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FOREST TYPE OF BEECH FIR SPRUCE AND SERBIAN SPRUCE FORESTS ON MOUNTAIN RADAVA IN THE REPUBLIC OF SRPSKA (BOSNIA AND HERZEGOVINA)

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ABSTRACT

Serbian spruce (*Picea omorika* (Pančić) Purk.) is tertiary relict and endemic species with restricted and fragmented natural range in Serbia and Bosnia and Herzegovina, mainly around the mid-course of the Drina river. Serbian spruce has been on The International Union for Conservation of Nature's Red List (IUCN) of Threatened Species since 1998. In the beginning it was marked as a vulnerable species and since 2010 as an endangered species. Serbian spruce is a tree species which has a wide ecological aspect in relation to the basic ecological factors, and the forest associations that were the subject of this research are among the most valuable forest associations in the region. The research described in this paper conducted with an aim to define the type of forests that contain Serbian spruce as an edifier in the area of mountain Radava in the Republic of Srpska (Bosnia and Herzegovina) in order to genetically preserve this rare and endangered tree species from the Balkans. Based on the research of ecological factors of habitats and the definition of production stand characteristics, the production type of forest was singled out - Forest type of European beech, silver fir, Norway spruce and Serbian spruce (*Piceo omorikae-Abietetum* [5]) on a series of soils on limestone.

KEYWORDS:
Serbian spruce, Radava, ecological characteristics, structure and productivity

INTRODUCTION

Serbian spruce (*Picea omorika* (Pančić) Purk.) is a tertiary relict and an endemic of the Balkan Peninsula. It is predominantly outcrossing species [1-2], with reported high self-fertility rates [1, 3-4]. Occurs at altitudes ranging between 400 and 1700 m above sea level, mainly growing on limestone. It forms pure or mixed stands with numerous species, including: beech, fir, spruce, black pine, maple, birch, etc. A number of phytocenoses with Serbian spruce are described [5-6].

The current area of Serbian spruce represents only the remnants of the former much larger area [7-8]. Today, Serbian spruce is located at 20 larger and smaller sites in Serbia and at about 10 sites in Bosnia and Herzegovina (around Milići, Srebrenica, Višegrad, Rogatica, Foča and on the mountains of Tara and Zvijezda). An accurate distribution map of Serbian spruce is still lacking, and the most comprehensive one available to date is that provided within the most recent IUCN report [9]. The first studies of Wettstein [10] and Tregubov [11] gave a great contribution to the knowledge on this tree species. Among the most important articles about the sites and distribution of Serbian spruce are studies by Fukarek [12-16], Čolić [17-19], Matović [20] and Tošić [21].

The production potentials of forests in the Republic of Srpska (Bosnia and Herzegovina), as well as in the research area, have not been sufficiently exploited and researched in terms of the production potentials of these forests and habitat types. Given the state of these forests and the tendency towards the optimum state, which is the main task of forest management, and in order to use the full potential of these forests, the defining of forest types at the local level is of great importance.

The basic task of this research was to define the forest type in the mixed forests of beech, fir, spruce and Serbian spruce on the basis of habitat and stand indicators in the territory of Mt. Radava. Also, the aim of the research was to analyze structural, dynamic and changes in dimensional diversity and composition of tree species. Assessment of the causes, degree and quality of the resulting changes are the starting point for a framework definition of further management treatment of this community in the context of the nature close and adaptive management. The results of this research should create con-

ditions for a more realistic definition of the objectives in the process of forest management planning for these and similar forest ecosystems. The research is based on the fundamental definition of a forest type that represents a part of the forest with equal ecological-biological and developmental-production characteristics, which is defined by the type or subtype of the soil and the basic tree species as edifiers.

MATERIALS AND METHODS

Study area. The research area, namely the wider area of Mt. Radava, occupies the southern part of the Milići forest-economic district and is located at an altitude ranging between 900 and 1 250 m above sea level (a.s.l). It is located in the eastern part of the Republic of Srpska, Bosnia and Herzegovina INA (Figure 1).

The research area is characterized by a temperate-continental climate. With the increase in altitude, the climate obtains a perhumid character. The mean annual temperature and the mean annual sum of precipitation indicate mesophilic conditions for the development of high-yield forest vegetation.

Field work and data analysis. A total of 4 experimental plots of an average size of about 0.5 ha were established, in the compartment 173/2 (Table 1). According to Hadživuković [22], Establishing of experimental plots, took into account the choice of high-quality stands characterized by site uniformity and the homogeneity of stand conditions, a good inventory structure and size, and that all the experimental plots are at approximately the same developmental phase. The typological research consists of two phases: the ecological phase and the production phase.

In the ecological phase, the basic data were collected on the geological, orographic, edaphic, climatic, hydrographic and biotic characteristics of the research area. The study of forest communities was performed by taking phytocoenological relevés following the Braun-Blanquet method [23]. Syntaxonomic names were given according to Tomić and Rakonjac [24]. The data on the soil characteristics were obtained by opening soil profiles.

