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THE STRUCTURE AND DYNAMICS OF MIXED-SPECIES STAND OF SCOTS PINE, NORWAY SPRUCE AND SILVER FIR ON MOUNTAIN KLEKOVAČA (BIH)

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Introduction

Forest stand dynamics is the study of changes in a forest stand structure over time, including stand behaviour during and after disturbances. Stand structure is the physical and temporal distribution of trees and other plants in a stand [1]. Understanding stand dynamics helps to focus management objectives by predicting future stand structures and development patterns, reducing silvicultural costs; increasing stand productivity, obtaining management information rapidly and inexpensively; obtaining desirable species compositions or physiognomies; developing diagnostic criteria for determining, prescribing, and making decisions for silvicultural operations; and enabling stands to be used as a general environmental "bioassay" for determining when stands are growing abnormally—perhaps as a result of pollution or other factors [2].

Materials and Methods

The research of the dynamics and structure was carried out in mixed stands of Scots pine (*Pinus sylvestris* L.), Norway spruce (*Picea abies* Karst.) and Silver fir (*Abies alba* Mill.) on mountain Klekovača. Significant complexes of that forest type are located in the western part of Bosnia and Herzegovina. The researched stand is exempted from regular management (seed stand). Mixed stand of Scots pine, Norway spruce and Silver fir, Abieti Piceetum illyricum (Fuk.) Stef. 1962 subass. *pinetosum sylvestris*, is the successive stage of pine forests with spruce *Piceo-Pinetum illyricum* Stef. 1959, towards the permanent stage *Abieti Piceetum illyricum* (Fuk.) Stef. In 1962.

For the study of the dynamics and structure of these mixed stands in the area of mountain Klekovača, the site Ravna Glavica at an altitude of 958 to 1011 m was selected (forest management unit "Klekovača-Drinić"), where 5 sample circular plots (n) were set (radius of 30 m). In addition to surveying the main elements of the trees growth, those had diameter at breast height (dbh) larger than 5 cm were cored with increment borer at height of 0.5 m from forest floor, to estimate tree age. Corim maxi (instrument) was used to determine the tree-ring width from core samples. To estimate the stem volume of each tree volume tables of Špiranec [3] and Bezak [4] were used.

Results and Discussion

For the researched forest stand site classes were determined by comparing the tree-species height curves with standard site classes curves [5] as follows: for the Silver fir class I / II, for Norway spruce class III and for Scots pine site class I. The estimated average number of trees (having dbh greater than 5 cm) per hectare is 798. The variation of the number of trees on

the sample plots, expressed by the coefficient of variation, is 14.8%. In the total number of trees the largest share has Silver fir with 46%, and the lowest Norway spruce with 19%. By observing species per sample plots, the largest variations are in the number of Silver fir trees (38.7%) and the lowest in the number of Norway spruce trees (15.7%). Estimated standing volume is 745.7 m^3 ha^{-1} with a variation of 9.2% in the sample plots. Contrary to the number of trees, the largest share in the standing volume has Scots pine with 69%. Volume increment is 11.54 m^3 ha^{-1} with a variation of 11.5% for all sample plots (Table 1).

Table 1. Basic stand structure elements (number of sample plots - n, number of trees – N, volume – V, current annual increment – Iv) and descriptive statistics (standard deviation - Std. dev., and coefficient of variation - CV)

Tree species	n	N			V			Iv		
		ha^{-1}	Std. dev. ha^{-1}	CV %	m^3 ha^{-1}	Std. dev. m^3 ha^{-1}	CV %	m^3 ha^{-1}	Std. dev. m^3 ha^{-1}	CV %
Silver fir	5	370	143	38.7	116.5	44.0	37.7	3.08	1.15	37.4
Norway spruce	5	154	25	15.7	108.1	49.4	45.7	2.63	1.01	38.4
Scots pine	5	271	68	25.1	518.0	112.7	21.7	5.83	1.21	20.8
Total	5	798	118	14.8	745.7	68.5	9.2	11.54	1.33	11.5

Diameter distribution of trees is shown in Figure 1. By using the appropriate statistical indicators, based on the measured trees diameter, the parameters that characterize the diameter distribution of the studied stand were obtained and presented in Table 2.

