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STRUCTURAL AND DYNAMIC CHANGES IN MIXED FORESTS OF BEECH AND FIR ON MT. GOČ

STRUKTURNE I DINAMIČKE PROMENE MEŠOVITIH ŠUMA BUKVE I JELE NA GOČU

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Abstract

The primary goal of this research was to analyze the structural, production and dynamic changes of the forests of beech and fir in permanent sample plots of Mt. Goč, excluded from regular management for a period of 35 years (1977–2011). The established principles of spontaneous development and self-regulatory processes could have implications on the regular management in these forests located in the area of Mt. Goč and other areas.

The results of this research in the permanent sample plots indicate that the mixed forests of beech and fir have suffered a number of changes in terms of structure and production in the investigated period. Structural disruptions have been the result of a decrease in the share of small and medium-diameter trees, as well as an increase in the share of trees of large dimensions in the total number of trees. The curves of distribution have been moved to the right and in terms of shape they differ from the lines that are typical of selection forests. A relatively large number of trees per hectare and the described distribution by diameter classes have resulted in the high values of basal area and stand volume. In addition, a high volume increment has also been recorded. The quality and incremental capacity of the stands have been reduced due to a significant share of old beech and fir trees. The accumulation of volume slowed down the dynamics of stand development and hindered rejuvenation and recruitment, as the necessary prerequisites for structural stability and functionality in selection forests.

The observed trends of development in these forests in the sample plots clearly indicate that a structurally stable, socio-economically and ecologically valuable selection forest is possible to achieve only with an active and continuous implementation of a set of management procedures, which primarily refers to selection cutting. Self-regulatory processes that are allowed over time, as in the case of the analyzed sample plots, are increasingly distancing us from this goal.

Keywords: forests of beech and fir, Mt. Goč, spontaneous development, stand dynamics, stand structure

1. INTRODUCTION / UVOD

Typical beech-fir forests *Polypodio-Fagetum moesiacae* B. Jovanović (59) 1979 (syn. *Abieti-Fagetum moesiacae* B. Jovanović 59) synthaxonomically belong to the alliance of moesian beech forests (*Fagion moesiacae* Blečić & Lakušić, 1976) and the suballiance of the forests of beech and fir (*Abieti-Fagenion moesiacae* B. Jovanović, 1976) (Tomić & Rakonjac, 2013). They developed as a powerful climate regional belt on Mt. Goč in Serbia, where they occupy areas in various orographic, edaphic and microclimatic conditions, at altitudes ranging from 800 to 1,200 m (Jovanović, 1959; Tomić

& Cvjetićanin, 1991; Tomić & Jović, 2000; Tomić & Rakonjac, 2013). They also constitute a significant share in the forests of the following mountains of Serbia: Mt. Kopaonik, Mt. Stara planina, Mt. Prokletije, Mt. Šara, Mt. Mokra Gora, Mt. Tara, Mt. Zlatar, Mt. Jadovnik, Mt. Željin, etc. In smaller areas and with a significantly smaller share of fir, beech-fir forests are distributed on several lower mountains: Mt. Maljen, the Gledićke mountains, Mt. Boranja, Mt. Povlen, Mt. Jastrebac, Mt. Suva planina, Mt. Malinik and Mt. Rtanj.

These forests are characterized by a structural diversity, i.e. a series of transitions from uneven-aged to selection structural forms. The interest of foresters for the management of selection forests, as an option to combine the protective and production aspects of management has been growing over the past several decades (Schütz, 1997). There is a growing insistence on the ways and systems of management that are both in line with nature and at the same time oriented towards the multifunctional use of forests. The selection forest is particularly suitable for achieving multiple effects. It can be designated as a system in which a balance of different interests is provided, while use is managed as a compromise. The selection forest connects nature and economy in an optimal way (Schütz, 2001) and thus represents an extraordinary model of close-to-nature management. Schütz (2002) points out a more pronounced diversity and greater social value of the selection forest, while Banković et al. (2009) highlight its high productivity in the conditions prevailing in Serbia.

The selection forest, as a rule, is not created naturally, but exclusively as a result of a consequent monitoring of this concept and by using silvicultural and management measures to support it. A permanent research of selection forests in Serbia was implemented in a series of permanent sample plots (SPs), over a period of more than 50 years. A number of these SPs are experimental and intended for the analysis of impacts of different management procedures on the structure, development and productivity of selection forests. The second group of SPs are subjected to spontaneous development and self-regulatory processes, in order to recognize certain regularities and trends of development, and thus to enrich the fundamental knowledge on these forests, which should be subsequently implemented in their regular management.

Structural changes, the dynamics of development and the productivity of the selection beech and fir forests on Mt. Goč in the SPs established 35 years before and exluded from regular management are the subject of these investigations, with the following starting hypotheses:

- structural disturbances occured in the stands in the analyzed period,
- productivity was maintained at a high level, but there was a decrease in the quality and incremental strength of the stands,
- the dynamics of the stands was slowed down, and rejuvenation and recruitment were hindered.

