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VARIATION IN GROWTH AMONG NINE BOSNIAN HERZEGOVINIAN PROVENANCES OF SILVER FIR (*Abies alba* Mill)

Varijabilnost u rastu devet bosanskohercegovačkih provenijencija jele (*Abies alba* Mill.)

Ćemal Višnjić[1], Besim Balić[1], Velid Halilović[1], Fuad Šehić[2]

Abstract

Provenance experiments with forest trees provide valuable information about the growth and adaptability of population, often transferred from remote geographical regions and various climate conditions. This study researches the growth of nine provenances of silver fir from the area of its natural distribution in Bosnia and Herzegovina. The experiment was established in the year 1991 in the form of a random block system with 5 repetitions. For planting, we used five-year-old seedlings (2/3), and planting spacing was 2x2 m. Each Silver fir provenance was included with 320 plants. Measurement results in the 28th year of age show the existence of variations between silver fir provenances in characteristics; mean height, mean diameter and average tree volume. Silver fir provenance from Bosanski Petrovac showed the best results. The mean height of this Silver fir provenance at the age of 28 was 9.1 m, while the mean diameter was 11.9 cm. Provenances that show the lowest growth (8.1 m) were from Pale, Olovo-Klis and Konjic. Silver fir provenance from Konjic has the lowest mean diameter (10.7 cm). In all provenances, we have had a culmination of height increment in age between 20 and 25 years. Variation between tested silver fir provenances for examined characteristic "mean height" was larger (four groups of population) compared to examined characteristic "mean diameter" (two groups of population). Volume of mean tree (0.062m^3) and assortment (111.33 m^3/ha) in Bosanski Petrovac provenance was larger than spreadsheet values for the first yield class for Central Europe conditions. The trial shows that silver fir in Bosnia and Herzegovina is variable on the local level due to specific micro-habitual conditions in which it grows.

Key words: *provenances, fir, silviculture, morphological characteristics*

INTRODUCTION - *Uvod*

Silver fir (*Abies alba* Mill.) is one of the ecologically most important and economically most productive tree species. Due to its shade tolerance, adaptability to exposure and ability to coexist with other species, it is fundamental species for

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preservation of forest ecosystem biodiversity (KERR, 2015, DOBROWOLSKA et al. 2017). According to STEFANOVIĆ, (1977) in Bosnia and Herzegovina, silver fir is in the whole spectre of forest communities. It can be found in all climate-edaphic zones, and ait builds our economically most significant mixed forests with beech and spruce. According to available data, silver fir spreads over clean or mixed assortments with beech and spruce on the area of 722,000 hectares which makes 40% of the total area of high economic forests. Fir growing stock in B&H is estimated to 66,000,000 m^3 or 15% of the total growing stock of high economic forests. Areal of silver fir in Bosnia and Herzegovina is in the area of Dinarides with a more humid climate.

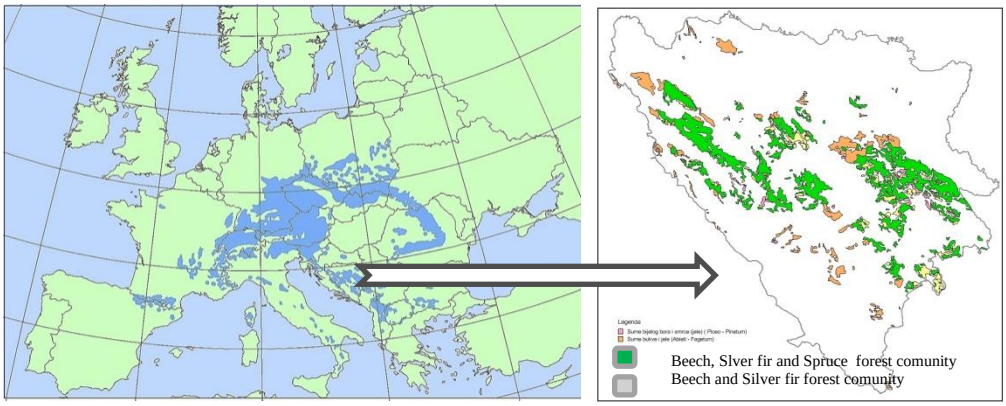


Figure 1. Areal of silver fir in Europe (Euforgen, Wolf, 2003), and Bosnia and Herzegovina (Stefanović and others, 1983)
Slika 1. Areal jele u Evropi (Euforgen, Wolf, 2003), i Bosni i Hercegovini (Stefanović i dr., 1983)

It appears on altitudes of 400-1500 (1600) m, grows in its natural enclaves on the border towards the Pannonian pool (Kozara). Local factors like orography, exposition and soil, can contribute to significant modifications of climate and therefore impact on expansion, narrowing, exclusion or interruption of vertical or horizontal distribution of fir (PINTARIĆ, 2002).

In the past 200 years, a natural area of silver fir reduced significantly (WOLF, 2003). Reduction of silver fir areal is mostly a consequence of stress caused by natural factors and inadequate management systems (BARBU, 1991, BADEA et al. 2004, ELLING et al. 1999, FILIPIAK and NAPIERALA-FILIPIAK 2009, UŠČUPLIĆ, 1992, UŠČUPLIĆ et al. 2007, WENTZEL, 1980, WOLF, 2003). Results of up-to-date research shows that basic reason for degradation of silver fir is air and soil pollution by industrial contamination, that has damaging effect on the silver fir, but also on other tree species (ELLING, 1993, MEKIĆ, 1988, LARSEN and FRIDRICH, 1988, MEKIĆ and LARSEN 1991, DUCCI, 1991, HALILOVIĆ et al. 2009a, 2009b, 2013, BALLIAN and HALILOVIĆ, 2016).

In the middle of the past century, intensive works started on the improvement of ecological conditions in habitats of silver fir, i.e. optimization of mixing of tree species, natural revitalization and preservation of closed-canopy density of mixed assortments that are favorable to the silver fir (UŠČUPLIĆ, 1992). As stated by MEKIĆ, (1992) on of long-term objectives is finding and selection of tolerant provenances and individual firs that could endure pollution. Besides that, it is necessary to work on hybridization within species with resilient provenances that showed tolerance to pollutants such as sulfur dioxide and fluorine (LARSEN, 1986, LARSEN and FRIDRICH 1988, MEKIĆ, 1988, MEKIĆ and LARSEN 1991), and hybridizations with other fir species from North America and Asia (KOBLIHA et al. 2013a and b, 2014, KORMUTAK et al. 2013).

The first trial with silver fir provenances was set-up in Switzerland at the beginning of the last century (ENGLER, 1905) and was focused on the research of individual growth of trees. BECKER, (1971) in his research with different fir provenances pointed out that the growth of fir is genetically conditioned and is different as per geographic regions. Examination of geographic variability of silver fir considering the dynamics of increment was conducted by LARSEN, (1986). The best growth was present in Calabrian provenance, while provenances from Western and Central Europe were worse, with much smaller variability within the population. Provenances from South-East Europe have had significant differences in increment one to another, and also comparing to Carpathian provenances. MEKIĆ, (1988) determined the existence of large variability of Calabrian provenances in terms of morphological and physiological indicators. Similar results reached DUCCI, 1991 showed significant variability of silver fir, within-population and between populations, from Central and Southern Italy. In trials in England, with 33 provenances of silver fir from whole Europe, the best growth was of the provenance from Calabria, worst growth was from French provenances, including Normandy, which has a climate similar to the one of England (KAJBA, 2001, KERR, 2015).