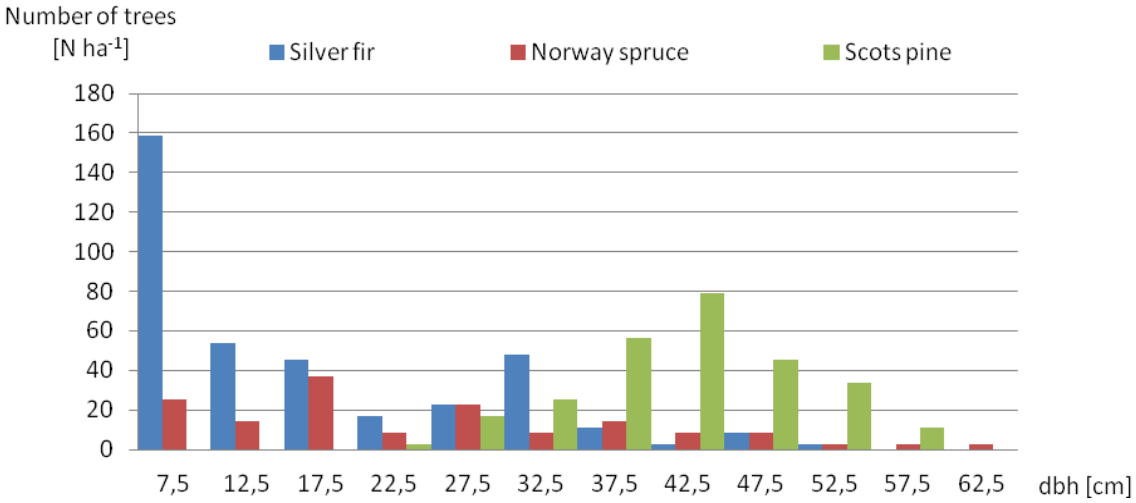

Figure 1. Diameter distribution of trees.

A significant difference is observed in the diameter distribution of those three species of trees. Arithmetic mean of the Silver fir trees dbh is 16.14 cm, for Norway spruce is 24.15 cm,

and 41.57 cm for Scots pine. The largest absolute variation, in terms of the trees dbh, is observed for Norway spruce (14.33 cm), and largest relative variation for Silver fir trees (71.19%). Both absolute and relative variability are the lowest in Scots pine sample. Diameter distribution of Scots pine is characterized by a small negative asymmetry (Skewness = - 0.15) comparing to the distributions of Silver fir and Norway spruce trees which are characterized by strong positive asymmetry (Skewness = 1.00; 0.74; respectively). Kurtosis (factor) shows that the distribution of all three species is flattened compared to normal distribution. Testing the difference between the actual diameter distribution and normal distribution using the Shapiro-Wilk test (if the *p*-value is less than the chosen alpha level, then the null hypothesis is rejected and there is evidence that the data tested are not from a normally distributed population) shows that the actual frequencies of Scots pine trees match with the theoretical frequencies (p = 0.8178). Distributions of Norway spruce and Silver fir trees deviate significantly (p = 0.0022, p= 0.0000, respectively) relative to the normal distribution.

Table 2. Diameter distribution of trees - descriptive statistics

Tree species	dbh (cm)	Variance (cm)	Std. dev. (cm)	CV (%)	Skewness	Kurtosis	Shapiro-Wilk	
							W	*p*
Silver fir	16.14	132.04	11.49	71.19	1.00	-0.05	0.84992	0.0000
Norway spruce	24.15	205.35	14.33	59.34	0.74	-0.35	0.92540	0.0022
Scots pine	41.57	58.18	7.63	18.35	-0.15	-0.15	0.99168	0.8178
Total	26.36	248.96	15.78	59.86	0.14	-1.32	0.90947	0.0000

Height distribution of trees is shown in Figure 2. Estimated average height of Silver fir trees is 11.81 m, for Norway spruce is 17.80 m, for Scots pine is 29.25 m. The Scots pine height distribution has strong negative asymmetry (Skewness = -0.7486), and the distribution of Silver fir has strong positive asymmetry (Skewness = 0.6209). The observed Norway spruce height distribution is not asymmetric, actually it is flattened compared to normal distribution (Kurtosis = -1.2073). Testing the difference between the actual tree species distributions and normal distribution by using the Shapiro-Wilk test showed significant differences.