2. MATERIAL AND METHODS / MATERIJAL I METODE

2.1 Study area / Objekat istraživanja

The research was carried out in FMU "Goč Gvozdac-A", which is part of the "Goč-Gvozdac" Nature Reserve and the Goč teaching base of the Faculty of Forestry in Belgrade. SP-27A, SP-27B and SP-28 were selected from a series of permanent SPs in this site. They are located in the type of beech and fir forest (*Abieti-Fagetum typicum*) on deep to very deep acid brown soils on granodiorites and quartzdiorites. They were established in 1977 and after that they were subjected to more or less spontaneous development. The basic spatial characteristics of these SPs are shown in Table 1.

The climatic conditions of Mt.Goč were analyzed on the basis of data obtained by the interpolation of meteorological elements from climatological stations in Kraljevo (215 m above sea level) and Kopaonik (1,710 m above sea level) for the period from 1961 to 1990, using the Kriging

Table 1. Basic spatial characteristics of the sample plots / **Tabela 1**. Osnovne prostorne karakteristike oglednih površina

SP	Area / Površina (ha)	Altitude / Nadmorska visina (m)	Exposure / Ekspozicija	Terrain slope / Nagib terena (°)	Coordinates / Koordinate	
					WGS N	WGS E
27A	0.99	1,032–1,061	southwest	13–18°	43°32′51′′	20°46′09′′
					43°32′55′′	20°46′15′′
27B	0.93	1,050–1,083	southwest	15–22°	43°32′51′′	20°46′03′′
					43°32′54′′	20°46′08′′
28	1.18	1,010–1,050	northeast	18–20°	43°32′45′′	20°45′54′′
					43°32′49′′	20°45′57′′

method (Ivetić et al., 2010). Mean annual air temperature on Mt. Goč is 6.9 °C. The lowest average temperature of -3.1 °C occurs in January, and the warmest month is July with 16.1 °C. The average temperature in the vegetation period is 12.7 °C. Autumn, with an average temperature of 7.7 °C is warmer than spring (6.5 °C). The annual rainfall amounts to 840.9 mm of precipitation. The highest precipitation occurs in June, when it reaches the value of 110.4 mm. The driest month is October with 46 mm of precipitation. The rainiest season is summer, while autumn and winter have almost the same average amount of precipitation of 57.5 and 57.2 mm. Precipitation is significantly higher during the vegetation period and amounts to 500 mm, which is favorable for the development of forest vegetation.

2.2 Data collection and processing / Prikupljanje i obrada podataka

The research used data from periodic measurements (1977, 1985, 1995 and 2011) in permanent SPs in the Mt. Goč forests, which are stored in the database of the Chair of Forest Management Planning at the Faculty of Forestry in Belgrade. The SPs were spatially defined by marking the boundaries and determining the coordinates. Their altitude, terrain slope and exposure were determined, and each tree in them was tagged. During periodic mesurements, the SP borders and tree tags were refreshed, and tagging of new, recruited trees was also performed.

The measurement in SPs, among other things, involved cross-measurement of diameter at breast height (DBH) and measurement of the height of all trees with DBH above 10 cm. The diameter was measured with an accuracy of 1 mm and height with an accuracy of 0.1 m.

In order to provide a reliable comparative analysis and avoid the multiplication of errors, the data of periodic measurements were processed using the same methodology. The volume was calculated by the method of volume tables, using the local table for fir on Mt. Goč (Banković et al., 1990) and the general table for the high beech forests of Serbia (Mirković, 1969). The method of increment percentage was used for the calculation of current volume increment, increment percentage being determined by regression models expressing its dependence on the number of trees per unit area, the share of particular species in the mixture, and the diameter and height of the mean tree in the stand (Banković et al., 2000, 2002). *The stand volume index (SVI)* (Klopčič & Bončina, 2011) was calculated using the formula:

$$SVI_{j,y} = \left(\frac{SV_{i,y} - SV_{i,yold}}{SV_{i,yold}} \right) \quad (1)$$

in which:

i – a group of tree species or individual tree species,
y - the year of the measurement,
yold - year of the first measurement,
SV – the wood volume in SPs (m^3/ha).

The diversity of tree dimensions in SPs was estimated on the basis of the Gini coefficient (GCy)

(Lexerød & Eid, 2006; O'Hara et al., 2007; Klopčič & Bončina, 2011), obtained by using the formula:

$$GCy = \frac{\sum_{j=1}^{n}(2j - N - 1)\times g_j}{\sum_{j=1}^{n} g_j \times (N-1)} \qquad (2)$$

in which:

y - the year of the measurement,
j - the rank of trees, ranging from 1 to n (from the thinnest to thickest tree),
N - total number of trees,
g – basal area of the tree.

Dixon et al. (1987), according to Lexerød & Eid (2006), consider that the Gini coefficient is precisely determined if the number of individuals on the basis of which it is calculated is equal to or greater than 50. Since the number of trees in the analyzed SPs is significantly higher than the above, it can be stated with certainty that the Gini coefficient was calculated with sufficient precision.

