskog prirasta u najzastupljenijim sastojinama četinarskih vrsta drveća u Srbiji*, Glasnik Šumarskog fakulteta 85, Univerzitet u Beogradu-Šumarski fakultet, Beograd (25-35)

Banković S., Pantić D. (2006): *Dendrometrija*, Univerzitet u Beogradu-Šumarski fakultet, Beograd

Banković S., Medarević M., Pantić D., Petrović N., Šljukić B., Obradović S. (2009): *Šumski fond Republike Srbije-Stanje i problemi*, Glasnik Šumarskog fakulteta 100, Univerzitet u Beogradu-Šumarski fakultet, Beograd (7-30)

Biriş I-A., Radu S., Doniţa N. (2000): *Criteria for identification, selection and assessment of virgin forests*. Document ICAS, Bucharest

Veen P., Fanta J., Raev I., Biriş I-A., Smidt J., Maes B. (2010): *Virgin forests in Romania and Bulgaria: results of two national inventory projects and their implications for protection*, Biodiversity and Conservation 19 (1805–1819)

Westphal C., Tremer N., Oheimb von G., Hansen J, Gadow von K, Härdtle W. (2006): *Is the reversed J-shape diameter distribution universally applicable in European virgin beech forest?*, Forest Ecology and Management 223 (75–83)

Govedar Z. (2005): *Načini prirodnog obnavljanja mešovitih šuma jele i smrče (Abieti- Piceetum illuricum) na području zapadnog dela Republike Srpske*, doktorska disertacija u rukopisu, Univerzitet u Beogradu, Šumarski fakultet, Beograd

Govedar Z., Stanivuković Z., Čuković D., Lazendić Z. (2006): *Osnovne taksacione karakteristike mješovitih sastojina bukve, jele i smrče u prašumi „Lom“ na području zapadnog dijela Republike Srpske*, Zbornik radova naučne konferencije “Gazdovanje šumskim ekosistemima nacionalnih parkova i drugih zaštićenih područja”, Jahorina- NP Sutjeska (285–295)

Goodburn J. M., Lorimer C. G. (1999): *Population structure in old-growth and managed northern hardwoods: an examination of the balanced diameter distribution concept*, Forest Ecology and Management 118 (11–29)

Diaci J., Roženbergar D., Kolar U., Pisek R., Nagel T., Hladnik D. (2006): *Metodologies for monitoring forest development in strict forest reserves*, Proceedings of Scientific conference: „Management of forest ecosystems in national parks and other protected areas“, Jahorina–NP Sutjeska (25-33)

Drinić P. (1956): *Taksacioni elementi sastojina jele, smrče i bukve prašumskog tipa u Bosni*, Radovi Poljoprivredno-šumarskog fakulteta, 1B (107-160)

Korpel Š. (1995): *Urwaelder der Westkarpaten*, Gustav Fischer Verlag, Sttutgart, Jena, New York

Korpel Š. (1996): *Razvoj i struktura bukovo-jelovih prašuma i njihova primjena kod gospodarenja prebornom šumom*, Šumarski list CXX, 3-4 (203-209)

Leibundgut H. (1978): *Über die Dynamik europaeisher Urwaelder*, Allgemeine Forstzeitschrift 24 (686–690)

Mayer H. (1976): *Gebirgswaldbau–Schutzwaldpflege*, Ein waldbaulicher Beitrag zum Umweltschutz und zur Landschaftspflege, Stuttgart

Medarević M. (2005): *Šume Tare*, Univrziet u Beogradu-Šumarski fakultet, Ministarstvo nauke i zaštite životne sredine Republike Srbije, JP Nacionalni park Tara

Medarević M., Obradović S. (2007): *Primena Gočke varijante kontrolnog metoda na Tari,* Zbornik radova „Osnovne ekološke i strukturno proizvodne karakteristike tipova šuma Đerdapa i Tare“ Ministarstvo nauke Republike Srbije, Univerzitet u Beogradu - Šumarski fakultet, Nacionalni park Đerdap, Nacionalni park Tara, Beograd (211-229)