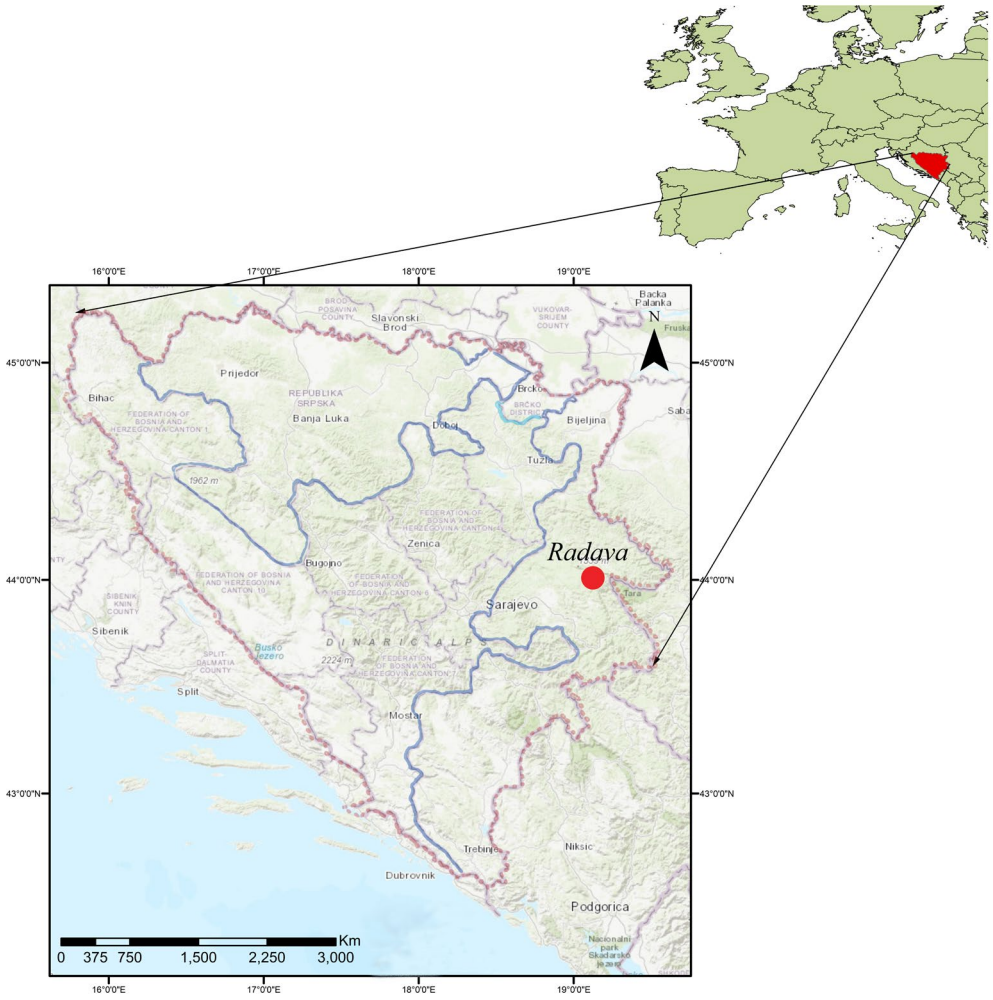

FIGURE 1
Geographical location of the research area

TABLE 1
Basic data on the experimental plot

Experimental plot	Management unit	Compartment (Section)	Area (ha)	Altitude (m)	Exposure	Inclination (º)	Geological base/ Soil
21	Gornji Jadar	173/2	0.48	1010	N	25	Limestone/ Cal-comelanosol
22	Gornji Jadar	173/2	0.46	1035	NE	25	Limestone/ Cal-comelanosol
23	Gornji Jadar	173/2	0.45	1055	NE	35	Limestone/ Cal-comelanosol
24	Gornji Jadar	173/2	0.51	1090	N	35	Limestone/ Cal-comelanosol

$$\bar{g} = \frac{G}{N} \Rightarrow d_g = 200 \cdot \sqrt{\frac{\bar{g}}{\pi}} \rightarrow h_g = f(d_g) \quad (3)$$

$$g_{\max} = \frac{G_{20\%}}{N_{20\%}} \Rightarrow d_{g\max} = 200 \cdot \sqrt{\frac{g_{\max}}{\pi}} \rightarrow h_{g\max} = f(d_{g\max}) \quad (4)$$

After the ecological phase of the study and upon defining the basic forest type, the second stage involved a study of production characteristics (production phase of the study) and defining of the production forest type.

Full callipering was performed in all experimental plots. The callipering threshold in high forests is 10 cm [25]. The trees were measured at breast height (cm), using two cross-sections of the stem diameter with an accuracy of 1 mm. For all trees, whose diameters were higher than the callipering threshold, heights (m) were measured using a "VERTEX 3" instrument with an accuracy of 0.1 m. Data processing and analysis involved the use of common dendrometric methods.

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Stand volume (m^3) as calculated by the method of volume tables according to the formula:

$V = n_1v_1 + n_2v_2 + ... + n_iv_i$

n_1, n_2....n_i – the number of trees in a diameter class

v_1, v_2....v_i – the volume of the mean tree in a diameter class

The "Tables of Taxation Elements of High and Coppice Forests in Bosnia and Herzegovina" [26-27] were used for the calculation of volume.