Statistical data processing implied the application of descriptive statistics. The arithmetic mean, minimum, maximum and variation coefficient were calculated from the periodic measurements in each SP, as the basic measures of variation for basal area, volume and current volume increment per hectare.

3. RESULTS / REZULTATI

The variation coefficient of the number of trees is 2.5% in SP-28, 3.9% in SP-27B and 5.2% in SP-27A, which indicates relative stability of this element over time. Unlike the

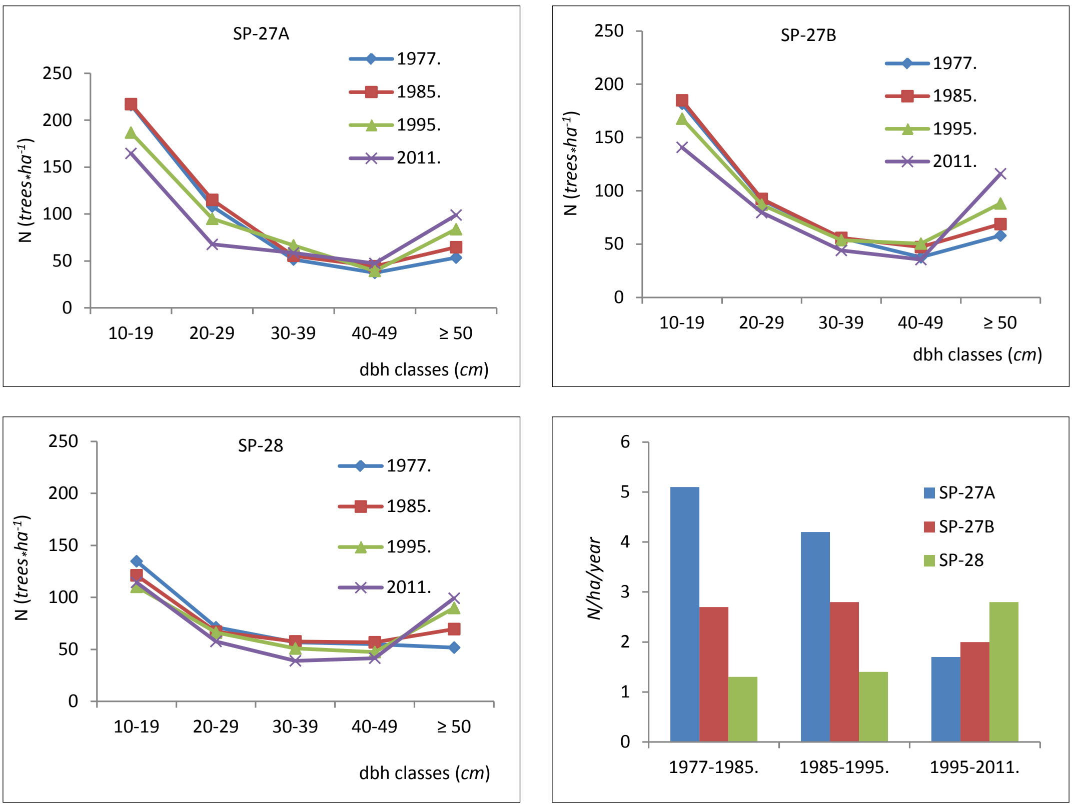

Figure 1. Changes in the distribution of the number of trees by DBH classes and the number of recruitment trees / **Slika 1**. Promene distribucije broja stabala po debljinskim razredima i broj uraslih stabala

total number of trees, their distribution by diameter classes significantly varied in the analyzed period. At the beginning of the period, the distribution curves used to have a more or less hyperbolic shape, typical of selection forests. Over time and especially after 1995, a decrease in the number of trees with a diameter of 10–39 cm was evident, and the share of trees of large dimensions (d ≥ 50 cm) increased. This trend led to structural disturbances and the shape of tree distribution curves became flatter, which differed significantly from shape that is typical of selection forests. The decrease in the number of small-diameter trees was influenced by the insufficient recruitment compared to the need to preserve the selection structure. Apart from being insufficient, the recruitment has a downward trend over time. The largest number of recruited trees at the beginning of the period (5.1 pcs·ha^{-1} per year) was recorded in SP-27A, and at the end of the period in SP-28, which was only 2.8 pcs·ha^{-1} per year (Figure 1).

The coefficient of dimensional diversity changed over time in the interval: Gcy (1977) = 0.581-Gcy (2011) = 0.592 in SP-27A, Gcy (1977) = 0.558-Gcy (2011) = 0.569 in SP-27B and Gcy (1977) = 0.528-Gcy (2011) = 0.559 in SP-28. A certain increase in this coefficient at the end of the observed period is the consequence of an increase in the variation width of the distribution of trees by diameter classes, i.e. the accumulation of trees of large dimensions (Figure 2).