Medarević M., Banković S., Pantić D., Petrović N. (2007): *Strukturne i proizvodne karakteristike tipova šuma Tare*, Zbornik radova „Osnovne ekološke i strukturno proizvodne karakteristike tipova šuma Đerdapa i Tare, Ministarstvo nauke Republike Srbije, Univerzitet u Beogradu-Šumarski fakultet, Nacionalni park Đerdap, Nacionalni park Tara, Beograd (179-209)

Medarević M., Banković S., Pantić D., Obradović S. (2010): *Effects of the control method (goč variety) in selection forest management in western Serbia*, Archives of Biological Sciences, 62 (407-418)

Meyer P. (2005): *Network of Strict Forest Reserves as reference system for close to nature forestry in Lower Saxony-Germany*, Forest Snow and Landscape Research 79 (33–44)

Miletić Ž. (1959): *Analiza nekih metoda određivanja broja i zapremine uraslih stabala*, Šumarstvo 5-6, SIT šumarstva i prerade drveta Srbije, Beograd (539-552)

Milojković D., Mirković D. (1955): *Istraživanja strukture i prirasta jele u čistim četinarskim sastojinama na Goču i Tari*, Glasnik Šumarskog fakulteta 9, Univerzitet u Beogradu-Šumarski fakultet, Beograd (187-269)

Milojković D. (1962): *Jedna nova varijanta kontrolne metode-Gočka metoda*, Glasnik Šumarskog fakulteta 26, Univerzitet u Beogradu-Šumarski fakultet, Beograd (129-149)

Milojković D. (1986): *Razvoj gazdovanja i uređivanja šuma G.J. Tara*, Šumarstvo, 1-2, SIT šumarstva i prerade drveta Srbije, Beograd (11-27)

Mirković D. (1959): *Brži metodi određivanja zapreminskog prirasta prebirne sastojine–osnovi i primena*, Simpozijum „Napredno prebirno gazdovanje na bazi uređivanja šuma“, Goč (1-14)

Mlinšek D. (1968): *Slobodna tehnika gajenja šuma na osnovu nege*, Posebno izdanje, Jugoslovenski poljoprivredno-šumarski centar, Beograd

(2003): MCPFE–Ministerial Conference on the Protection of Forests in Europe Liaison Unit Vienna, 2003: State of Europe's Forests 2003. The MCPFE Report on Sustainable Forest Management in Europe. Jointly prepared by the MCPFE Liaison Unit Vienna and UNECE/FAO.URL on 20031220: http://www.mcpfe.org/content/index.php?lang=

Peterken G. F. (1996): *Natural Woodland*, Cambridge University Press, Cambridge

Prpić B. (1972): *Neke znacajke prašume Čorkova uvala*, Šumarski list XCVI, 9–10 (325– 333)

Prpić B. (1979): *Struktura i funkcioniranje prašume bukve i jele (Abieti-Fagetum illyricum /Horv. 1938/) u Dinaridima SR Hrvatske*, II. kongres ekologa Jugoslavije, Zadar–Plitvice, (899–924)

Stojanović Lj., Ostojić D., Vukin M. (2007): *Stanje i perspektive zaštite strogog prirodnog rezervata „Mustafa“*, Šumarstvo 1-2, SIT šumarstva i prerade drveta Srbije, Beograd (13-24)

Schütz J.P. (1989): *Der Plenterbetrieb*, Fachbereich Waldbau ETH, Zürich

Tomanić L. (1996/1997): *Optimalno stanje sastojina jele, bukve i smrče na trijaskim krečnjacima planine Tare*, Glasnik Šumarskog fakulteta 78-79, Univerzitet u Beogradu-Šumarski fakultet, Beograd (129-139)