This study researches variability in growth among nine Bosnian-Herzegovinian provenances of silver fir. Measurements were conducted on 28-year old fir trees planted on plots on location Delimusa near Olovo (Central Bosnia).

MATERIAL AND METHODS – *Materijal i metode*

Experiment with nine Bosnian-Herzegovinian provenances of silver for was established on location "Delimusa" near Olovo in Central B&H. The experimental plot is located in the area of beech and fir forests with spruce an altitude of 970 m, exposed towards the north with the slope of terrain between 10 and 20%. Soil belongs to the type of deep brown soils (distric cambisol) on volcanic and sediment rocks.

Seeds for the trial have the origin from nine locations in Bosnia and Herzegovina (Bugojno, Bosanski Petrovac, Olovo-Palež, Pale, Konjic, Fojnica, Sokolac, Olovo-Klis and Prozor), from the position of altitude between 850 m and 1.300 m. The most western

provenance comes from Bosanski Petrovac, while the most southern comes from the Herzegovina area –Konjic. Geographic distribution of the source populations and their ecological – vegetation origin are provided in Figure 2.

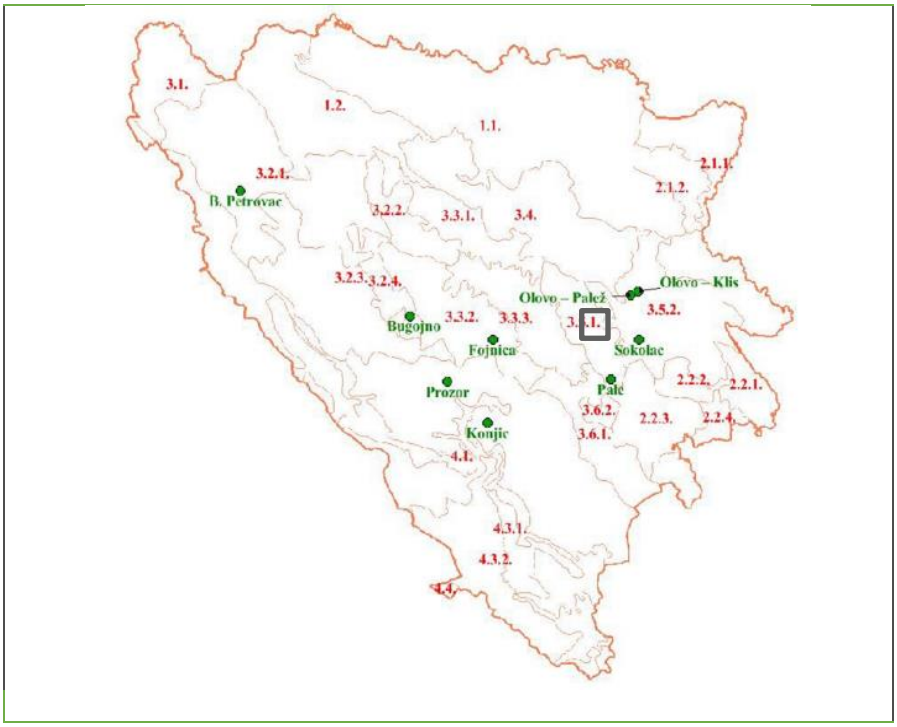


Figure 2. Origin of the seeds used for the provenance test as per ecological-vegetation areas
Karta 2. Porijeklo sjemena koje je korišteno za test provenijencija po ekološko-vegetacijskim područjima

☐ Delimusa –Location with experimental plot/area
Delimusa - Lokalitet sa eksperimentalnom površinom

Overview and main orographic – edaphic characteristics of original assortments of fir from which we gathered seeds for the provenance test are provided in Table 1.

Table 1. Main ecological – habitat characteristics of assortments from which the seeds were collected for fir provenance test on location "Delimusa" near Olovo
Tabela 1. Osnovne ekološko–stanišne karakteristike sastojina sa kojih je prikupljano sjeme za test provenijencija jele na lokalitetu "Delimusa" kod Olova

No	Provenance	Soil type	Geological- petrographic	Altitude (m)	Ex.	Slope of terrain (%)
1.	Sokolac	calcocambisol, calcomelanosol	Limestone	940	S – W	13
2.	Prozor	calcomelanosol, luvisol	Limestone moraine	1,300	N - E	5 – 10
3.	B. Petrovac	rendzina, calcocambisolpseudogle	Dolomite	900	N	2
4.	Fojnica	districcambisol	Rhyolite	1,010	-	-
5.	Olovo – Palež	calcocambisol, luvisol	Limestone	960	N – E	12
6.	Olovo – Klis	calcocambisol, luvisol	Limestone	850	N – W	13
7.	Bugojno	rendzina, calcocambisol	Dolomite and limestone	1,090	N – W	10 – 25
8.	Konjic	calcocambisol, calcomelanosol	Firm limestone	1,030	E – EN	10 – 22
9.	Pale	districcambisol, calcomelanosol	Verfene schist, sandstone, limestone	1,200	N – E	20

The experiment was established in a form of random block system with five repetitions (five belts). Each of five belts is separated into ten small plots of square shape in dimensions of 14 x 14 meters. Within plots, we planted 5-year old silver fir seedlings (2/3), with planting spacing of 2x2 meters. On each of the plots we planted 64 seedlings, so the number of seedlings planted per one provenance was 320 (64 x 5 blocks). On the whole experimental plot/area we planted 2,880 seedlings (9 provenances x 320 seedlings).

Table 2. Design of the experiment with nine provenances of fir – random block system
Tabela 2. Dizajn eksperimenta sa devet provenijencija jele -slučajni blok sistem

Bugojno	Ol. Klis	Ol. Palež	Fojnica	Prozor	B. Petrovac	Sokolac	Pale	Konjic	Control
B. Petrovac	Sokolac	Pale	Konjic	Control	Bugojno	Ol. Klis	Ol. Palež	Fojnica	Prozor
Control	Bugojno	Ol. Klis	Ol. Palež	Fojnica	Prozor	Konjic	Sokolac	Pale	B. Petrovac
Fojnica	Prozor	B. Petrovac	Sokolac	Konjic	Pale	Control	Bugojno	Ol. Klis	Ol. Palež
Pale	Konjic	Control	Bugojno	Ol. Klis	Ol.Palež	Fojnica	B. Petrovac	Prozor	Sokolac

Measurements on experimental plot/area were done on the 28-year old age of trees. On all live trees we determined breast height diameter (1.30 m), with millimetercaliper in a cross manner, with accuracy up to 1 mm, and height of all trees in meters (±10cm).

From each provenance we further extracted 5 trees each, representatives of provenance per mean diameter and mean height (5 x 9 = 45 trees). On trees-representatives we performed dendrometric analysis of trees in software application "DAS-v1" (BALIĆ and MEŠKOVIĆ, 2012).