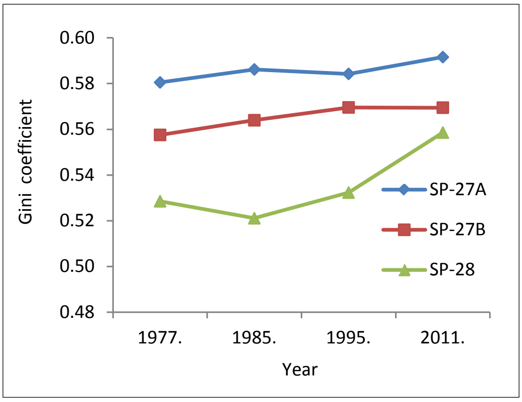

Figure 2. Gini coefficient / **Slika 2**. Džini koeficijent

Basal area has significantly increased in all SPs: by 50% in SP-27A, by 56.4% in SP-27B and by 30.6% in SP-28 compared to the measuring from 1977. At the end of the period in 2011, the values of basal area are high and amount to 53.7 m^2·ha^{-1} in SP-27A, 54.6 m^2·ha^{-1} in SP-27B and 46.5 m^2·ha^{-1} in SP-28 (Table 2). Since the number of trees has slightly changed over time, a marked increase in basal area can only be explained by the accumulation of fir and beech trees of large dimensions.

Table 2. Changes in the value of basal area / **Tabela 2**. Promene vrednosti temeljnice

SP	Tree species / Vrsta	Year of measurement / Godina merenja				G	min.	max.	c_G
		1977	1985	1995	2011	(1977–2011)			
		m^2·ha^{-1}							%
27A	Beech / Bukva	5.6	6.5	6.9	7.0	6.5	5.6	7.0	9.8
	Fir / Jela	30.2	35.2	41.2	46.7	38.3	30.2	46.7	18.7
	In total	35.8	41.7	48.1	53.7	44.8	35.8	53.7	17.3
27B	Beech / Bukva	7.3	8.3	10.3	11.7	9.4	7.3	11.7	21.0
	Fir / Jela	27.6	33.0	38.6	42.9	35.5	27.6	42.9	18.8
	In total	34.9	41.3	48.9	54.6	44.9	34.9	54.6	19.3
28	Beech / Bukva	12.8	14.3	16.3	16.8	15.0	12.8	16.8	12.2
	Fir / Jela	22.8	26.2	28.4	29.7	26.8	22.8	29.7	11.4
	In total	35.6	40.5	44.7	46.5	41.8	35.6	46.5	11.6

In the period of 35 years, the volume per hectare increased by 75.6% in SP-27A, i.e. 78.7% in SP-27B and by 54.2% in SP-28. The current volume values are high and range from 770.6 $m^3 \cdot ha^{-1}$ in SP-28 to 820.2 $m^3 \cdot ha^{-1}$ in SP-27A (Table 3). The values of the volumetric index, as an indicator of increase in volume compared to the first measurement (Figure 3), confirm the findings of a sudden increase in this element in the analyzed period. The volume structure of the Biolei thickness classes was also changed in favor of the category of large-dimension trees. In all SPs, from one period to another, the share of small and medium-sized trees in the total volume decreased, and the share of trees with diameters of over 50 cm increased (Figure 3).