The volume increment Iv (m^3) and the percentage of volume increment p_{iv} (m^3) were calculated using equations 1 and 2.

$$Iv = V \cdot \frac{piv}{100} \quad (1)$$

$$piv = \frac{Iv}{V} \cdot 100(\%) \quad (2)$$

The values of average stand tree by the cross section (dg), the average diameter of 20% of the thickest trees (dgmax) and their respective heights (hg, hgmax) were calculated using equations 3 and 4 (above).

RESULTS

Ecological characteristics. The studies were conducted in 4 experimental plots no. 21, 22, 23 and 24. The edificators are European beech (*Fagus sylvatica* L.), silver fir (*Abies alba*), Norway spruce (*Picea abies* (L.) Karst.) and Serbian spruce (*Picea omorika* (Pančić) Purk.), with an individual occurrence of sycamore (*Acer pseudoplatanus* L.) (Figure 2). In the ground layer, in addition to the main edificators there are also *Rhamnus fallax* Boiss. and *Sambucus racemosa* L. The following species occur in the layer of ground vegetation: *Oxalis acetosella* L., *Carex digitata* L., *Cardamine bulbifera* (L.) Crantz, *Sambucus racemosa* L., *Dryopteris filix mas* (L.) Schott., *Mycelis muralis* (L.) Dum., *Athyrium filix femina* (L.) Roth, *Gentiniana asclepiadea* L., *Veratrum album* L., *Lamium galeobdolon* (L.) Crantz., *Poa pratensis* L., *Rubus hirtus* Wald. & Kif., *Veronica chamaedrys* L., *Daphne mezereum* L., *Urtica dioica* L., *Aegopodium podagraria* L. and *Prenanthes purpurea* L.

Limestone-dolomite chernozem (Calcomelanosol) is the primary development phase of the soil stage on limestone, and it mainly occurs in (two-member and three-member) soil combinations. These are shallow, dry, skeletal and humus-rich soils with a significant surface rockiness (Figure 3). The structure of the profile in the investigated stands is Olf-A-AC. The surface rockiness is high, over 30%. The layer of litter is medium-developed, up to 2 cm.

Below the organogenic horizon is a humus-accumulating horizon, with a thickness of 15 cm. It is brown to dark brown in color and has polyhedral structure. It contains well-humidified organic matter of colloidal character mixed with the mineral part in the form of an organo-mineral complex. Physical and chemical properties of the humus-accumulating horizon are favorable. The transient AC horizon is characterized by a high percentage of medium-sized limestone parts (up to 80%) and a power of 7 cm. It has a pea structure and clay texture. Due to a high content of humus, the saturation level with the bases is high. These are non-carbonate soils of mildly acidic to neutral reaction.

FIGURE 2
A detail from an experimental plot

The ecological and production potentials of these soils are generally not favorable, and they are conditioned by the relief, the degree of surface rockiness, climatic characteristics and soil combinations that these soils build. High water permeability, low solum depth, satisfactory aeration and a high percentage of rockiness cause pedoclimatic dryness of the organomineral chernozem on limestone.

Based on the results of phytocenological and pedological research, the vegetation-ecological type of polydominant forest of spruce, spruce, fir and other tree species (*Piceo omorikae-Abietetum* [5]) on limestone-dolomite chernozem (Calcomelanosol) was defined.

Production characteristics. The number of trees for this forest type is on average 350.5 pcs/ha, from 325 in experimental plot (EP) 21 to 376.47 pcs/ha in EP 24 (Table 2). Individually, it is dominated by Norway spruce with 169.4 pcs/ha or 48.3% of the total number of trees, which is evenly distributed in all experimental plots. After Norway spruce, according to the number of trees, Serbian spruce is the most common with an average of 22% or 77.1 pcs/ha. The number of silver fir trees and European beech trees is smaller, and they participate in the total number of trees with 16.1% and 13.6%, respectively. By observing the diameter structure of this forest type (Figure 4), we can notice the presence of a more pronounced maximum in the 22.5 cm diameter class, as well as of two smaller peaks in the 12.5 cm and 17.5 cm diameter classes, due to the distribution and domination of Norway spruce, indicating the age structure of the stand. The line of diameter class structure of the other tree species is negligible, with a relatively broad frequency and the largest share of thin and medium thick trees.

FIGURE 3
Calcomelanosol in experimental plot

The line of height structure as a whole for this forest type is primarily conditioned by the distribution of Norway spruce by height classes, and it is irregular with two pronounced maximums (Figure 5). The first maximum is in the 21 m class, and the second one which is more pronounced in the 27 m class, while the downward trend starts at a height of 39 m. The summary line of the structure is conditioned by the Norway spruce line in which also maximums are observed in the same height classes. For silver fir, the line of the structure is laid and moved to the left, due to a significant presence of smaller trees observed (a slight maximum appears in the degree of 18 m, after which it decreases). The structural line of European beech is bell-shaped, shifted to the right, which indicates a significant share of trees in higher degrees. For Serbian spruce, the distribution of trees is aligned with height along with a wide distribution. The presence of trees from all height classes can be observed, with a slightly higher participation of higher trees from the 27 m, 30 m and 33 m classes.