Tomanić L., Jelisavčić D. (1997): *Research of Development of the Reserves Gorušica and Šljivovica on Mt. Tara*, in „Forest ecosystems of the National Parks“, Ministry of Enviroment of the Republic of Serbia, Belgrade (181-183)

Tomanić L., Malinić M. (1997): *Regeneration and Recruitment in the Forestrs of the National Park „Tara”*, in „Forest ecosystems of the National Parks“, Ministry of Enviroment of the Republic of Serbia, Belgrade (183-185)

Cvjetićanin R., Novaković M. (2010): *Floristički diverzitet šume jele, bukve i smrče (Piceo-Fago-Abietetum Čolić 1965) u nacionalnom parku „Tara“*, Glasnik Šumarskog fakulteta 102, Univerzitet u Beogradu-Šumarski fakultet, Beograd (129-144)

Čurović M. (2011): *Tipovi šuma u nacionalnom parku „Biogradska gora“*, doktorska disertacija u rukopisu, Univerzitet u Beogradu, Šumarski fakultet, Beograd

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СТРУКТУРНЕ, ПРОИЗВОДНЕ И ДИНАМИЧКЕ КАРАКТЕРИСТИКЕ СТРОГОГ ШУМСКОГ РЕЗЕРВАТА „РАЧАНСКА ШЉИВОВИЦА“ НА ТАРИ

Резиме

Мешовите шуме лишћара и четинара, с обзиром на високу производност и изражени биодиверзитет, представљају највредниј део шумског фонда Србије. Очуваност дела инвентара утицала је на то да се поједине састојине које припадају овој категорији шума заштите као строги шумски резервати Један од њих јесте и резерват „Рачанска Шљивовица“ на Тари, којим су обухваћене мешовите шуме јеле, смрче и букве прашумског карактера на типу шуме (*Piceo-Abieti-Fagetum typicum*) на дубоким до средње дубоким смеђим земљиштима на кречњаку. Циљ истраживања у овом резервату (прашуми) био је да се уоче неке законитости везане за структурну изграђеност, производност и развој (динамику) ових мешовитих шума на конкретном станишту.

Подаци периодичних потпуних (тоталних) премера у периоду од 1960. до 2010. године, депоновани у бази података информационог система о шумама Србије, представљали су основ за спроведена истраживање. Запремина састојине обрачуната је по методу тарифа, запремински прираст по методу процента прираста, док је статистичка обрада података подразумевала утврђивање основних параметара варијационе статистике.

Дистрибуција стабала јеле током прва два премера, због мањка најтањих и вишка стабала у средње јаким степенима (32,5-47,5 *cm*), има атипичну пребирну структуру. Стварањем повољнијег светлосног режима у резервату након 1980. године интезивира се урастање, смањује се број средње јаких стабала, што резулитра расподелом блиском типичној пребирној структури. Повећано урастање код смрче није било пропраћено падом броја стабала средње јаких пречника, због чега ова врста дрвећа након помнеутог периода има прикривену биномску дистрибуцију. Буква током читавог истраживаног периода има изузетно неправилну дисрибуцију-јако удаљену од типичне пребирне структуре. Како је јела доминантна врста дрвећа у резервату логично је да дистрибуција укупног броја стабала у најавећој мери има одлике дистрибуције стабала ове врсте дрвећа. Претходни наводи недвосмислено указују на то да је у мешовитости са смрчом и буквом јела градитељ и фактор одржања структурне изграђености ових шума.