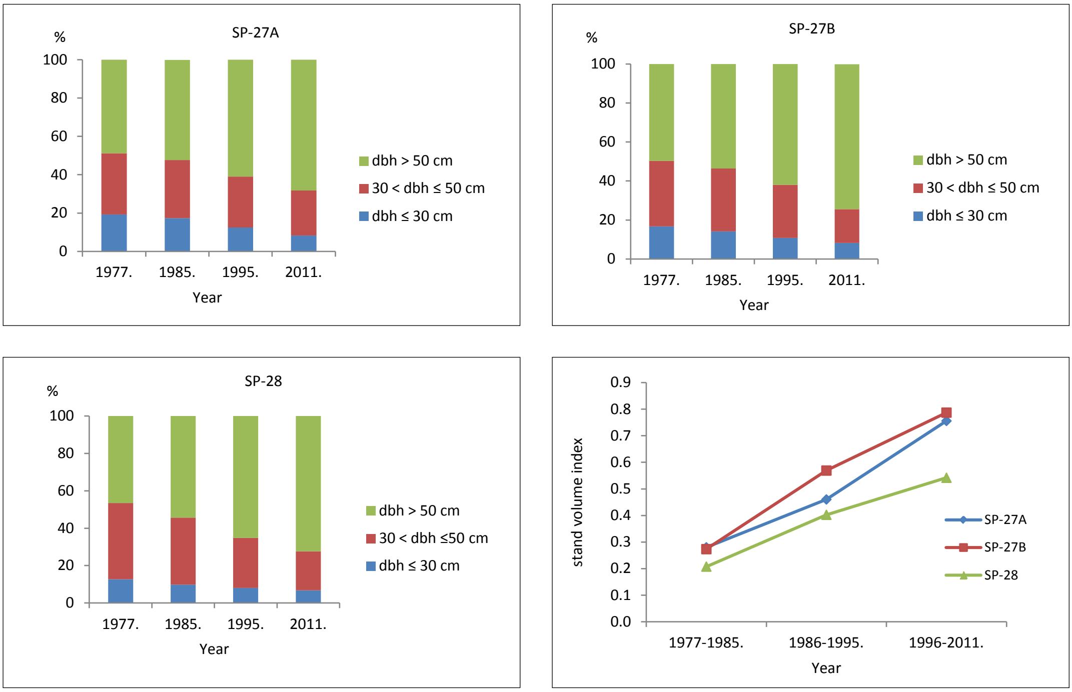

Figure 3. Changes in the distribution of volume by Bioley DBH classes and stand volume index / **Slika 3**. Promene distribucije zapremine po klasama debljine Bioleja i zapreminski indeks sastojine

Table 3. Changes in the value of volume / **Tabela 3**. Promene vrednosti zapremine

SP	Tree species / Vrsta	Year of measurement / Godina merenja				∇	min.	max.	c_v
		1977	1985	1995	2011	(1977–2011)			
		m³·ha⁻¹							%
27A	Beech / Bukva	81.8	98.2	104.2	108.4	98.2	81.8	108.4	11.9
	Fir / Jela	385.3	499.8	577.9	711.8	543.7	385.3	711.9	25.2
	In total	467.1	598.0	682.1	820.2	641.8	467.1	820.2	23.1
27B	Beech / Bukva	110.6	131.6	165.2	187.9	148.8	110.6	187.9	23.1
	Fir / Jela	340.1	442.3	542.0	617.6	485.5	340.1	617.6	24.8
	In total	450.7	573.9	707.2	805.5	634.3	450.7	805.5	24.4
28	Beech / Bukva	199.4	229.2	263.9	272.7	241.3	199.4	272.7	13.9
	Fir / Jela	300.4	374.3	437	497.9	402.4	300.4	497.9	21.0
	In total	499.8	603.5	700.9	770.6	643.7	499.8	770.6	18.3

The mixture ratio varied in all three SPs in favor of fir (Table 4) and was increasingly moving away from the optimal ratio, which, according to Milojkovic (1962), amounts to 70:30% in favor of fir. From the aspect of preserving the natural composition of these forests and sites, the decline in the share of beech in mixed forests with fir is worrying, especially in SP-27A, where at the end of the period it was only 13.2%.

Table 4. Changes in the shares of tree species in the mixature / **Tabela 4**. Promene razmera smese

SP	1977		1985		1995		2011	
	beech / bukva : **fir** / jela		**beech** / bukva : **fir** / jela		**beech** / bukva : **fir** / jela		**beech** / bukva : **fir** / jela	
	%							
27A	17.5	82.5	16.4	83.6	15.3	84.7	13.2	86.8
27B	24.5	75.5	22.9	77.1	23.4	76.6	23.3	76.7
28	39.9	60.1	38.0	62.0	37.6	62.4	35.4	64.6

Current volume increment (Table 5) increases over time, whereby fir, as the dominant species, gives a greater contribution to this trend. At the end of the analyzed period, the increment is high and amounts to 14.0 $m^3 \cdot ha^{-1}$ in SP-28 to 15.8 $m^3 \cdot ha^{-1}$ in SP-27A. Unlike the absolute value of the increment, the percentage of increment is constantly decreasing for both tree species. This trend indicates a decline in the incremental capacity of these forests, as a consequence of structural disruptions (decrease in the share of thin and medium trees - carriers of increment) and reduced vitality of old and overmatured trees of beech and fir.

Table 5. Changes in the current volume increment / **Tabela 5**. Promene tekućeg zapreminskog prirasta

SP	Tree species / Vrsta	Year of measurement / Godina merenja				Tv	min.	max.	c_{Iv}
		1977	1985	1995	2011	(1977–2011)			
		$m^3 \cdot ha^{-1}$							%
27A	Beech / Bukva	1.8	2.1	2.1	2.3	2.1	1.8	2.3	9.9
	Fir / Jela	8.9	11.0	11.8	13.5	11.3	8.9	13.5	16.9
	In total	10.7	13.1	13.9	15.8	13.4	10.7	15.8	15.8
27B	Beech / Bukva	2.0	2.3	2.7	2.9	2.5	2.0	2.9	16.3
	Fir / Jela	8.0	9.8	11.3	12.0	10.3	8.0	12.0	17.2
	In total	10.0	12.1	14.0	14.9	12.8	10.0	14.9	17.0
28	Beech / Bukva	3.5	3.9	4.1	4.1	3.9	3.5	4.1	7.3
	Fir / Jela	6.7	7.8	8.8	9.9	8.3	6.7	9.9	16.4
	In total	10.2	11.7	12.9	14.0	12.2	10.2	14.0	13.4

4. DISCUSSION / DISKUSIJA

Significant changes in the dynamism, structure and productivity of mixed beech-fir forests were recorded in the SPs on Mt. Goč over the period of 35 years. At the same time, both compatibility and certain differences were found when the results of this research were compared to findings from similar types of beech-fir and fir-spruce-beech forests in the region (Čavlović 1999, Klopčič & Bončina, 2011; Bončina et al., 2014; Keren et al., 2014), as well as in Central Europe (O'Hara et al., 2007; Vrška et al., 2009).