TABLE 2
The number of trees found during field research on experimental plots 21, 22, 23 and 24. Four dominant tree species were: European beech, silver fir, Norway spruce and Serbian spruce

Experimental plot	Number of trees (pcs/ha)				
	European beech	Silver fir	Norway spruce	Serbian spruce	Total
EP 21	37.5	60.4	152.1	75.0	325.0
EP 22	52.2	69.6	182.6	67.4	371.8
EP 23	42.2	44.4	164.4	77.8	328.8
EP 24	58.8	51.0	178.4	88.2	376.4
Average	47.7	56.4	169.4	77.1	350.5

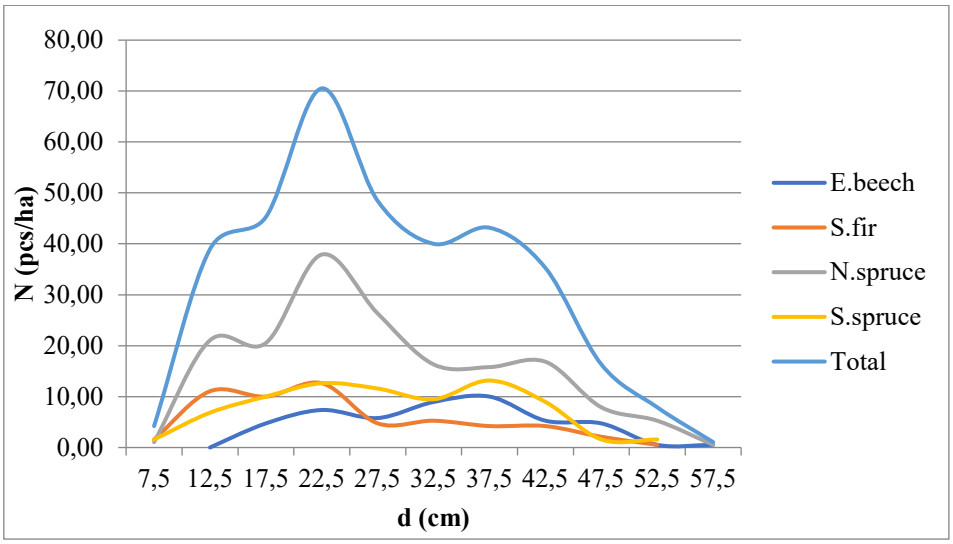

FIGURE 4
Diameter structure observed across four dominant tree species at experimental plot

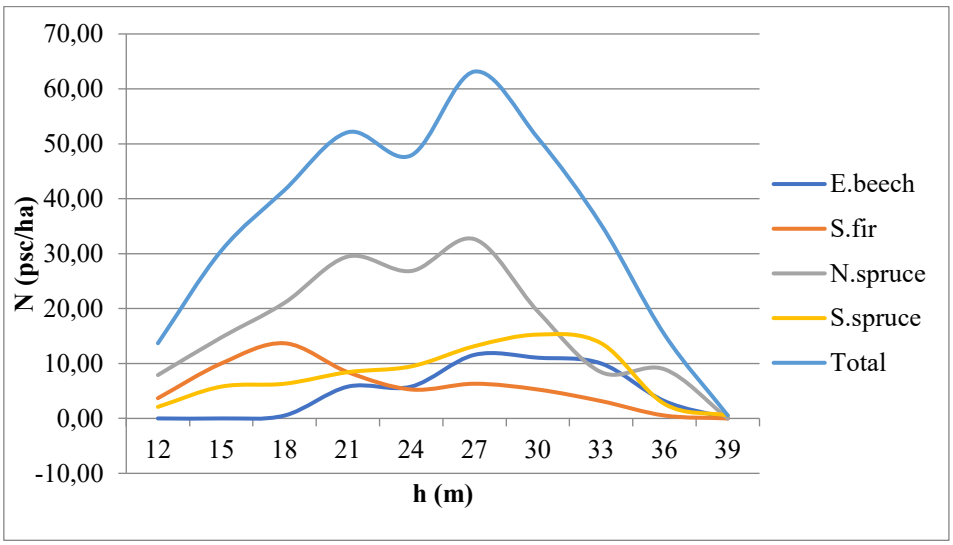

FIGURE 5
Height structure observed across four dominant tree species at experimental plot

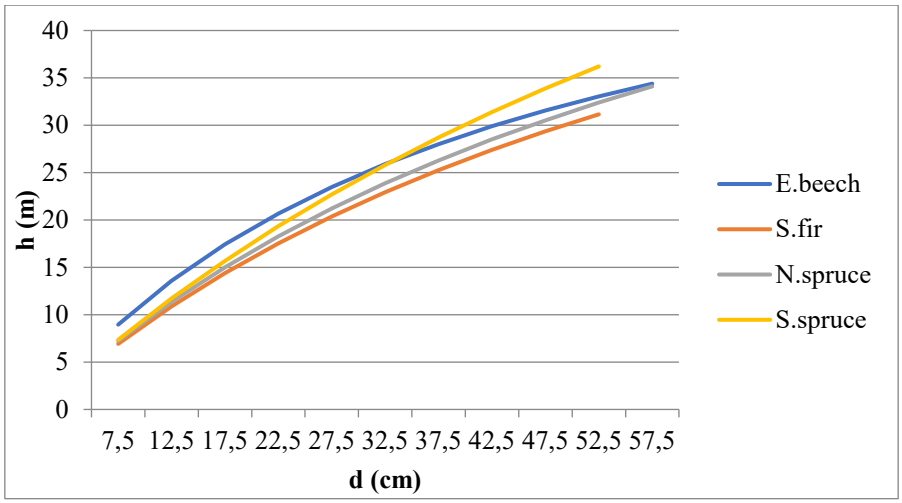

FIGURE 6
Height curves obtained across four dominant tree species at experimental plot

