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SPONTANEOUS DEVELOPMENT OF MIXED STANDS OF FIR, SPRUCE AND BEECH ON MT. TARA

Snežana OBRADOVIĆ[1], Milan MEDAREVIĆ[1], Damjan PANTIĆ[1], Biljana ŠLJUKIĆ[1], Nenad PETROVIĆ[1], Dragan BOROTA[1], Aleksandar POPOVIĆ[1]*

Abstract: *The main objective of this study is to analyze the structural production and dynamic changes of mixed forests of fir, spruce and beech on Mt. Tara, in permanent sample plots which were exempt from the regular management over a period of more than 60 years (1955-2017). The results of the research indicate that during the analyzed period mixed forests of fir, spruce and beech have undergone a number of changes in structural and production terms. The significant presence of trees of large dimensions (volume accumulation) slowed down the developmental dynamics of these stands and made regeneration and recruitment difficult, which had a negative impact on their structural development and, in general, on the stability of these stands. The results show that selection forests are possible to achieve only with a permanent management approach and adherence to the modern principles of close-to-nature forest management. In this sense, selection cutting in the context of close-to-nature forest management is imposed as a means of accelerating the dynamics of development of these forests, repairing their structural development (by achieving and preserving their selection structure), ecological stability and functional values. On the contrary, the absence of activity and spontaneous development of these stands leads to a general devitalization and a deviation from the desired goals.*

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

SPONTANI RAZVOJ MEŠOVITIH SASTOJINA JELE, SMRČE I BUKVE NA TARI

Sažetak: *Osnovni cilj ovih istraživanja jeste da se analiziraju strukturne, proizvodne i dinamičke promene mešovitih šuma jele, smrče i bukve na Tari, na stalnim oglednim površinama, koje su izuzete iz redovnog gazdovanja u periodu dužem od 60 godina (1955-2017). Rezultati istraživanja ukazuju na to da su u analiziranom periodu mešovite šume jele, smrče i bukve pretrpele niz promena u strukturnom i proizvodnom smislu. Značajno prisustvo stabala jakih dimenzija (nagomilavanje zapremine) usporilo je dinamiku razvoja ovih sastojina i otežalo podmlađivanje i urastanje, što se negativno*

[1]Faculty of forestry, Kneza Viseslava 1, 11.000 Belgrade, Serbia
*Corresponding author. E-mail: snezana.obradovic@sfb.bg.ac.rs

odrazilo na njihovu strukturnu izgrađenost i, generalno, na stabilnost ovih sastojina. Rezultati pokazuju da je prebirna šuma moguća jedino uz permanentan gazdinski pristup i poštovanje savremenih principa prirodi bliskog gazdovanja. U tom smislu, prebirna seča, u kontekstu prirodi bliskog gazdovanja, nameće se kao sredstvo ubrzanja dinamike razvoja ovih šuma, popravke njihove srukturne izgrađenosti (postizanja i očuvanja prebirne strukture), ekološke stabilnosti i funkcionalne vrednosti. Suprotno, odsustvo aktivnog delovanja i spontani razvoj sastojina vode ka njihovoj devitalizaciji i udaljavanju od željenih ciljeva.

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

1. INTRODUCTION

The forest of fir, spruce and beech *Piceo-Abietetum* Col. 1965 (syn. *Piceo-Fago Abitetum* Chol. 1965; *Piceo-Abieti-Fagetum moesiacum* Mišić et al., 1978) is a specific three-dominant community, which can be found in Serbia on Mt. Tara, Mt. Zlatar, Mt. Golija, the Mojstirsko-Draške mountains, Mt. Kopaonik, Mt. Stara planina, and Pešter Plateau, etc. In Mt. Tara and the Pešter Plateau, this community occurs as a climate regional belt (Gajić, 1992; Tomić, Rakonjac, 2013). The ratio of spruce, fir, and beech in the association changed during the historical development of the vegetation, depending on the climatic conditions and the way of management (Tomić, Rakonjac, 2013).