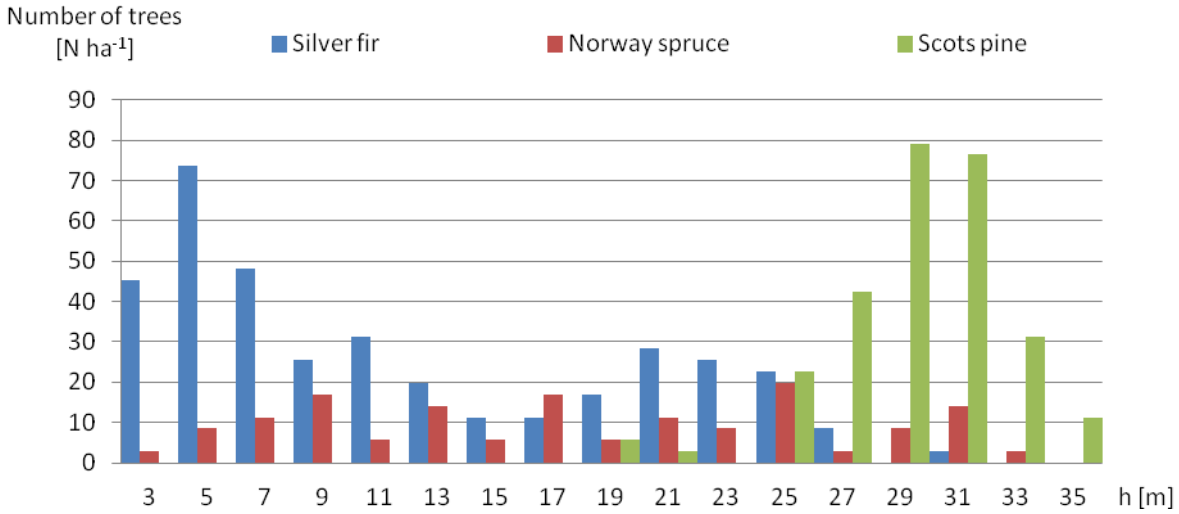

Figure 2. Height distribution of trees.

Homogeneity is defined with stand homogeneity index (H), according to De Camino [6], and it is graphically presented with the Lorenz's curve. According to Kramer [7], homogeneous stands have a higher stand homogeneity index. In even-aged stands with low thinnings, stand homogeneity indexes vary between 4 and 10, while in uneven-aged the indexes range from 1.3 and 2.8. The estimated stand homogeneity index ($H_{Silver\ fir}$ = 1.7, $H_{Norway\ spruce}$ = 2.1 and $H_{Scots\ pine}$ = 6.4) and the Lorenz's curve (where N% represent sum of stem percentages up to dbh class i, and V% is the sum of volume percentages up to dbh class i) indicate a significantly higher degree of homogeneity of the Scots pine component in the stand, in relation to Silver fir and Norway spruce (Figure 3). The stand homogeneity index of Scots pine component of stands tends to have the value typical for even-aged stands. On opposite, stand homogeneity index of Silver fir and Norway spruce components tend to the typical value for uneven-aged stands.

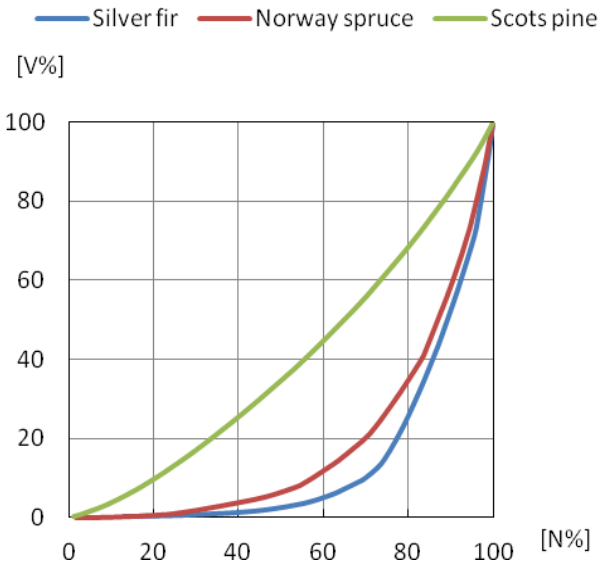

Figure 3. Lorenz's curve.

Figure 4 shows the distribution (relative frequency) of measured trees of tree species by age classes. The estimated average age of Silver fir trees is 65 years, for Norway spruce and Scots pine is 84 and 121 years respectively. The youngest Silver fir tree was 19 years old, while Norway spruce and Scots pine trees were 34 and 83 years old respectively. Accordingly, the youngest Scots pine tree reached breast height in 1930, Norway spruce in 1979 and Silver fir tree in 1994. Furthermore, in actual stand 24% of currently alive Silver fir trees, 15% of Norway spruce trees and 84% of Scots pine trees reached breast height until 1910.