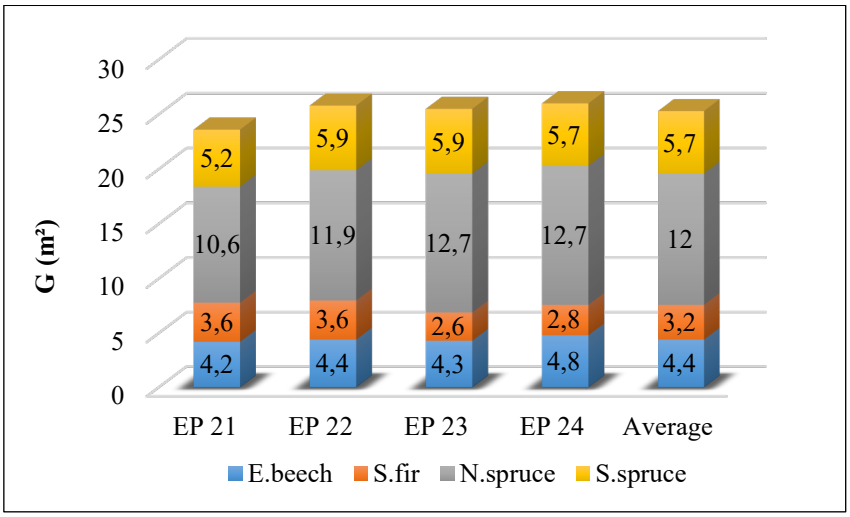

FIGURE 7
Basal area structure obtained for four dominant tree species at experimental plot

TABLE 3
The basic callipering data per tree species, including the number of trees (N), basal area (G), mean diameter (dg) and height (hg), maximum diameter (dg_{max}) and height (hg_{max}), volume (V), volume increment (Iv) and the percentage of volume increment (Piv)

Tree species	European beech	Silver fir	Norway spruce	Serbian spruce	Total
N (pcs/ha)	47,7	56,4	169,4	77,1	350,5
G (m^2/ha)	4,4	3,2	12	5,7	25,3
dg (cm)	34,7	26,8	30	30,7	/
hg (m)	26,9	19,9	22,6	24,7	/
dg_{max} (cm)	45,5	41,5	45,1	43,1	/
hg_{max} (m)	30,7	26,9	29,6	31,6	/
V (m^3/ha)	86,6	53,4	196,1	96,4	432,5
Iv (m^3/ha)	1,4	1,4	5,3	2,4	10,5
Piv (%)	1,6	2,6	2,7	2,5	2,4

The height curve of European beech is more laid than the height curves of the other three tree species. The height curves of Serbian spruce, silver fir and Norway spruce overlap in lower thicknesses. However, Serbian spruce has a higher degree of increase and dominates in height in the higher classes (Figure 6).

The basal area of this forest type is characterized by mostly equal values in all experimental plots (Figure 7). The average value is 25.3 m^2/ha, and the shares by tree species are the following: Norway spruce 12 m^2/ha or 47.4%, Serbian spruce 5.7 m^2 /

ha or 22.5%, European beech 4.4 m^2/ha or 17, 4% and silver fir 3.2 m^2/ha or 12.7% (Table 3). The highest value was recorded in EP 24, 26 m^2/ha, and the lowest one of 23.6 m^2/ha in EP 21, with the dominance of Norway spruce in all experimental plots.

The average value of volume for this forest type is 432.52 m^3/ha, i.e. it ranges from 412.25 m^3/ha in EP 21 to 440.29 m^3/ha in EP 23. Both on average and individually by experimental plots Norway spruce is dominant over the other species and its share is 45.3% or 196.04 m^3/ha. The share of Serbian spruce is 22.3% or 96.41 m^3/ha. The share of European beech is 20% or 86.65 m^3/ha and silver fir has the smallest share of 12.4% or 53.41 m^3/ha (Table 3). The mixture ratio by species is Norway spruce: Serbian spruce: European beech: silver fir = 45%: 22%: 20%: 13%. On the line of volume distribution by diameter classes a slight increase can be observed when moving to higher degrees, and the highest values are reached in the degrees of 37.5 cm and 42.5 cm, where the values of 171.14 m^3/ha or 39.6% can be found, after which it suddenly decreases to the degree of 57.5 cm. When total distribution is concerned, the maximum is asymmetric to the right as close as possible to the even-aged structure (Figure 8).

The values of current volume increment for this forest type are shown in figure 9. They range from 9.9 m^3/ha (EP 21) to 10.8 m^3/ha (EP 24), which is 10.5 m^3/ha on average. The largest share in this forest type belongs to Norway spruce, whose values range from 4.9 m^3/ha in EP 21 to 5.5 m^3/ha in EP 24 (average 5.3 m^3/ha or 50.5%). The second place in terms of share belongs to Serbian spruce, whose share is equal in all experimental plots (on average 2.4 m^3/ha or 22.9%). An equal value of current volume increment is reached by silver fir and European beech, which on average produce 13.3% or 1.4 m^3/ha. The productivity of Serbian spruce is very important for this forest type as an indicator of its stability and health condition, and in the aim of sustainability considering its importance as a relict species.