These forests are characterized by structural diversity, i.e. a series of transitions from diverse to complex selection structural forms. In recent decades, there has been a growing interest of the international forestry circles in selection (uneven-aged) forest management systems, as these systems have been recognized as more natural, associated with more pronounced diversity and a greater social value of forests (Schütz, 2002). Increasingly, the focus is placed on the management methods and systems that are in harmony with nature and at the same time oriented toward multifunctional use. It is precisely the selection forest that is a silvicultural form suitable for producing multiple effects. It can therefore be referred to as a system in which the interests are balanced and the use is regulated as a compromise.

The selection forest is not created naturally, but solely in a way that continuously supports this concept by silvicultural measures. The structural changes, productivity and dynamics of development of the selection forests of fir, spruce and beech on Mt. Tara have been monitored since 1955 in a series of permanent sample plots (SPs). These SPs were exempt from regular management and left to spontaneous development and self-regulatory processes. The aim was to identify and analyze certain laws and trends in the development of these forests, as well as to implement new knowledge into a management process that aims at structurally and ecologically stable and highly functional selection forests. In those terms, from a time distance of more than 60 years, the goal of these studies was defined, and the following hypotheses were formulated:

- in the analyzed period (1955-2017) there were structural disturbances of the stands,
- the developmental dynamics of the stands was slowed down and regeneration and recruitment became difficult,
- the stability and functional value of these forests were reduced.

2. MATERIAL AND METHODS

2.1 Research object

The research was carried out in the "Tara" MU, which is an integral part of the national park with the same name. From the series of permanent SPs in this locality, sample plots SP-1, SP-2 and SP-4 were selected, which are located in the type of spruce, fir and beech forest (*Piceo - Abieti - Fagetum typicum*), on deep to medium deep brown soils on limestone. They were established in 1955 and subsequently largely left to spontaneous development. The basic spatial features of the SPs are shown in Table 1.

Table 1. *The basic spatial features of the SPs*

SP	Area (*ha*)	Altitude (*m*)	Exposure	Terrain slope (°)	Coordinates WGS N	Coordinates WGS E
SP-1	1.44	1099-1116	East	10-15 °	43 ° 55'10 " N 43 ° 55'16 " N	19 ° 25 '06"E 19 ° 25'11"E
SP-2	1.04	1157-1174	Southeast	5- 10 °	43 ° 54'46"N 43 ° 54'51"N	19 ° 24'33"E 19 ° 24'40"E
SP-4	1.00	1152-1174	West	10-15 °	43 ° 54'43"N 43 ° 54'48"N	19 ° 25'42"E 19 ° 25'45"E

The average annual air temperature on Mt. Tara is 5.2°C, the coldest month being January, while the warmest is July, with an average temperature of 13.8°C. The average air temperature in the vegetation period is 10.8°C, while in autumn the mean temperature is 6.1°C, which makes it warmer than spring (4.6 ° C). Annual precipitation is 1,005 mm of water sediment. The rainiest month is May and January and March are the driest months. Rainfall is more abundant during the vegetation period (584 mm of water sediment), which favors the development of forest vegetation.

2.2 Data collection and processing

The surveys used data from periodic measurements (1955, 1975, 2005 and 2017) of permanent SPs in the Mt. Tara forests, which are in the database of the Chair of Forest Management Planning of the Faculty of Forestry in Belgrade. The SPs were spatially defined by marking their boundaries and determining their coordinates, altitude, slope and exposure, while each tree in them was numbered. During periodic measurements, the boundaries of the SPs and the tree numbers were renewed, and the numbering of newly-recruited trees was also performed.

The measurement in the SPs involved a cross measurement of the diameter at breast height and a measurement of the height of each tree above the forest estimation threshold of 10 cm. The diameter was measured with an accuracy of 1 mm and height with an accuracy of 0.1 m.