For each tree on the experimental plot, we calculated the volume. Volume was calculated as per the regression model (NAGEL, 1988), as follows:

$V0=\exp (a*\ln(d)+b*\ln(h-1.3)+c)$

where:

d – breast height diameter on the distance of 1.30 m from the ground

h –tree height

a, b, c – parameters of the function; a=1.86089, b=0.85685, c= - 9.31895

RESULTS - *Rezultati*

Mean tree diameter

Research results for characteristic "mean diameter" are shown in Table 3. From the table, it is visible that the highest mean diameter is in the provenance Bosanski Petrovac. In this provenance in 28-years of age, we recorded a mean breast height diameter of 11.9 cm. Somewhat smaller diameters we recorded in provenances Fojnica (11.2 cm), Sokolac and Olovo-Klis (11.1 cm). The smallest mean diameters were recorded in provenances Konjic (10.7 cm), Olovo-Palež, Bugojno and Pale (10.8 cm).

Table 3: Mean diameters for fir provenances in 28-years of age on experimental area Delimusa
Tabela 3: Srednji prečnik provenijencija jele u 28. godini starosti na oglednoj površini Delimusa

No.	Provenance	N	Mean diameter (cm)	Std	CV%	Duncan group	
						1	2
1.	Bos. Petrovac	218	11.9	±3,4	28.28	*	
2.	Fojnica	271	11.2	±3,3	29.49		*
3.	Sokolac	243	11.1	±3,2	28.43		*
4.	Olovo-Klis	202	11.1	±2,7	24.50		*
5.	Prozor	246	10.9	±3,2	29.70		*
6.	Pale	228	10.8	±3,2	29.48		*
7.	Bugojno	194	10.8	±3,1	28.66		*
8.	Olovo-Palež	256	10.8	±3,2	29.73		*
9.	Konjic	240	10.7	±2,8	26.29		*
F= 3.087				Sig. 0.005			

Analysis of variance determines that there is a statistically significant difference in the examined characteristic "mean breast height diameter" between tested provenances on the level of significance of 95%. Duncan test determines the grouping of silver fir provenances, in terms of mean diameter of trees of tested provenances, into two Duncan groups. The first group, with the largest breast height diameter, includes provenance Bosanski Petrovac, while the second group, with smaller diameter, includes all other fir provenances. Based on the results of the conducted test it is visible that there is no grouping of provenances in terms of mean diameter per ecological production zones, areas and regions in B&H conducted by STEFANOVIĆ et al., (1983). However, provenance Bosanski Petrovac which is geographically most distant related to the location where experiment with fir provenances was set, shows the best results in terms of mean diameter, while one of the local provenances Olovo-Palež has the lowest values of mean diameter.The coefficient of variability (CV%) of the mean diameter in all provenances is in a range up to 30%.

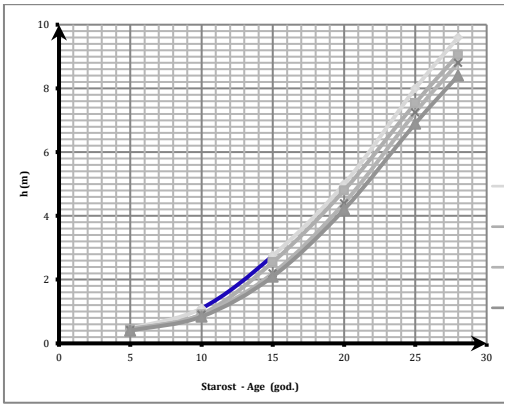
Mean tree height

Measurement results for tree heights of 9 provenances of silver fir are presented in Table 4. From the table, it is visible that the highest mean height is in the provenance Bosanski Petrovac (9.1m). Somewhat smaller values of mean height are shown by provenances Sokolac (8.7 m) and Fojnica (8.6 m). Then follows provenances Prozor (8.3 m) and provenances Olovo-Palež and Bugojno with 8.2 m. Provenances with the lowest mean height are Olovo-Klis, Konjic and Pale (8.1 m). Analysis of variance shown that there are statistically significant differences in the level of statistical significance of 95% for examined characteristic mean height. Results of the Duncan test show grouping of fir provenances in terms of mean height into 4 Duncan groups. The first group, characterized by highest mean height of fir trees, includes provenance Bosanski Petrovac, and the second group, with some lower mean height, includes provenances Sokolac and Fojnica, the third group includes provenances Prozor, Olovo-Palež and Bugojno and the fourth Duncan group with the lowest value of mean height, includes provenances Olovo-Klis, Konjic and Pale.

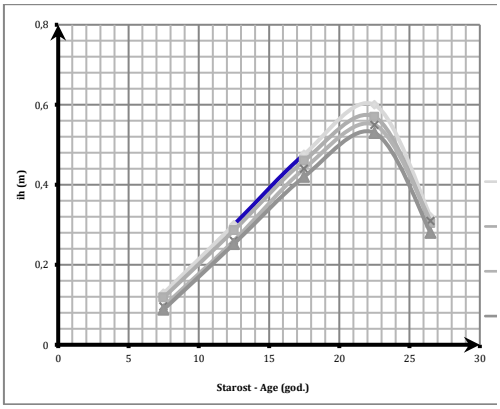
Table 4. Mean height of 9 provenances of fir in 28-years of age on experiment area Delimusa
Tabela 4. Srednja visina 9 provenijencija jele u 28. godini starosti na eksperimentu Delimusa

No.	Provenance	N	Mean height (cm)	Std	CV%	Duncan group			
						1	2	3	4
1.	Bos. Petrovac	218	9.1	±2.6	28.89	*			
2.	Sokolac	243	8.7	±2.2	25.00		*		
3.	Fojnica	271	8.6	±1.9	22.09		*		
4.	Prozor	246	8.3	±1.9	22.32		*	*	
5.	Olovo-Palež	256	8.2	±2.0	24.57		*	*	*
6.	Bugojno	194	8.2	±2.0	24.06			*	*
7.	Olovo-Klis	202	8.1	±1.3	16.50			*	*
8.	Konjic	240	8.1	±1.6	20.25				*
9.	Pale	228	8.1	±1.9	23.09				*
F= 6.125					Sig. 0.005				

Having in mind gained grouping of fir provenances in terms of mean tree height, we cannot notice the link of this characteristic with the origin of provenances to individual areas defined by ecological – production regionalization. However, we notice certain grouping of provenances based on geographic position. The most western provenance Bosanski Petrovac that makes a separate group has the highest mean height, while provenances with the lowest mean height, Olovo-Klis, Konjic and Pale in geographic sense are located in south-east part of B&H. The coefficient of variability (CV%) of examined characteristics is in range up to 29%.