Поред подмлађивања, несметано урастање је неопходна претпоставка трајне пребирне шуме. Перманентно, у довољном броју и са повољним односом према излучивању стабала из састојине урастање указује на њену биолошку и структурну стабилност. Урастање букве у појединим уређајним раздобљима је изостајало, а у другим се кретало у интервалу од 0,2 до 0,9 стабала по хектару. Током последњег уређајног периода констатован је однос урасла стабла/излучена (мртва) стабала који је износио 0,75. Код смрче урастање се кретало од 5,1 стабло по хектару у периоду 1960-1970. године, преко максималне вредности од 32,7 стабала по хектару у периоду 1970-1980. године, након чега показује опадајући тренд. Током последњег уређајног периода оно је износило 14,6 стабала по хектару са односом према излученим стаблима од 1,45. Број ураслих стабала јеле кретао се од 18,7 у првом уређајном

раздобљу до 44,8 стабала по хектару у последњем периоду током којег је однос према излученим (мртвим) стаблима износио 1,88. Укупан број ураслих стабала варирао је од 23,7 до 72,2 по хектару, с тим што је током последњег уређајног периода (2000-2010. године) износио 60,3 стабала по хектару са односом према изумрлим стаблима у истом периоду од 1,72. Изнети подаци указују на релативно добре динамичке процесе у резервату. Изузетак од овакве оцене представља позиција букве која је у конкретним условима инфериорна врста у односу на јелу и смрчу и чији је опстанак и даљи развој у економским шумамам сличних карактеристика нужно стимулисати газдинским мерама. Када је у питању динамика урастања стабала будућим истраживањима треба испитати и моделовати везу између броја ураслих стабала и запремине састојине на хектару. Тачка у којој са даљим порастом запремине број ураслих стабла пада испод критичног минимума при којем је однос према излученим стаблима повољан, треба да представља један од индикатора за утврђивање уравнотежене запремине.

Последњим премером (2010. год.) у резервату је регистровано 35,1 одумрлих стабала по хектару. Више од половине наведеног броја припада категорији танких стабала (дебљински степени 12,5-22,5 *cm*). Основни разлог овакве дистрибуције броја стабала мртвог дрвета налази се екстремној засени стабла најтањих дебљинских категорија, коју већина преживљава уласком у стадијум вегетирања, док мањи број одумире. Према овом индикатору, а и због мешовитости, разнодобности у најширем смислу и низа других параметара шуме целог подручја Таре, не само истраживаног резервата, карактеришу се израженим биодиверзитетом.

Број стабала букве у посматраном периоду смањио се за 11,1%, код смрче и јеле се повећао за 43,4%, односно за 22,0%. Укупан број стабала и његов тренд последица су заступљености појединих врста дрвећа у резервату и кретања њиховог броја стабала током посматраног периода. У том смислу, укупан број стабала углавном је имао континуирани раст и кретао се од 342,7 до 422,2 $kom \cdot ha^{-1}$. Премером 2010. године регистровано је повећање овог таксационог елеемнта у односу на 1960. годину за 23,2%. Учешће танких стабала ($d \leq 30$ *cm*) у релативном смислу повећало се за 22,3%, стабала јаких димензија ($d > 50$ *cm*) за 41,8%, док је учешће средње јаких стабала ($d = 30{,}1\text{-}50$ *cm*) у односу на 1960. годину смањено за 47,6%.

Дистрибуција запремине по дебљинским степенима директно је условљена дистрибуцијом броја стабала, бонитетом станишта, особинама врста дрвећа итд. Осим у појединим уређајним периодима код букве, запреминску структуру све три врсте дрвећа и сумарно углавном карактерише јака и позитивна асиметирја, изражена спљоштеност и варијациона ширина која је износила од 80/85 до 95 *cm*. Оваква структура индикатор је нагомилавања запремине у јачим дебљинским степенима, као и значајних димензија стабала које се достижу на овом станишту, пре свега код јеле, о чему свакако треба водити рачуна приликом дефинисања пречника сечиве зрелости у шумама у којима се редовно газдује.