To enable a reliable comparative analysis, the data of periodic measurements were processed using the same methodology. The volume was calculated by the volume tables method, using the local tables for fir and spruce on Mt. Tara (Banković, 1991) and general tables for high beech forests of Serbia (Mirković, 1969). The current volume increment method was used to calculate the current volume increment, whereby the increment percentage was determined by regression models expressing its dependence on the number of trees per unit area, the share of a particular tree species in the mixture and the diameter and height of the mean stand tree (Banković et al. 2000, 2002).

The diversity of tree dimensions in the SPs was estimated on the basis of the Gini coefficient (GCy) (Lexerød & Eid, 2006; Klopčič & Bončina, 2011), which was obtained using the formula:

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

in which:
y- is the year in which the measurement was performed,
j- is the rank of trees ordered from 1 to n (from the thinnest to the thickest),
N- is the total number of trees,
g- is the basal area of a tree.

Statistical data processing was performed by applying descriptive statistics. Using the data of periodic measurements, the arithmetic mean, minimum, maximum and variation coefficient were calculated in each SP as the basic measures of variation in the number of trees (N), basal area (G), volume (V) and current volume increment (Iv) per hectare.

Within this chapter there can be subtitles of first and second line. In the description of material, it should be given enough information to allow other researchers to repeat the experiment at a different location. It is necessary to provide information on the material, subject of the study that precisely defines its origin, physical characteristics etc. If a device or instrument is used to obtain experimental results should be specified: name of the device or instrument, model, manufacturer's name and country of origin. If a scientifically recognized method is used it has to be cited in the References, without the explanation of the steps of the used method. If changes were made in a scientifically recognized method should be provided the original literature references that will support – justify those changes.

3. RESULTS AND DISCUSSION

The variation coefficient of the number of trees is 26.6% in SP-1, 19.3% in SP-2 and 33.6% in SP-4 (Table 2), indicating a more pronounced variation of this element over time. There is an evident decrease in the total number of trees compared to the beginning of the analyzed period and it amounts to 30.9% in SP-1, 32.1% in SP-2 and 50.5% in SP-4. The accumulation of trees of large dimensions ($d \geq 50$ *cm*) (Figure 1) resulted in the reduction of light in the stand, the reduction of growth space, as well as the absence of recruitment, which led to the extinction of thin trees (trees of lower storeys), i.e. to a decrease in the total number of trees in the observed period. Such a trend led to structural disturbances and tree distribution curves developed a flatter form, thus moving away from the shape that is typical of selection forests (Figure 1). The consequence of these changes is also a decrease in dimensional diversity, as indicated by the Gini coefficient, which declines over time (Figure 1). The trend of this coefficient in the observed period ranged from 0.556 to 0.547 in SP-1, i.e. from 0.557 to 0.536 in SP-2 and from 0.493 to 0.451 in SP-4.

Table 2. *Measures of variation in the basic numerical elements in the SPs*

SP	$\bar{N}$ (trees · ha^{-1})	min.	max.	C_N (%)	$\bar{G}$ ($m^2 \cdot ha^{-1}$)	min.	max.	C_G (%)
SP-1	436	327	564	26.6	47.1	36.2	52.4	7.4
SP-2	550	422	650	19.3	47.5	35.2	55.7	9.9
SP-4	609	384	789	33.6	46.3	36.7	51.9	6.8
SP	$\bar{V}$ ($m^3 \cdot ha^{-1}$)	min.	max.	C_v (%)	$\bar{I}v$ ($m^3 \cdot ha^{-1}$)	min.	max.	C_{Iv} (%)
SP-1	715	498	828	20.8	13.3	10.6	15.1	14.9
SP-2	701	450	898	31.6	14.1	10.2	17.3	22.4
SP-4	659	457	796	21.8	13.8	13.1	15.1	5.7

The basal area increased significantly in all SPs, i.e. by 44.3% in SP-1, 57.4% in SP-2 and by 26.4 % in SP-4 compared to the 1955 diameter. At the end of the period in 2017, the value of the basal area was high and it amounted to 52.4 $m^2 \cdot ha^{-1}$ in SP-1, 55.4 $m^2 \cdot ha^{-1}$ in SP-2 and 46.4 $m^2 \cdot ha^{-1}$ in SP-4. The significant increase in the basal area can only be explained by the accumulation of trees of large dimensions.