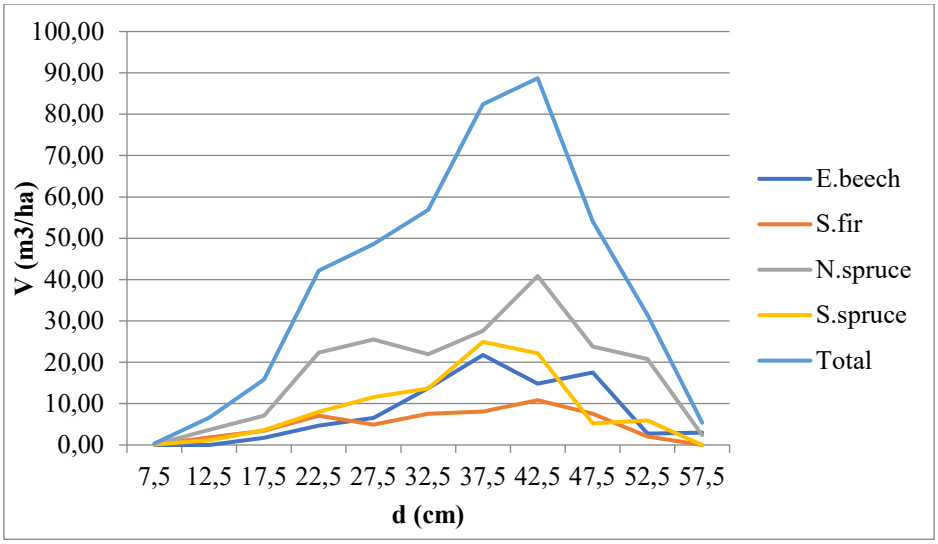

FIGURE 8
Volume structure obtained for four dominant tree species at experimental plot

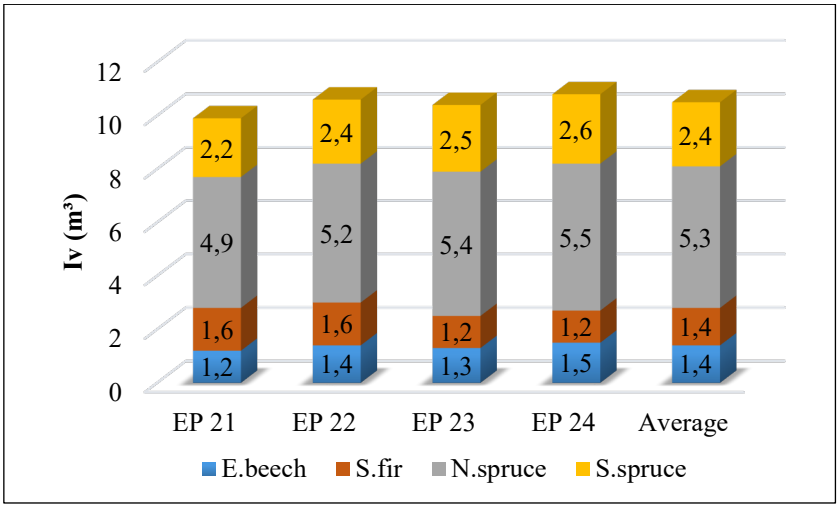

FIGURE 9
The structure of current volume increment across four dominant tree species at experimental plot

DISCUSSION

The number of trees for this forest type is on average 350.5 pcs/ha (325 to 376.47 pcs/ha). The dominant species is Norway spruce with 169.4 pcs/ha or 48.3% of the total number of trees. Serbian spruce is the most common after spruce in terms of the number of trees with an average of 22%. The shares of silver fir and European beech in the total number of trees are 16.1% and 13.6%, respectively. In a research on Mt. Tara (Serbia), in the *Omorikae Pineto-Piceeto-Abieto-Fagetum mixtum* community [28] found the number of trees which ranged from 1021.7 to 1663.0 pcs/ha, with the share of Serbian spruce ranging from 24.2% to 39.6%. In addition, in another research on Mt. Tara, [29] identified the number of trees ranging from 1732.1 pcs/ha to 2179.3 pcs/ha, while the share of Norway spruce in the total number of trees was 18-42.1%. The number of trees found in this research for this forest type is considerably lower than the number of trees found by other authors in their research. Reducing the number of trees in selective forests is an occurrence characteristic of most countries in Southeast Europe [30]. Reducing the number of trees under strict control and their spatial distribution are a basic element of the selective management method, which aims to create favorable spatial relationships between edificator [31].

The diameter structure of this forest type is conditioned by the distribution of Norway spruce and it is characterized by the presence of a more pronounced maximum in the 22.5 cm diameter class and two smaller peaks in the 12.5 cm and 17.5 cm diameter classes, which shows the age structure of the stand. The line of the height structure follows the line of the diameter structure, which is primarily conditioned by the distribution of the height classes of Norway spruce, and it is irregular, with two expressed maximums. The first maximum is in the 21 m class, and the second one is more pronounced in the 27 m height class.