In addition to a more or less constant number of trees per hectare over time, significant changes have been noted in their distribution by diameter classes. The share of small-diameter trees was reduced, and trees of over 50 cm in diameter accumulated, which disrupted the selection structure. The accummulation of trees of large dimensions was also recorded in the selection forests of beech, fir and spruce on Mt. Tara (Medarević & Obradović, 2007; Obradović, 2008; Medarević et al., 2010; Pantić et al., 2012), in beech and fir forests in Slovenia (Bončina et al., 2002), and in the beech and fir forests in Croatia (Čavlović, 2000; Čavlović et al., 2006). Such a process negatively affects rejuvenation, recruitment, further development and stability of these forests, and according to O'Hara & Gersonde (2004), it is necessary to control the number and distribution of trees within the stands, i.e. the distribution of space for growth.

One of the characteristics of selection forests is marked dimensional diversity. This research used the Gini coefficient as an objective ecological measure for comparing the diversity of different stands (Latham et al., 1997 according to Lexerød & Eid, 2006) and for estimating its changes over time (Lundqist, 1994; Hessburg et al., 2000). The marked diversity of dimensions, i.e. variations in the dimensions of trees, makes the forest more valuable in ecological and socio-economic terms. In the SPs on Mt. Goč, the value of the Gini coefficient was moderately increased due to an increase in the variation width of the diameter, and in the last analyzed period it ranged from 0.559 to 0.592. Similar changes in the Gini coefficient were recorded in uneven-aged stands of beech and fir in Switzerland (O'Hara et al., 2007) and in the Leskovo Plain and Trnovo (Klopčič & Bončina, 2011).

Recruitment plays an important role in the life and development of the selection forest (Miletić, 1950, 1954, 1957, 1959, Milojković, 1986, Tomanić, 1989, Duc, 1991, Medarević, 2006, Čavlović, 2013) The number of recruited trees and structure in terms of tree species are significant elements of development, structural stability and functionality of the selection forest (Medarević, Obradović, 2007; Medarević et al., 2010). In the investigated SPs on Mt. Goč, recruitment is unsatisfactory and amounts to only 2.5 trees per hectare per year on average. From the aspect of maintaining a permanent selection structure, the number of grown trees should be from 5.9 to 10 pieces per hectare per year (Miletić, 1959, Čavlović, 2000; Klepac, 2001; Medarević et al., 2010). Čavlović et al. (2006) also found unsatisfactory recruitment in the selection forests of fir and beech in the mountain region of Gorski Kotar. Climate change (Nagel et al., 2010), air pollution (Chmelar, 1959) and growing deer populations (Rehak, 1963; Klopčič et al., 2010) were the reasons quoted for hindered recruitment. Under the conditions prevailing on Mt. Goč, a high number of trees of large dimension, which, as a rule, have large crowns (especially beech), reduce space for trees growth and in that way negatively affect the volume and dynamics of recruitment. Fir and beech have different degrees of shade tolerance, and therefore require different procedures in performing selection cuts aimed at achieving sufficient and high quality rejuvenation and recruitment of these tree species. Therefore, Malcolm et al. (2001) propose a combination of single-tree and group selection cuts, in order to stimulate the regeneration and recruitment of both extremely shade- tolerant species (fir) and less shade-tolerant ones (beech, spruce, maple). Site conditions, such as weediness, soil pH, etc. should not be neglected as factors with an impact on recruitment (Nagel et al., 2010; Klopčič & Bončina, 2012).

Basal area of the stands increased in all three SPs over time, as a result of the accumulation of trees of large dimensions. O'Hara et al. (2007) recorded similar results in a study of the dynamics of selection stands in permanent SPs in Switzerland, and Keren et al. (2014) found the same in the forests of Janj in Bosnia and Herzegovina. In a study of the dynamics of virgin forests of fir, beech and spruce in Slovenia, Croatia, Bosnia and Herzegovina and Slovakia, Diaci et al. (2011) found similar values of basal area that ranged from 33.6 to 59.0 $m^2 \cdot ha^{-1}$.