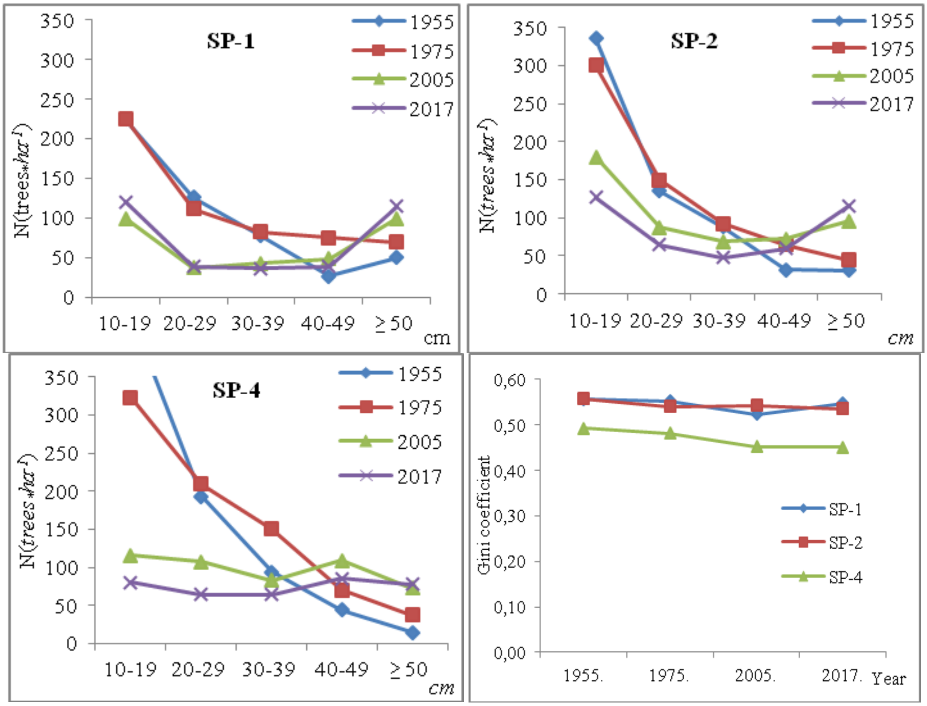

Figure 1. *Changes in the distribution of the number of trees by diameter classes and the Gini coefficient*