The value of the mean diameter (dg) is the highest in beech and it amounts to 34.7 cm. It is followed by Serbian spruce with 30.7 cm, Norway spruce with 30.6 cm and silver fir with 26.8 cm. The value of dg_{max} is also the highest in European beech and it amounts to 45.5 cm, slightly lower in Norway spruce with 46.8 cm, followed by Serbian spruce with 43.1 cm and 41.5 cm for fir. The corresponding heights (hg) are accompanied by diameters (dg, dg_{max}), i.e. European beech reaches the highest value of hg = 26.9 m, followed by Serbian spruce (hg = 24.7 m), and the lower values were found for Norway spruce (hg = 22, 6 m) and silver fir (hg = 19.9 m). The highest value of hgmax was recorded for Serbian spruce - 31.6 m, followed by European beech, Norway spruce and silver fir.

The basal areas for this forest type are mostly equal in all experimental plots. The average amount is 25.3 m^2/ha, and the shares by tree species are as follows: Norway spruce 47.4%, Serbian spruce 22.5%, European beech 17.4% and silver fir 12.7%. Stojanović [28] recorded the values of the basal area on Mt.Tara which ranged from 17.95 m^2/ha to 39.21 m^2/ha, with the dominance of Serbian spruce relative to the other species. In a research on Mt.Tara by Ostojić [29] the values of basal area ranged from 31.12 to 53.69 m^2/ha. In comparison with the values obtained by other authors, the value of the basal area obtained in this research for the investigated production type of forest is within the limits or slightly below the average values.

The average value of volume for this forest type is 432.52 m^3/ha. Norway spruce is dominant over the other species and its share is 45.3%. Serbian spruce accounts for 22.3%, European beech for 20%, and the smallest share of 12.4% belongs to silver fir. The mixture ratio by tree species is the following: Norway spruce: Serbian spruce: European beech: silver fir = 45%:22%:20%:13%. In a research on Mt.Tara, Stojanović [28] found a volume in the range from 99.6 to 357.2 m^3/ha. In another research on Mt.Tara Ostojić [29] found the volume which ranged from 273.1 m^3/ha to 677.62 m^3/ha, with the dominance of Serbian spruce, Norway spruce and black pine compared to the other species. The values of volume found in this research are slightly higher or within the average values that other authors have found so far. On the line of distribution of volume by diameter, the highest values were reached in the 37.5 cm and 42.5 cm classes, after which they sharply declined.

The current volume increment for this forest type ranges from 9.9 m^3/ha to 10.8 m^3/ha, which is 10.5 m^3/ha on average. The largest share belongs to Norway spruce - an average of 5.3 m^3/ha or 50.5%. The second place in terms of share is taken by Serbian spruce, which is equally common in all experimental plots (on average 2.4 m^3/ha or 22.9%). The same share of current volume increment, which is on average 13.3%, is reached by fir and beech.

CONCLUSIONS

This research was conducted in the area of Mt. Radava, in the eastern part of the Republic of Srpska (Bosnia and Herzegovina). A total of 4 experimental plots with an average size of about 0.5 ha were established in mixed forests of European beech, silver fir, Norway spruce and Serbian spruce.

Phytocoenological relevés were taken in the experimental plots and the soil profile was opened and analyzed. The studied soil was limestone chernozem (calcomelanosol). Based on the analyzed characteristics and the determined differences in ecological and production sense, the following production type of forest was determined: Production forest type – Forest type of European beech, silver fir, Norway spruce and Serbian spruce (*Piceo omorikae-*

Abietetum [5]) on a series of soils on limestone.

In terms of production characteristics of the stand, the dominance of spruce is pronounced. On the other hand, the lag of the beech is evident, because the research area is located on the upper limit of its height distribution. The determined productivity of spruce is of great importance because it is an indicator of its stability and health condition. Having all this in mind, the defined production type of forest needs to be excluded from the regular way of management and a different aspect and special management measures should be applied in order to maintain the sustainability of this rare and endangered tree species.

Forest associations that were the subject of this research are among the most valuable forest associations in this region.

The exceptional value of these forests, on the one hand and the numerous problems they are burdened with, on the other hand, impose the need for comprehensive research into the dynamic processes and conditions in them.

Given the state of these forests and the production potentials of forest and habitat types, the definition of the production forest type at the local level is of great importance and should be the basis for further research in this area.

The results of such research offer assumptions for the success of further management and restoration of ecologically stable and functionally valuable forests.

REFERENCES

[1] Kuittinen, H. and Savolainen, O. (1992) Picea omorika is a self-fertile but outcrossing conifer. Heredity. 68, 183–187.

[2] Aleksić, M.J. and Geburek, T. (2014) Quaternary population dynamics of an endemic conifer, Picea omorika and their conservation implications. Conservation Genetics. 15, 87–107.

[3] Langner, W. (1959) Results of some hybridization attempts between *Picea sitchensis* (Bong.) Carr. and *Picea omorika* (Pancic) Purkyne (in German). Silvae Genetica. 8, 138-143.

[4] Schemske, D.W. and Lande, R. (1985): The evolution of self-fertilization and inbreeding depression in plants. Evolution. 39, 41–52.