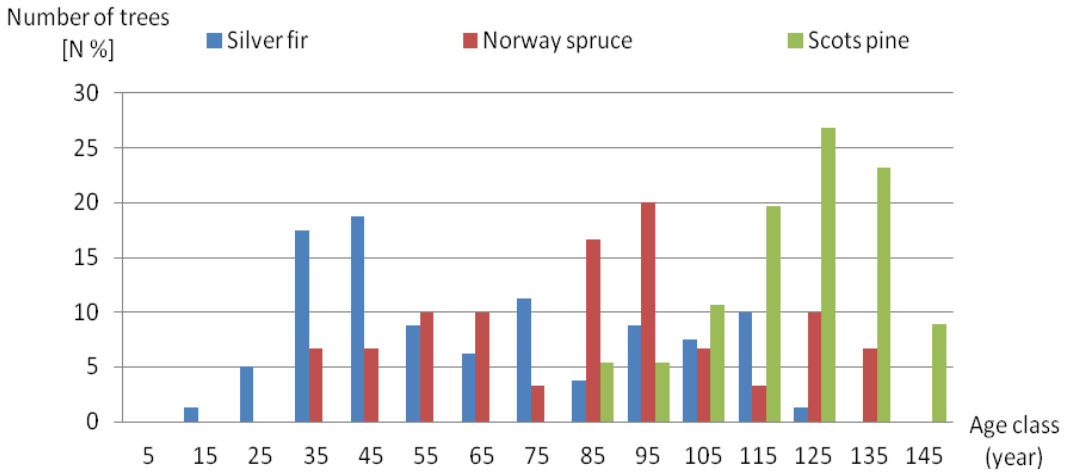

Figure 4. Age structure of living trees.

The dominant Scots pine trees had the largest diameter increment (I_d) until about 1945 and after then the smallest diameter increment comparing to other tree species. From 1945 until the last decade of twentieth Century, Norway spruce trees had the largest diameter increment, while in the first decades of 21st century, Silver fir and Norway spruce trees had similar diameter increment (Figure 5).

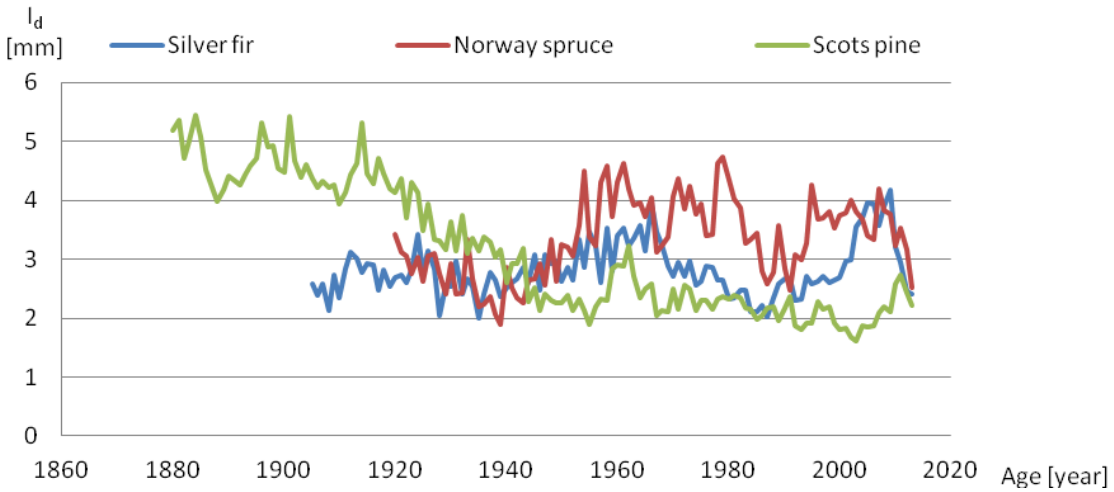

Figure 5. Average diameter increment (dominant trees, age > 100 years)

Conclusion

Performed analysis, primarily of diameter, height and age structure in the studied uneven-aged stand dominated by Silver fir, Norway spruce and Scots pine, indicated a very complex structure and dynamic change, especially in terms of the ratio of the tree species. The analysis of the age structure showed the dynamics of succession in the researched stand towards to a permanent state of *Abieti Piceetum illyricum* (Fuk.) Stef. 1962 and towards to the mixed Silver fir and Norway spruce forest. The youngest Silver fir tree was 19, Norway spruce is 34 and Scots pine is 83 years old, which means that the youngest tree of Scots pine reached breast height in 1930, Norway spruce in 1979 and silver fir in 1994. In the last two observed decades, no trees reached 5 cm at breast height, which is consequence of very high stand density currently. The estimated number of trees per hectare is 798 and standing volume is 745.7 m^3 ha^{-1}.

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