The wood volumes at the end of the analyzed period in the SPs on Mt. Goč were high and they ranged from 771 $m^3 \cdot ha^{-1}$ to 820 $m^3 \cdot ha^{-1}$. Many authors recorded high production of beech and fir forests. Puncer & Zupančić (1970) recorded a volume of 768 $m^3 \cdot ha^{-1}$ in the forest stands of beech and fir Rajhenavski Rog in Kočevsko in Slovenia. A little lower volume of 671 $m^3 \cdot ha^{-1}$ was recorded by Anić & Mikac (2008) in the "Čorkova uvala" virgin forest in the National Park Plitvice Lakes in Croatia. According to Govedar et al. (2006) and Dukić & Maunaga (2008), the volume in SPs of the virgin forest of Lom ranged from 1,108 to 1,216 $m^3 \cdot ha^{-1}$, while according to Motta et al. (2011) and Keren et al. (2014) the average volume in the entire forest area was 763 $m^3 \cdot ha^{-1}$. Keren et al. (2014) stated that the average volume in the forest of Janj was 1,215 $m^3 \cdot ha^{-1}$, and in Perucica 937 $m^3 \cdot ha^{-1}$. In a study of the dynamics of virgin forests of beech and spruce in Slovenia, Croatia, Bosnia and Herzegovina and Slovakia, Diaci et al. (2011) reported a minimum volume of 446 $m^3 \cdot ha^{-1}$ and a maximum volume of 1,010 $m^3 \cdot ha^{-1}$. Depending on the phase of development and the number of trees, Korpel (1996) reported that in the forests of Slovakia, the volume ranged from 450/550 $m^3 \cdot ha^{-1}$ to 900/1,100 $m^3 \cdot ha^{-1}$. In addition, this author noted that the volume was higher if the share of conifers (especially fir) in the mixture was larger. In this way, it was clearly indicated that fir was the bearer of high productivity of these mixed forests. The increase in volume in the analyzed stands on Mt. Goč was also reflected on its distribution by Biolay diameter classes. The share of trees with large dimensions (d > 50 cm) in the total volume was 68–74% at the end of the period. A large share belonged to overmatured trees with reduced technical quality and significantly reduced incremental capacity. In addition, the accummulation of trees of large dimensions is one of the causes of slow and insufficient regeneration and recruitment. Similar problems were described by other authors who studied the dynamics of selection forests. Matić et al. (1996) concluded that one of the main reasons for the slow regeneration and recruitment of fir in selection forests of beech and fir in Croatia was disturbed selection structure, i.e. the share of large diameter-trees that ranged from 76 to 89%. In the teaching base Zalesina of the Faculty of Forestry, University of Zagreb (FMU "Belevine"), Čavlović (2000) reported an extreme excess of wood stock above 50 cm as one of the problems of beech and fir forests, which resulted in a lower increment and had an impact on regeneration and recruitment. Korpel (1996) pointed out that the proportion of large-diameter trees (over 52 cm in diameter) in the total volume in the virgin forests of Slovakia ranged from 75 to 78%, while Anić (2007) and Anić, Mikac (2008) found the share of large-diameter trees of 72.5% in the virgin forest Čorkova uvala.

The share of fir in the total volume of the investigated SPs on Mt. Goč increased. In studies of the dynamics of selection forests, numerous authors have also noted changes in the mixture, which mainly refers to the spread of beech at the expense of fir (Čavlović, 2000; Bončina et al., 2003; Čavlović et al., 2006; Vrška et al., 2009; Klopčič et al. al., 2010, Bončina, 2011; Diaci et al., 2011). However, Keren et al. (2014) emphasize the stability of the share of fir in virgin forests of Bosnia and Herzegovina due to lower SO2 emissions and smaller deer populations in this region than in other parts of eastern and southeastern Europe. The increase in the share of fir on Mt. Goč is a process that must be controlled and stopped in stands where mixture ratio is significantly disturbed at the expense of beech and far from the optimum (fir: beech = 0.7 : 0.3). In addition, the optimum share of beech is very important for the stability and functional value of these forests.

Current volume increment increased since the beginning of the analyzed period in the investigated SPs on Mt. Goč, and in 2011 it reached 14.0-15.8 $m^3 \cdot ha^{-1}$. A similar trend of volume increment has been recorded in the selection forests of fir, spruce and beech on Mt. Tara (Medarević, 2005; Medarević & Obradović, 2007; Obradović, 2008). High values of volume increment of 17.9 $m^3 \cdot ha^{-1}$ has been found by Puđa (2010) in the community Piceo-Abieti-Fagetum illyricum in the Drvar-Petrovac forest-economic area, while Kneginjić (2010) has recorded that it ranged from 14.1 to 24.4 $m^3 \cdot ha^{-1}$ in mixed forests of beech and fir on Mt. Kozara. According to Lučić (2012), the highest value of volume increment in the SPs of the virgin forest Perućica has amounted to 13.6 $m^3 \cdot ha^{-1}$. The absolute values of volume increment indicate high productivity of mixed forests of beech and fir in the investigated sites on Mt. Goč. However, a decline in the increment percentage to below 2% at the end of the analyzed period, has unambiguously pointed to a reduced incremental capacity of these forests as a consequence of structural and spatial disorders.