[5] Čolić, D. (1965) Origin and succession of forest communities with Pančić spruce (*Picea omorika* Panč.) on the Tara Mountain (In Serbian). Nature Protection. 29-30, 65-90.

[6] Gajić, M., Kojić, M., Karadžić, D., Vasiljević, M. and Stanić, M. (1992) Vegetation of Tara National Park (In Serbian). University of Belgrade, Faculty of Forestry, Belgrade. 1-288.

[7] Wettstein, R. (1890) The occurrence of the *Picea omorika* (Panč) Wilk. in Bosnia (in German). 10, 1-357.

[8] Adamović, L. (1909) Phytogeographical formations Zagorje parts of Dalmatia, Bosnia and Herzegovina and Montenegro. The work of the Yugoslav Academy of Knowledge and Art. Book. 1-193.

[9] Aleksić, J.M., Ballian, D., Isajev, D., Mataruga, M., Christian, T. and Gardner, M. (2017) *Picea omorika*. The IUCN Red List of Threatened Species. e.T30313A84039544.

[10] Wettstein, R. (1891) The Omorika spruce, *Picea omorika* (Pančić) Willk. (in German). A monographic study. 99, 503-557.

[11] Tregubov, V. (1934) Forest study on *Picea omorika* Panc. (in French). National School of Water and Forests, Nancy. 5(2), 117-178.

[12] Fukarek, P. (1941) About the third area of Pančić spruce in Drobljanci (in Serbian). Journal of Forestry. 3, 25-3.

[13] Fukarek, P. (1950) Today's distribution of Pančić spruce (*Picea omorika* Panč.) And some data on its stands (in Serbian). Yearbook of the Biological Institute in Sarajevo. 1-2, 141-190.

[14] Fukarek, P. (1951) Habitats of Pančić spruce after the forest fires of 1946/47 years (in Serbian). Journal of Forestry. 75 (1/2), 61-75.

[15] Fukarek, P. (1955) Protection of endemic Pančić spruce in the PR of Bosnia and Herzegovina (in Serbian). Our antiques. 3, 289-298.

[16] Fukarek, P. (1957) Some older and newer discussions about Pančić spruce (in Serbian). Forestry. 10(3/4), 245-257.

[17] Čolić, D. (1953) Habitats of Pančić spruce on the right side of the Drina. (in Serbian). Protection of Nature. 4-5, 425-659.

[18] Čolić, D. (1957) Some pioneering characteristics of Pančić spruce and their role in the succession of plant communities (in Serbian). Archives of Biological Sciences. 9, 51-60.

[19] Čolić, D. (1986) Traces of more continuous spreading of Pančić spruce within its recent area (in Serbian). Protection of Nature. 33, 1-1966, special edition.

[20] Matović, M. (1983) Relict community of Pančić spruce (Eri-co-Piceeum omorikae mixtum) in Mileševka canyon (in Serbian). Forestry 2, 18-23.

[21] Tošić, M. (1983) About a new spruce site (Picea omorika Pančić) in Serbia (in Serbian). Proceedings on the occasion of the jubilee of P. Fukarek. 21, 267-274.

[22] Hadživuković, S. (1973) Statistical Methods (in Serbian). Workers' University-7. Radivoj Ćirpanov, Novi Sad.

[23] Braun-Blanquet, J. (1964) Plant sociology, basics of vegetation science (in German). 3rd edition. Springer, Wien. 1-631.

[24] Tomić, Z. and Rakonjac, L.J. (2013) Forest Phytocenoses of Serbia. Institute of Forestry and Faculty of Applied Ecology, Singidunum University, Belgrade. 1-147.
[25] Banković, S. and Pantić, D. (2006) Dendrometry (in Serbian). University of Belgrade, Faculty of Forestry, Belgrade. 1-556.
[26] Matić, V. (1959) Taxation elements of selective fir, spruce and beech forests in Bosnia (in Serbian). Papers of the Faculty of Forestry and the Institute of Forestry and Wood Industry. II-4, 1-162.
[27] Drinić, P., Matić, V., Pavlić, J., Prolić, N., Stojanović, O. and Vukmirović, V. (1980) Tables of taxonomic elements of high and coppice forests in FR Bosnia and Herzegovina (in Serbian). Faculty of Forestry, University of Sarajevo, Special Editions 13, Sarajevo. 1-224.
[28] Stojanović, L. (1973) Investigation of the influence of some habitat and stand factors on the dynamics of development of Pančić spruce trees in characteristic habitats in SR Serbia (in Serbian). Master's thesis, University of Belgrade, Faculty of Forestry, Belgrade.
[29] Ostojić, D. (2005) Ecological factors of natural 0maintenance and renewal of conopopulations of Pančić spruce in NP Tara (in Serbian). Doctoral dissertation. University of Belgrade, Faculty of Forestry, Belgrade.
[30] Diaci, J., Rozenbergar, D., Anic, I., Mikac, S., Saniga, M., Kucbel, S., Višnjic, C. and Ballian, D. (2011) Structural dynamics and synchronous silver fir decline in mixed old-growth mountain forests in Eastern and Southeastern Europe. Forestry. 84(5), 479–491.
[31] O´Hara, K.L. and Gersonde, R.F. (2004) Stocking control concepts in uneven-aged silviculture. Forestry. 77 (2), 131-143.

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