Graph 1. Growth of height of representatives of four provenance groups
Grafikon 1. Razvoj visine predstavnika 4 grupe provenijencija



Graph 2. Increment in height of representatives of four provenance groups
Grafikon 2. Prirast u visinu predstavnika 4 grupe provenijencija

Analysis of growth and increment in height of fir provenances was done for representatives of 4 (four) provenance groups which between themselves are statistically significantly different in growth in height (see Table 4. Duncan test). Graph 1 shows the curve of growth in height for four fir provenance groups. From the Graph, it is visible that during the set-up of experiment plants of different fir provenances have had approximately the same height (for planting used seedlings 5-years old). In further phases of growth appeared differentiation in height. From the Graph is visible that provenance Bosanski Petrovac, which is in the first group, from the start (5 years of age) shows the best growth, but it gets clearly isolated related to the provenances of third and fourth groups only after 15 years. Fir provenance Bosanski Petrovac shows better growth than fir provenances from the second group only after the 20th year. Provenances from the second group from the 10th year of age are separating from the third and fourth group by better growth. In growth fir provenances that belong to the third and fourth group have no larger differences. Graph 2 shows the curve of height increment of fir provenances determined by Duncan groups by characteristic of mean height (1-4). Graph makes it visible that the culmination of height increment of different provenances of fir appeared between 20 and 25 years of age. All fir provenances had height increment culmination in approximately the same age, but the current height increment had different values in specific groups. Analog to the height, the height increment in fir provenance from Bosanski Petrovac during its entire growth has had the highest values, and those are particularly highlighted in period of height increment culmination. The lowest height increment was in the fir provenances of the third and fourth Duncan group. Having in mind the flow of the curve of height increment of four fir provenances it is possible to conclude that even in the later stages of growth there will be no significant oscillations in the intensity of growth of provenances. It is to expect that Bosanski Petrovac's provenance in further will have the best growth and increment.

Tree volume

Based on measured diameters and heights for each tree, according to NAGEL, (1988) its average volume per one tree. Results of the examination of characteristic "average tree volume" are provided in Table 5. From the table, we can see that the largest average tree volume is in the provenance Bosanski Petrovac (0.061 m^3). Then follows provenances Fojnica and Sokolac with 0.051m^3. Somewhat smaller tree volume is in provenances Prozor, Olovo-Palež, Bugojno, Pale, Olovo-Klis that is in the range from 0.470to 0.450 m^3. Provenance Konjic has the smallest average tree volume (0.043m^3). Analysis of variance showed that there are statistically significant differences in the level of statistical significance of 95% for the examined characteristic "average tree volume".

Table 5. Average tree volume of 9 Bosnian-Herzegovinian fir provenances on experimental plot/area Delimusa
Tabela 5. Prosječna zapremina stabla 9 bosanskohercegovačkih provenijencija jele na ekperimentalnoj površini Delimusa

No.	Provenance	N	V of the tree (m^3)	Std	CV%	Duncan group		
						1	2	3
1.	Bos. Petrovac	218	0.06185	±0.04161	67.28	*		
2.	Fojnica	271	0.05164	±0.03482	67.42		*	
3.	Sokolac	243	0.05107	±0.03417	66.92		*	
4.	Prozor	246	0.04711	±0.03238	68.73		*	*
5.	Olovo-Palež	256	0.04638	±0.03315	71.49		*	*
6.	Bugojno	194	0.04615	±0.03132	67.86		*	*
7.	Pale	228	0.04564	±0.03336	73.10		*	*
8.	Olovo-Klis	202	0.04560	±0.02545	55.81		*	*
9.	Konjic	240	0.04342	±0.02856	65.77			*
F= 5.845				Sig. 0.005				

In order to determine statistical differences between fir provenances, we conducted the Duncan test. Results of the test showed grouping of fir provenances, as per examined characteristic "average tree volume", into three Duncan groups. In the first group with the largest average tree volume is provenance Bosanski Petrovac. This provenance in terms of average tree volume is statistically significantly different than the other provenances. The second group, with lower average tree volume, includes provenances Fojnica, Sokolac, Prozor, Olovo-Palež, Bugojno Pale and Olovo-Klis. The third group, with the lowest average tree volume, includes provenances Prozor, Olovo-Palež, Bugojno, Pale, Olovo-Klis and Konjic. Provenance Konjic, that is in the third group, is statistically significantly different than provenances of the first and the second Duncan group as per the lowest average tree volume. Provenances from the second Duncan group Fojnica and Sokolac as per larger average tree volume are different than all provenances of the third Duncan group (Table 5). The coefficient of variability (CV%) for characteristic average tree volume is in a range from 55 to 73%.

DISCUSSION - *Diskusija*

In the 70s of the past century, due to noticeable degradation of fir caused by effects of damaging agents, intensified the works on setting-up of provenance experiments with the fir (WOLF, 2003). In many countries of Europe, experiments were established with silver fir provenances from all areas of its natural distribution (LARSEN, 1986, KRAMER and STEPHAN 1992, MEKIĆ, 1991, HALILOVIĆ et al. 2013, KERR, 2015, STOJNIĆ et al. 2016.). Lately, we are faced with new challenges in the form of climate changes that can lead to dying-out of specific native tree species, even fir. Up-to-date research in Austria and Germany has shown that the silver fir, unlike spruce, is more resilient to drought and it shows significantly better adaptability and plasticity (ROTHE et al. 2011). Actual studies from Switzerland show that large

complexes of spruce forests, according to forecasted scenarios of climate changes, shall disappear and that their place can be replaced by the silver fir, exactly due to its adaptability to increased temperatures and drought (FRANK et al. 2017). In his work KERR, (2015) concludes that fir is a very adaptable and productive tree species that can be used outside its natural areal with the objective to raise mixed forests resilient to climate changes, pests and diseases. These statements show that we have to establish new, and monitor old provenance trials with silver fir, and find resilient, adaptable and fast-growing populations that can be used for afforestation on local and global levels. These researches also showed that examined Bosnian-Herzegovinian provenances of silver fir are vital, resilient and adaptable to habitat conditions that rule on the location of "Delimusa".

Table 6: Growth of heights in specific age classes of researched fir provenances in 14th, 20th (HALILOVIĆ and others 2013) and 28th year of age
Tabela 6: Razvoj visina u pojedinim starosnim klasama istraživanih provenijencija jele u 14.-oj, 20.-oj (HALILOVIĆ i dr. 2013) i 28-oj godini starosti

Rang	Provenance	H (m) 14	Duncan group		Provenance	H(m) 20	Duncan group		Provenance	H(m)28	Duncan group			
1.	B. Petrovac	1.71	*		B. Petrovac	4.07	*		B. Petrovac	9.1	*			
2.	Konjic	1.68	*		Fojnica	3.99	*		Sokolac	8.7		*		
3.	Prozor	1.68	*		Bugojno	3.89	*	*	Fojnica	8.6		*		
4.	Fojnica	1.67	*	*	Sokolac	3.88	*	*	Prozor	8.3		*	*	
5.	Bugojno	1.67	*	*	Prozor	3.87	*	*	Olovo-Palež	8.2		*	*	*
6.	Sokolac	1.64	*	*	Konjic	3.83	*	*	Bugojno	8.2			*	*
7.	Olovo-Palež	1.63	*	*	Olovo-Palež	3.76		*	Konjic	8.1			*	*
8.	Pale	1.57		*	Pale	3.70		*	Pale	8.1				*
9.	Olovo-Klis	1.55		*	Olovo-Klis	3.64		*	Olovo-Klis	8.1				*
F = 2.55					F = 3.24				F= 6.12					

Table 6 shows a comparative analysis of mean heights of 9 fir provenances in 14th, 20th and 28th year of age. It is visible from the table that provenance Bosanski Petrovac from the start shows the best growth. This provenance in its mean height is statistically significantly different than the other 8 provenances. Provenances with the smallest growth; Olovo-Klis and Pale, have the lowest mean height since the age of 14. Fir provenance Konjic in the 14th year belonged to the provenance group with the best growth, while in the 28th year of age it fell under group with the smallest growth. Vice

versa, provenance Sokolac that at the age of 14 was in a group with the smallest growth in the 28th year shows good growth.