Запремина по хектару све три врсте дрвећа перманетно расте, а повећање 2010. године у односу на почетак истраживаног периода код букве износи 78,0%, код смрче 38,5% и код јеле 52,7%. Логична последица повећања запремине врста дрвећа које граде резерват јесте и повећање укупне запремине на хектару. Оно се кретало у интервалу 532,1-800,3 $m^3 \cdot ha^{-1}$, да би на крају педесетогодишњег периода износило 50,4%. Учешће запремине танких стабла ($d \leq 30$ *cm*) у укупној запремини резервата на хектару смањило се за 14,3%, запремине стабала средње јаких димензија ($d = 30{,}1\text{-}50$ *cm*) за 53,3%, док се учешће запремине стабала јаких димензија ($d > 50$ *cm*) повећало за 39,5%.

Текући запремински прираст код букве кретао се у распону 1,10-2,38 $m^3 \cdot ha^{-1}$, са падом након 2000. године. Код смрче он је износио од 2,90 до 5,18 $m^3 \cdot ha^{-1}$, са падом након 1980. године. Прираст јеле варирао је у интервалу 4,87-7,12 $m^3 \cdot ha^{-1}$, достигао је максимум 2000. године и након тога почео падати. Збирно посматрано, текући запремински прираст у периоду 1960-2010. године износио је 8,87-13,40 $m^3 \cdot ha^{-1}$. Максимална вредност достигнута је 1990. године, да би у последња два уређајна периода дошло до његовог блажег пада за 4-8% у односу на максималну вредност.

Изнети подаци о висини запремине и запреминског прираста, у комбинацији са динамиком подмлађивања и урастања, као и односа према одумирању стабала, намећу потребу преиспитивања и евентуалног кориговања утврђеног износа уравнотежене запремине на конкретним стаништима у условима Таре, имајући при томе у виду и све специфичности прашуме у односу на редовно газдоване шуме

И поред низа ограничења у овим истраживањима, произашлим из режима заштите резервата, могуће је извести следеће закључке:

– у смеси са буквом и смрчом јела је врста дрвећа која гради и обезбеђује структурну и производну трајност ових шума;
– на конкретном станишту, у односу на спонтани развој инвентара, буква је инфериорна врста у односу на четинаре. Због тога је у шумама привредног карактера одређеним газдинским мерама (побољшањем светлосног режима у састојини) потребна подршка њеном подмлађивању, урастању, опстанку и повећању учешћа у смеси;
– број стабала основних врста дрвећа (едификатора) у посматраном периоду био је уједначен код букве (сво време), код смрче знатније увећан (у периоду 1970-1980. године) и код јеле увећан (у периоду 1960-1970. године). Период од 1980-2010. године карактерише стабилност (уједначеност) броја стабала у резервату;
– у исто време запремина састојине континуирано и стабилно расте од 1960-2010. године. Код повећања укупног броја стабала у посматраном периоду за 23,2% запремина се акумулирала и увећала за 50,4%. До диспропорције претходног односа довела је промена учешћа основних дебљинских категорија у укупној запремини током времена. Учешће запремине танких стабала у поматраном периоду (50 година) смањило се за 14,3%, средње јаких стабала за 53,3%, док се учешће запремине јаких стабала повећало за 39,5%. Ово указује на присутан процес „раслојавања“ састојине у структурном смислу, али и на „фазу стабилности“ у односу на животни циклус прашуме. Покрет првог спрата ка дебљим категоријама и физиолошкој зрелости одумирања води у догледном времену ка „фази разградње“ и структури у мањој или већој мери блиској пребирној. Производна стабилност, мерена континуитетом прираста и продукције посебно у последњих 40 година, такође, указује на „фазу стабилности“ прашуме у развојном смислу.
– специфичност и спонтаност производности прашума намеће потребу за додатним и комплекснијим истраживањима и континуелним праћењима инвентара, како би се створили реални основи за утврђивање норматива и смерница за газдовање у економским шумама;
– износ запремине састојине након којег долази до пада броја ураслих стабала испод критичног минимума који обезбеђује повољан однос према излучивању стабала треба истражити и евентуално користити као један од индикатора за утврђивање уравнотежене запремине.