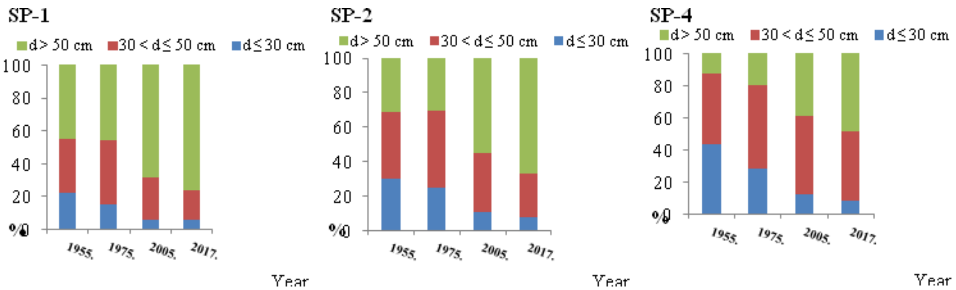

Figure 2. *Changes in the volume distribution by Biolay diameter classes*

In 62 years' time the volume per hectare increased by 66.1% in SP-1 and 94.9% in SP-2 and by 52.2% in SP-4. The current volume values are high and range from 659.1 $m^3 \cdot ha^{-1}$ in SP-4 to 866.1 $m^3 \cdot ha^{-1}$ in SP-2. The volume structure by Biolay diameter classes also varied in favor of the category of trees of large dimensions. In all SPs, the share of thin and medium-sized trees in the total volume declined from one period to another, and the share of trees with diameters of over 50 cm increased (Figure 2). It is worrying that the share of thin trees in all SPs was lower than 10%, and according to Biolay, it should not be less than 20%, i.e. according to more recent research by Schütz (2001), lower than 15%.

The current volume increment increases over time. At the end of the analyzed period, the increase was high and it amounted to 14.4 $m^3 \cdot ha^{-1}$ in SP-1, 15.9 $m^3 \cdot ha^{-1}$ in SP-2 and 12.9 $m^3 \cdot ha^{-1}$ in SP-4.The aforementioned amount of increase indicates a still high production of the stands, but the pronounced disturbances regarding the reduction of the share of thinner, and as a rule, more vital and trees with a more intensive increment, indicate that this trend of current volume increment will not last long (Obradović, 2015).

4. CONCLUSION

The starting hypotheses of this research have been confirmed. Structural disturbances of fir, spruce and beech forests in the analyzed SPs in Mt. Tara were found. They arose as a result of the decrease in the total number of trees, which also resulted in a decrease in dimensional diversity. The decrease of the share of thin trees is particularly pronounced, as well as the increase in the share of trees of large dimensions (d ≥ 50 cm). The distribution curves have developed a flatter form and are moving further away from the distribution that is typical of the selection forest.

Despite the reduction in the total number of trees, the accumulation of trees of large dimensions resulted in high values of basal area and volume per hectare. High absolute values of the current volume increment were also noted, which all together indicate a good production potential of a particular site. However, high volume does not always mean the desired state, especially if it is distributed among old trees (of large dimensions), of reduced technical value and if it slows down the development of the stand.

Insufficient regeneration and recruitment are the consequence of the stated distribution of trees by diameter classes, that is, reduced space for growth, with a negative impact on the preservation of these stands as stable and functional forms.

The trends observed in the fir, spruce and beech forests of Mt. Tara indicate that it is necessary to conduct permanent monitoring of all developmental processes, implement appropriate silvicultural and management measures that regulate them, and over time adjust and direct them towards the set goal, which is a structurally stable, socio-economically and ecologically valuable selection forest as a sustainable category. The leaving of stands to spontaneous development and self-regulation processes that happen over time, as is the case in the investigated SPs, moves us further away from this goal.

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SPONTANEOUS DEVELOPMENT OF MIXED STANDS OF FIR, SPRUCE AND BEECH FROM PERMANENT SAMPLE PLOTS ON MT. TARA

Snežana OBRADOVIĆ, Milan MEDAREVIĆ, Damjan PANTIĆ, Biljana ŠLJUKIĆ, Nenad PETROVIĆ, Dragan BOROTA, Aleksandar POPOVIĆ

Summary

The forest of fir, spruce and beech Piceo-*Abietetum* Col. 1965 (syn. Piceo-*Fago Abitetum* Chol. 1965; *Piceo-Abieti-Fagetum moesiacum* Mišić et al., 1978) is a specific three-dominant community, which can be found in Serbia on Mt. Tara, Mt. Zlatar, Mt.