5. CONCLUSIONS / ZAKLJUČCI

The starting hypotheses of these studies have been fully confirmed. There are structural disorders in the forests of beech and fir in the analyzed SPs on Mt. Goč. They are a result of a decrease in the share of trees with a diameter d < 50 cm, and in particular trees from small-diameter categories and an increase in the share of trees with large dimensions of d ≥ 50 cm in the total number of trees. The curves of distribution have moved to the right, getting a flatter shape, which made them significantly different from the distribution that is typical of selection forests.

A relatively large number of trees, with a significant share of large-dimension trees, logically have resulted in high values of basal area and volume per hectare. High absolute values of the current volume increment have also been recorded, which altogether points to a good production potential of the investigated site. However, high volume does not necessarily mean a desirable state, especially if it is distributed to old trees with reduced technical values and if it disturbs (slows down) stand development.

Insufficient rejuvenation and recruitment are the result of tree redistribution by diameter classes, or reduced space for growth, with a negative impact on the preservation of these stands as stable and functional forms.

The trends identified in the forests of beech and fir in the SPs on Mt. Goč indicate that it is necessary to permanently monitor all developmental processes and implement a set of silvicultural measures that regulate them, which should be adjusted over time and directed towards the set goal, which is a structurally stable, socio-economically and ecologically valuable selection forest as a permanent category. If stands are subjected to spontaneous development and self-regulatory processes over time, as is the case of the investigated SPs, they are being increasingly distanced from that goal.

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Sažetak

Primarni cilj ovih istraživanja bio je da se analiziraju strukturne, proizvodne i dinamičke promene bukovo-jelovih šuma na stalnim oglednim površinama (OP) Goča, koje su izuzete iz redovnog gazdovanja tokom 35 godina (1977–2011). Utvrđene zakonitosti spontanog razvoja i samoregulacijskih procesa imale bi implikacije na redovno gazdovanje ovim šumama na prostoru Goča i šire.

Osnov za ova istraživanja su podaci periodičnih premera OP (1977, 1985, 1995. i 2011. godine), koji su pohranjeni u bazi podataka Katedre Planiranja gazdovanja šumama Šumarskog fakulteta u Beogradu. Pored ostalog, svaki premer na OP je podrazumevao merenje prečnika i visine svih stabala iznad taksacione granice od 10 cm. Kao rezultat obrade ovih podataka dobijen je broj stabala, temeljnica, zapremina, zapreminski prirast i njihove distribucije, te vrednosti Džini koeficijenta i zapreminskog indeksa.

Rezultati ukazuju na to da su mešovite šume bukve i jele na stalnim OP pretrpele niz promena u strukturnom i proizvodnom smislu u periodu od 35 godina. Strukurni poremećaji nastali su kao posledica smanjenja učešća tankih i stabala srednje jakih prečnika (d < 50 cm), te povećanja učešća stabala jakih dimenzija (d ≥ 50 cm) u ukupnom broju stabala. Linije raspodele se pomeraju udesno i po obliku sve više udaljavaju od linija karakterističnih za prebirne šume. Relativno veliki broj stabala na hektaru i opisana distribucija po debljinskim razredima rezultirali su visokim iznosima temeljnice i zapremine sastojine, a utvrđen je i visok zapreminski prirast. Temeljnica se uvećala za 30,6–54,6% i na kraju analiziranog perioda je iznosila 46,5–54,6 $m^2 \cdot ha^{-1}$. Poslednjim premerom konstatovana je zapremina u intervalu 771–820 $m^3 \cdot ha^{-1}$, što je uvećanje za 54,2–78,7% u odnosu na početak perioda (1977. godina). Razmer smese se menjao u korist jele, do te mere da to predstavlja negativan trend, jer je dovedena u pitanje prirodna kompozicija i stabilnost ovih šuma. Tekući zapreminski prirast je dostigao iznos od 14,0 do 15,8 $m^3 \cdot ha^{-1}$, ali je procenat prirasta pao ispod 2%. Kvalitet i prirasna snaga sastojina su umanjeni zbog značajnog prisustva starih stabala bukve i jele. Nagomilavanje zapremine usporilo je dinamiku razvoja sastojina i otežalo podmlađivanje i urastanje. Urastanje je u proseku iznosilo 2,5 stabla po hektaru godišnje, što je znatno ispod broja koji bi obezbedio strukturnu stabilnost prebirne šume.

Trendovi koji su konstatovani u bukovo-jelovim šuma na OP Goča upućuju na to da je nužno permanetno praćenje svih razvojnih procesa i sprovođenje seta uzgojno-uređajnih mera kojima se oni regulišu, tokom vremena podešavaju i usmeravaju ka postavljenom cilju, a to je strukturno stabilna, socio-ekonomski i ekološki vredna prebirna šuma kao trajna kategorija. Prepuštanje sastojina spontanom razvoju i samoregulacijskim procesima tokom vremena, kao što je to slučaj na istraživanim OP, sve više nas udaljava od ovog cilja.

Ključne reči: dinamika sastojine, Goč, spontani razvoj, struktura sastojine, šume bukve i jele