If we analyse the mean height of provenances in the 28th year of age it moves in all provenances in the range from 8.1 to 9.1 m. SZELIGOWSKI et. al (2011) in their research with 5 Polish and one German provenance of fir in 30-years of the age of the trees, gained mean heights in a range from 5.4 to 7.8 meters. According to SCHOBER, (1979) mean height of fir of the first yield class, in 30-years of age, for the area of Central Europe amounts to 7.7 m.In these researches mean heights in all researched Bosnian-Herzegovinian fir provenances in 28-years of age are larger than mean heights of 30-years of age firs as per tables of SCHOBER, (1979) and research of SZELIGOWSKI and others (2011). Better increment of South-European provenances of silver fir is confirmed by many researches (LARSEN, 1986; LARSEN and MEKIĆ 1991; MAYER et al. 1980; MEKIĆ, 1992; KAJBA, 2001; KERR, 2015).

Table 7. Mean diameter of 9 Bosnian-Herzegovinian fir provenances in 20th year of age (HALILOVIĆ et al. (2013)) and 28th year of age

Tabela 7. Srednji prečnik 9 bosanskohercegovačkih provenijencija jele u 20-oj godini (HALILOVIĆ i dr. (2013) i 28-oj godini starosti

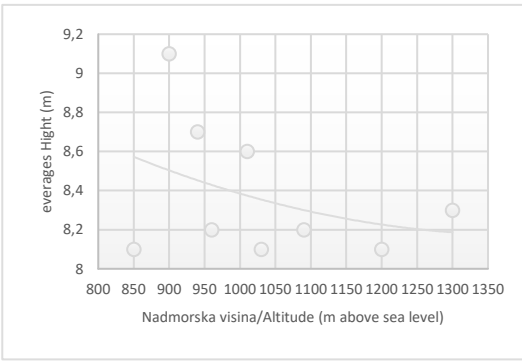
Rang	Provenance	D(cm) 20	Duncan group		Provenance	D (cm) 28	Duncan group	
1.	Bos.Petrovac	4.7	*		Bos. Petrovac	11.9	*	
2.	Fojnica	4.63	*	*	Fojnica	11.2		*
3.	Konjic	4.50	*	*	Sokolac	11.1		*
4.	Sokolac	4.47	*	*	Olovo-Klis	11.1		*
5.	Bugojno	4.45	*	*	Prozor	10.9		*
6.	Prozor	4.41	*	*	Pale	10.8		*
7.	Olovo-Palež	4.25		*	Bugojno	10.8		*
8.	Olovo-Klis	4.17		*	Olovo-Palež	10.8		*
9.	Pale	4.16		*	Konjic	10.7		*
F= 2.19					F= 6.12			

From Table 6. We can see that growth of mean diameter in provenances of fir in the 20th year of age and 28th year of age. Provenance Fojnica in the 20th year had a larger mean diameter while in the 28th year the larger mean diameter was recorded in provenance Bosanski Petrovac. Provenance Konjic in the 20th year belonged to the provenance group with the best mean diameter, and in the 28th year, it would have the smallest mean diameter (10.7 cm). SZELIGOWSKI, (2011) determined the mean

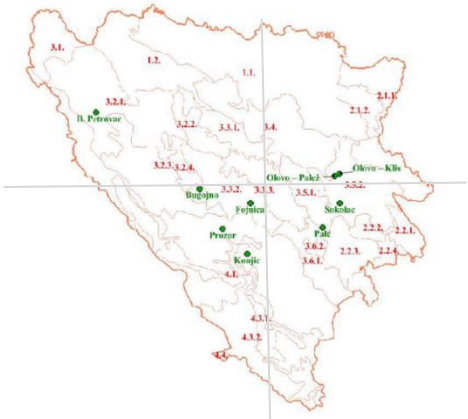
diameter of 6 tested provenances of fir of 6.2 cm. According to yield tables of SCHOBER, (1979), fir in its best habitats in the 30th year of age has a mean diameter of 8 cm. Results of the research shows that 28th year-old Bosnian-Herzegovinian silver fir provenances that have the smallest increment (Konjic, Olovo-Klis, Pale) have larger mean diameter, from the mean diameter of 30-year old silver fir of the first yield class for area of Central Europe according to SCHOBER, (1979), and Polish provenances of fir (SZELIGOWSKI, 2011).

From the results of the study, we can see that the smallest volume of the mean tree is in the provenance of (0.043 m^3), while the largest volume was recorded in provenance Bosanski Petrovac with 0.062 m^3. If the volume of the mean tree is calculated for hectare, then fir provenance Konjic has a volume of 90.09 m^3/ha, and provenance Bosanski Petrovac has a value of 111.33 m^3/ha. The difference in percentage between volume of mean tree in these two provenances is 29.8%, while the difference in percentage in volume per hectare between provenances Konjic (smallest volume) and provenance Bosanski Petrovac (largest volume) is significantly smaller and amounts to 19%. This appearance that difference in percentage between volume of mean trees of provenances Konjic and Bosanski Petrovac is significantly larger in relation to difference in percentage in volume of these provenances per hectare (29.8% vol.trees m^3> 19% vol. m^3/ha) can be explained with larger number of trees determined in provenance Konjic (2,075 trees/ha), related to Bosanski Petrovac (1,800 trees/ha), which finally influences on the total volume of assortment. In yield tables of SCHOBER, (1979) for the first yield class, the mean diameter of fir in 30 years of age amounts to 8.0 cm, and mean height is 7 m, which is below mean values of poorest ranked provenance in these researches. According to yield tables of SCHOBER, (1979) volume of fir assortment in 30 years of age amounts to 105 m^3/ha, but such large volume is influenced by a significantly larger number of fir trees per hectare (6,320 trees/ha).

Graphs 3. and 4. Depicts the influence of altitude and geographic position of assortment from which we collected seed material for the experiment.



Graph 3. Growth in height of provenances depending on source origin of reproductive material
Grafikon 3. Razvoj visine provenijencija u zavsnosti od izvornog porijekla reproduktivnog materijala



Graph 4. Geographic origin of researched fir provenances
Grafikon 4. Geografska pripadnost istraživanih provenijencija jele

Graphs make it possible to see that there is none correlating dependence between mean height of fir provenances and altitude of source origin of seed material of individual fir provenances. There is less expressed trend that fir provenances from lower altitudes have larger mean height, especially in fir whose source assortment is located on altitudes below 1,000 meters. Graph 4 shows the geographic position of source assortments of fir. Analysis determined that fir provenance from Western Bosnia has the largest values of mean diameter and mean heights, while local provenances Pale and Olovo-Klis showed the lowest values of mean height and mean diameter. Gained differences in growth between local provenances of fir could be explained by specific micro-climate and habitat conditions that are changing in a very small area. On larger inner-population variability of local Calabrian silver fir provenances, MEKIĆ, (1988) points out in his researches. STEFANOVIĆ, (1986) emphasizes that the area of Dinarides mountains is very specific in terms ofenvironmental conditions because in a very small area there are a large variety of climate, edaphic, orographic and other factors that impact on differentiation of various eco-types, and especially in the area of Central Bosnia. Because of that forest tree species from the Dinarides mountains show large variability compared to the same species from the north, therefore, on relatively small areas we could find large tree species variability (BALLIAN and ČABARAVDIĆ 2005, BALLIAN and HALILOVIĆ 2016).