Golija, the Mojstirsko-Draške mountains, Mt. Kopaonik, Mt. Stara planina, and Pešter Plateau, etc. These forests are characterized by structural diversity, i.e. a series of transitions from diverse to complex selection structural forms. The structural changes, productivity and dynamics of development of the selection forests of fir, spruce and beech on Mt. Tara have been monitored since 1955 in a series of permanent sample plots (SPs). These SPs were exempt from regular management and left to spontaneous development and self-regulatory processes. The surveys used data from periodic measurements (1955, 1975, 2005 and 2017) of permanent SPs in the Mt. Tara forests, which are in the database of the Chair of Forest Management Planning of the Faculty of Forestry in Belgrade. The results of the research indicate that during the analyzed period mixed forests of fir, spruce and beech have undergone a number of changes in structural and production terms. The significant presence of trees of large dimensions (volume accumulation) slowed down the developmental dynamics of these stands and made regeneration and recruitment difficult, which had a negative impact on their structural development and, in general, on the stability of these stands. The results show that selection forests are possible to achieve only with a permanent management approach and adherence to the modern principles of close-to-nature forest management. In this sense, selection cutting in the context of close-to-nature forest management is imposed as a means of accelerating the dynamics of development of these forests, repairing their structural development (by achieving and preserving their selection structure), ecological stability and functional values. On the contrary, the absence of activity and spontaneous development of these stands leads to a general devitalization and a deviation from the desired goals.

SPONTANI RAZVOJ MEŠOVITIH SASTOJINA JELE, SMRČE I BUKVE SA STALNIH OGLEDNIH POVRŠINAMA NA TARI

Snežana OBRADOVIĆ, Milan MEDAREVIĆ, Damjan PANTIĆ, Biljana ŠLJUKIĆ, Nenad PETROVIĆ, Dragan BOROTA, Aleksandar POPOVIĆ

Rezime

Šuma jele, smrče i bukve *Piceo-Abietetum* Čol. 1965. (syn. *Piceo-Fago Abitetum* Čol. 1965.; *Piceo-Abieti-Fagetum moesiacum* Mišić *et al.*, 1978.) je specifična trodominantna zajednica, koja je u Srbiji zastupljena na Tari, Zlataru, Goliji, Mojstirsko-Draškim planinama, Kopaoniku, Staroj planini, Pešterskoj visoravni itd. Ove šume se karakterišu strukturnom raznolikosti, tj. nizom prelaza od raznodobnih ka prebirnim strukturnim oblicima. Strukturne promene, proizvodnost i dinamika razvoja prebirnih šuma jele, smrče i bukve na Tari prate se od 1955. godine, na seriji stalnih oglednih površina (OP). Ove OP su izuzete iz redovnog gazdovanja i prepuštene su spontanom razvoju i samoregulacijskim procesima. U istraživanjima su korišćeni podaci periodičnih premera (1955, 1975, 2005. i 2017. godine) stalnih OP u šumama Tare, koji se nalaze u bazi podataka Katedre Planiranja gazdovanja šumama, Šumarskog fakulteta u Beogradu. Rezultati istraživanja ukazuju na to da su u analiziranom periodu mešovite šume jele, smrče i bukve pretrpele niz promena u strukturnom i proizvodnom smislu. Značajno prisustvo stabala jakih dimenzija (nagomilavanje zapremine) usporilo je dinamiku razvoja ovih sastojina i otežalo podmlađivanje i urastanje, što se negativno odrazilo na njihovu strukturnu izgrađenost i, generalno, na stabilnost ovih sastojina. Rezultati pokazuju da je prebirna šuma moguća jedino uz permanentan gazdinski pristup i poštovanje savremenih principa prirodi bliskog gazdovanja. U tom smisli, prebirna seča, u kontekstu prirodi bliskog gazdovanja, nameće se kao sredstvo ubrzanja dinamike razvoja ovih šuma, popravke njihove srukturne izgrađenosti (postizanja i očuvanja prebirne strukture),

ekološke stabilnosti i funkcionalne vrednosti. Suprotno, odsustvo aktivnog delovanja i spontani razvoj sastojina vode ka sveopštoj devitalizaciji i udaljavanju od željenih ciljeva.