CONCLUSION - *Zaključak*

This paper researches morphological characteristics of 28-year old trees of nine provenances of silver fir on the experimental area "Delimusa" near Olovo.

Tested populations of fir are statistically significantly different in sense of height and mean diameter which can have large economic and ecological importance. Silver fir provenance from Bosanski Petrovac showed to be superior related to all other provenances. The mean height of this provenance of fir in 28 years of age amounts to 9.1 m, while the mean breast height diameter is 11.9 cm. Provenances that show the lowest growth (8.1 m) are Pale, Olovo-Klis and Konjic, while the silver fir provenance Konjic is with the smallest mean diameter (10.7 cm). In all provenances culminated increment in height in ages between 20 and 25 years. Variability of silver fir for examined characteristic "mean height" is larger (four population groups) compared to examined characteristic "mean diameter" of two population groups.

Calculated volume of mean tree ($0.062m^3$) and assortment ($111.33\ m^3/ha$) in provenance Bosanski Petrovac is larger than silver fir volume for the first yield class in Central Europe. All 9 Bosnian-Herzegovinian fir provenances on the experimental area showed good adaptability, resilience, vitality and growth. Results of these researches open possibility of introduction of Bosnian-Herzegovinian silver fir into some areas of Central Europe whose ecological characteristics are suitable to biological characteristics of the silver fir, and in which individual tree types are currently endangered by climate changes.

Variability in growth of 9 Bosnian-Herzegovinian fir provenances developed as a consequence of specific climate and orographic – edaphic conditions in B&H, which are changing/alternatingon very small area creating ecological niche suitable for differentiation of silver fir.

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SAŽETAK

U ovom radu istraživan je rast devet provenijencija jele iz područja njenog prirodnog rasprostranjenja u Bosni i Hercegovini. Eksperiment je postavljen 1991. godine u obliku slučajnog blok sistema sa 5 ponavljanja. Za sadnju su korištene petogodišnje sadnice jele (2/3) a razmak sadnje je bio 2x2 m. Svaka provenijencija jele je bila zastupljena sa 320 biljaka. Rezultati mjerenja u 28-oj godini starosti pokazuju postojanje varijabilnosti između provenijencija jele u obilježjima; srednja visina, srednji prečnik i prosječna zapremina stabla. Provenijencija jele iz Bosanskog Petrovca je pokazala najbolje rezultate. Srednja visina ove provenijencije jele u starosti od 28 godina iznosi 9,1 m, dok je srednji prečnik 11,9 cm. Provenijencije koje pokazuju najslabiji rast (8,1 m) su Pale, Olovo-Klis i Konjic. Provenijencija jele Konjic ima najmanji srednji prečnik (10,7 cm). Kod svih provenijencija je kulminirao prirast u visinu u starosti između 20 i 25 godina. Varijabilnost između testiranih provenijencija jele za ispitivano obilježje "srednja visina" je veća (četiri skupine populacija) u odnosu na ispitivano obilježje "srednji prečnik" (dvije skupine populacija). Zapremina srednjeg stabla (0,062 m^3) i sastojine (111,33 m^3/ha) kod provenijencije Bosanski Petrovac je veća od tabličnih vrijednosti za prvu prinosnu klasu za uvjete srednje Evrope.
Varijabilnost u rastu 9 bosansko-hercegovačkih provenijencija se razvila zbog specifičnih klimatskih i orografsko edafskih uvjeta koji vladaju u BiH, i smjenjuju se na vrlo malom prostoru stvarajući ekološke niše pogodne za diferencijaciju jele.
Rezultati ovih istraživanja otvaraju mogućnost introdukcije bosanskohercegovačke jele u neka područja srednje Evrope kao i šire van njenog prirodnog areala, gdje stanišne karakteristike odgovaraju biološkim svojstvima jele, a u kojim su pojedine vrste drveća trenutno ugrožene klimatskim promjenama.

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REGRESSION MODEL FOR ASSESSMENT OF VOLUME OF MERCHANTABLE WOOD OF EVEN-AGED NOT-TENDED FOREST PLANTATIONS OF SCOTS PINE ON CARBONATE SUBSTRATES IN B&H

Regresioni model za procjenu zapremine krupnog drveta jednodobnih nenjegovanih šumskih zasada bijelog bora na karbonatnim supstratima u BiH

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Abstract

As the result of sporadic afforestation of not-grown forest land in the past, today in B&H we have significant areas of even-aged forest plants of Scots pine of different ages. Estimate of yield capabilities of habitats/sites of these stands is one of very real issues in even-aged management planning for this tree species. In order to get the clear idea on the value of yield of even-aged stands, it is necessary to conduct long-term researches on permanent experimental plots. Considering that for the results of those researches it is necessary to wait approximately for the duration of production periods for specific tree species, to gain orientation solutions of the problem we can apply short-term researches – using temporary experimental plots set in stands of different ages. Members of the Forest Management Department of Forestry Faculty in Sarajevo in a period from 1985 to 1990 gathered data on temporary experimental plots in existing even-aged forest plantations of spruce, Scots pine and black pine in order to research their growth, structural and production characteristics. Part of those data for Scots pine is used for making of this document. Objective of this research was, based on data on measurement of 77 experimental plots positioned in even-aged not-tended plantations of Scots pine Bosnia-wide, to reach relevant information on the value of wood volume depending on their age and site quality, and to create the most favourable regression model for assessment of volume of large wood value based on known values of the stand taxation elements that could be easily and quickly determined. Besides this, in this document by comparing gained results with appropriate data from other authors we have evaluated productivity of even-aged not-tended forest plantations of Scots pine in B&H.

Key words**:** *even-aged forest plantations of Scots pine, volume of large wood of the stand, yield, multiple regression analysis, net correlation.*

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INTRODUCTION – *Uvod*

Parts of not-grown forest land in B&H in the past were afforested with seedlings of spruce, Scots and black pine, so today we have significant areas of even-aged forest plantations of these tree species of different ages. It is assumed that their total area in 1985 was approximately 150,000 hectares. (PAVLIČ, 1999). Plantations of Scots pine within even-aged stands cover significant areas with tendency of further increase in size. This was foreseen by long-term forestry development program in B&H for period 1986-2000 (IZETBEGOVIĆ, 1986) which, due to past war, was not completely implemented. For those reasons, as necessity we have the need to research these stands in terms of determining the values of individual taxation elements, as first, the value of wood volume per hectare. In other words, in general we have a problem of managing even-aged stands because forest management companies on whose territory those even-aged stands are located do not have available basic findings and data about when to start with thinning, what type and intensity of thinning to use, how long production period should be and what yield could be produced, etc. We can get reliable answer to these questions through long-term researches on permanent experimental plots. Considering that for the results of those researches it is necessary to wait approximately for the duration of production periods for specific tree species, to gain orientation solutions of the problem we can apply short-term researches – using temporary experimental plots set in stands of different habitat conditions and different ages. Such researches were started by Forestry Faculty in Sarajevo in 1985, more precisely Forest Management Department (PAVLIČ, 1999). Gathered data served as basic scientific background for making of this document.

MATERIAL AND METHODS – *Materijal i metode*

Selection of stands in which temporary experimental plots are positioned and gathering of necessary data was done using previously developed methodology (PAVLIČ, 1999). In a period from 1986-1990, basic and taxation data on 88 temporary experimental plots in plantations of Scots pine all over Bosnia in the age interval from 10 to 138 years of age were collected. However, since stands in age interval from 55 to 100 years of age were not included in the sample, all considerations and analysis were conducted for 77 experimental plots positioned in plantations from 10 to 54 years of age. Additional to this, we have uncertainty in projection of received average values of taxation elements for stands older than 55 years.

Basic material was gathered on temporary experimental plots of circular shape whose area depended on the age of the stand. Areas and diameters of experimental plots for stands of different age are presented in Table 1.

Table 1. Areas and diameters of experimental plots depending on the age of the stand
Tabela 1. Površine i radijusi oglednih ploha u zavisnosti od starosti sastojine

Age of the stand (year)	Diameter of experimental plot (m)	Area of experimental plot (ha)	Age of the stand (year)	Diameter of experimental plot (m)	Area of experimental plot (ha)
10 – 15	4,0	0,0050	66 – 75	12,5	0,0491
16 - 25	5,0	0,0079	76 – 85	14,5	0,0661
26 – 35	6,5	0,0133	86 – 95	16,5	0,0855
36 – 45	7,5	0,0177	96 – 105	18,0	0,1018
46 – 55	9,5	0,0284	106 – 115	19,5	0,1195
56 – 65	10,5	0,0346	116 i više	21,0	0,1385

On selected temporary experimental plots, we gathered more various data which were recorded in manuals prepared in advance. Data were inserted separately for each experimental plot for which we later also determined the values of taxation elements of the stand.

Method of taxation element calculation for trees and stands - *Metode obračuna taksacionih elemenata stabala i sastojina*

On basis of taxation elements that were measured (and determined) in the field directly by method of simple and multiple correlation and regression, we have determined the most probable values of volume of large wood of trees and stands. For interconnections analysis and dependence between individual taxation elements we used method of multiple regression, while method of net-correlation was used to determine and analyse "pure" relations between the value of larger timber volume of the stand and each individual taxation element taken for the analysis. Overall calculation and statistical procedure of data processing, graphical interpretation of results and individual table overviews were done using statistical software „*Statistica 8.0*" and statistical „package" in „*Microsoft Excel*".

Determination of the volume of trees and stands per hectare - *Određivanje zapremine stabala i sastojina po hektaru*

Before creating model for assessment of the stand volume we have determined the value of volume of large wood for each experimental plot. In the process volume of large wood (7 cm and more) of each tree on experimental plot was taken from two-entry volume tables of BEZAK, (1992). These tables were selected because of most probably "the smallest" difference in climate, edaphic and other conditions between habitats/sites of even-aged stands of Scots pine (between Croatia and Bosnia), as well as because of possibility to accurately calculate tree volume per determined function for assessment based on diameter at breast height (DBH) and height. Actually, based on parameters of Schumacher-Hall function (KRAMER & AKÇA, 1995, CALDERON, 1989) that was used

for assessment of tree volume in development of mentioned tables, we can calculate the value of tree volume for each combination of data pairs (DBH and tree height). Equation of the model used to calculate volume of large wood is:

$$V_7 = 0,0000383293 d_{1,3}^{2,087561} h^{0,875764} 1,004013 \quad (1)$$

where:

V_7 - volume of large wood of trees (above 7 cm),

$d_{1,3}$ - diameter at breast height (DBH),

h – tree height,

a,b,c – parameters of the function.

Stand volume per ha was determined as product (multiplication) of volume of all trees on the plot and reduction factor (reciprocal value of plot area F ha):

$$V_{7(\frac{m^3}{ha})} = V_{7(\frac{m^3}{plot})} \frac{1}{F_{(ha)}} \quad (2)$$

RESULTS AND DISCUSSION - *Rezultati i diskusija*

After calculating typical values of taxation elements for each experimental plot, we have created regression model for assessment of volume of large wood value of even-aged stands (dependent variable) and for analysis of "net" impact of individual independent variables.

Model of the function of multiple regression for assessment of volume of large wood value of even-aged stands and impact analysis of individual independent variables - *Model funkcije višestruke regresije za procjenu veličine zapremine krupnog drveta jednodobnih sastojina i analizu uticaja pojedinih nezavisnih varijabli*

After testing multiple models, while sticking to criteria that there is no correlation connection between independently changeable values or that it is expressed in as smaller measure as possible (KOPRIVICA, 1997; STOJANOVIĆ, 1966), we have chosen (determine) the regression model in which as independent variables the following taxation elements of the stand were selected:

α - age of the stand,

β - site quality class[1],

δ - degree of land coverage by forest stand canopy.

[1] Issue of assessing quality of even-aged not-tended forest plantations og Scots pine in B&H is described in published document of Balić, B. (2003): „Bonitiranje jednodobnih zasada bijelog bora (*Pinus sylvestris* L.) na karbonatnim supstratima u Bosni" („Assessing quality of even-aged plantations of Scots pine (*Pinus sylvestris* L.) on carbonate substrates in Bosnia". I Simposium of agriculture, veterinary and forestry. Neum. Collection of papers of Forestry Faculty in Sarajevo. page 67-79.

Function of selected regression model is:

$$V_k = a + b\left(1 - exp^{(-c\alpha)}\right)^d + e\beta + f\delta + g\delta^2 + h\beta\delta \quad (3)$$

In determined regression model the impact of age on volume of large wood value is expressed using Chapman-Richard function (KRAMER & AKÇA, 2003; CALDERON, 1989), impact of site quality is expressed in linear manner, while impact of degree of land coverage by forest stand canopy is expressed by second-order polynomial form. Besides four elements of determined model, which summarises the impact of independent variables, the model has one more element in which impacts of site quality and degree of land coverage by forest stand canopy are mutually multiplied. Based on assessed values of statistic parameters of multiple regression equation presented in Table 3 one can get an insight in what amount the changes in values of volume of large wood of the stand could be attributed to overall action of all factors covered by the regression model. Average values of variables taken into regression model are presented in the following table.

Table 2. Basic statistical parameters of independent variables in regression model
Tabela 2. Osnovni statistički parametri nezavisnih varijabli u regresionom modelu

Variables	Average	Standard deviation	Minimum	Maximum
Age (year)	24,65	9,18	10	54
Site quality class	3,00	1,10	1	5
Degree of land coverage by forest stand canopy	0,87	0,08	0,58	1,00
Volume of large wood (m^3/ha)	196,78	114,25	7,88	512,61

Assessed values of parameters with basic statistical indicators of determined regression model are presented in Table 3.

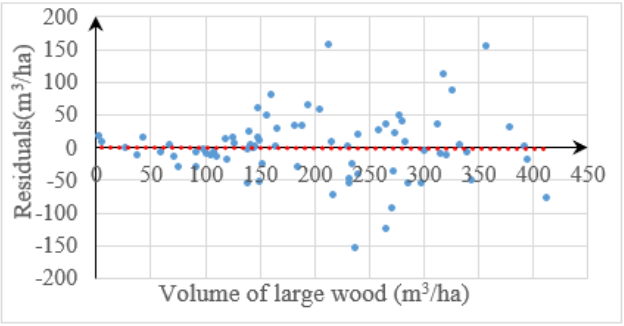
Table 3. Basic statistical indicators of regression function
Tabela 3. Osnovni statistički pokazatelji funkcije regresije

Label parameter	*Estimated value*	Multiple correlation coefficient	Determination coefficient	Standard error of assessment
a	*40,6657*	$R = 0,90$	$R^2 = 0,81$	$S_{ey} = 52,33 m^3 / ha$
b	*541,857*			
c	*0,05311*			
d	*2,70291*			
e	*7,59204*			
f	*-241,833*			
g	*271,915*			
h	*-33,4267*			

According to determined value of determination coefficient (R^2), relative statistical indicator of assessment precision, chosen independent variables and chosen regression model explain 81% of varying in the value of volume of large wood of Scots pine stand, while the rest is attributed to other not covered impact factors.

Pretty large value of standard error of assessment (Sey) in amount of 52.33 m^3/ha, (absolute statistical measure of assessment precision) is the result of large variation of volume of large wood of individual experimental plots/areas (from 7.88-512.61 m^3/ha).

Quality of the regression model was checked also with analysis of residuals (deviation of assessed compared to empirical data). Based on diagram of dispersion of residuals we can conclude on the character of residual distribution, i.e. whether they are systematically (or non-systematically) distributed around assessment line, which indicates the potential systematic error of regression model (EKINOVIĆ, 1997). Diagram of dispersion of residuals of selected model is represented in Graph 1.



Graph 1. - Diagram of dispersion of residuals around regression model

Grafikon 1. - Dijagram rasturanja reziduala oko regresionog modela

On presented diagram of dispersion of residuals (Graph 1) we can notice their approximately symmetric distribution around regression, i.e. absence of systematic distribution, and can conclude that the selected model is adequate to present analysed dependences.

Based on assessed parameters of regression model (3) and average values of independent variables, we have analysed individual (net) impacts of independent variables on the value of volume of large wood as dependable variable, in order to gain insight into character and intensity of the connection between dependable variable and individual included independent variables (VUKMIROVIĆ et al., 1966). In the process, in regression model (3) we include different values (in the variation interval) of independent variable whose impact is examined, and to others we assign average values (KOPRIVICA, 1997).

Net correlation between the volume of large wood and the age of even-aged Scots pine stands - *Neto korelacija između veličine zapremine krupnog drveta i starosti jednodonih sastojina bijelog bora*

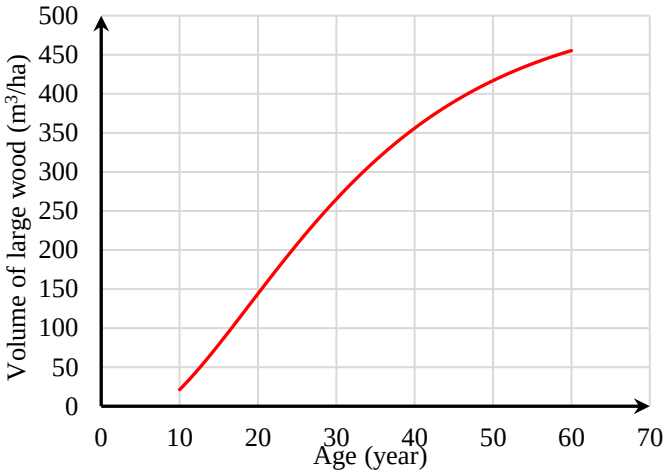
By including average values of site quality and degree of land coverage by forest stand canopy into determined regression model (3) we have reached an equation

of net correlation between volume of large wood and age of even-aged Scots pine stands:

$$V_k = -28{,}1699 + 541{,}85654794\left(1 - exp^{(-0{,}05311435x)}\right)^{2{,}70290864} \quad (4)$$

This equation shows how the volume of large wood changes with the change in age of the stand with average values of other independent variables.

Graphical form of gained equation of net regression is shown in Graph 2.



Graph 2. Net correlation between volume of large wood and age of even-aged Scots pine stands

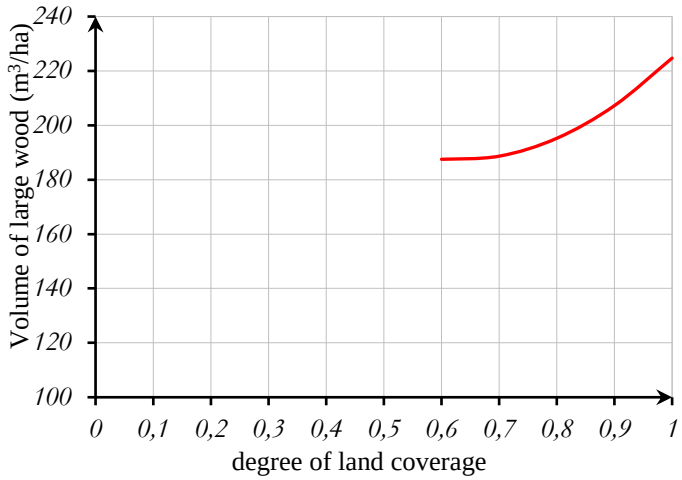
Grafikon 2. Neto korelacija između zapremine krupnog drveta i starosti jednodobnih sastojina bijelog bora

Based on given graphical depiction we can conclude that the value of volume of large wood of Scots pine stands with average habitat/site conditions and average degree of land coverage by forest stand canopy with age is increasing as per extended "S-shaped" curve. This is general characteristic of growth curves of all taxation elements of trees and stands, i.e. all living organisms.

Net correlation between the volume of large wood value and degree of land coverage by canopy of even-aged stands of Scots pine - ***Neto korelacija između veličine zapremine krupnog drveta i stepena zastrtosti zemljišta krošnjama stabala jednodobnih sastojina bijelog bora***

Net correlation equation, of impact of degree of land coverage by forest stand canopy onto the value of volume of large wood of even-aged stands of Scots pine, is:

$$V_k = 294{,}8603 - 342{,}0716319\delta + 271{,}91457458\delta^2 \quad (5)$$



Graph 3. Net correlation between the volume of large wood value and degree of land coverage by canopy of even-aged stands of Scots pine

Grafikon 3. Neto korelacija između veličine zapremine krupnog drveta i stepena zastrtosti zemljišta krošnjama stabala jednodobnih sastojina bijelog bora

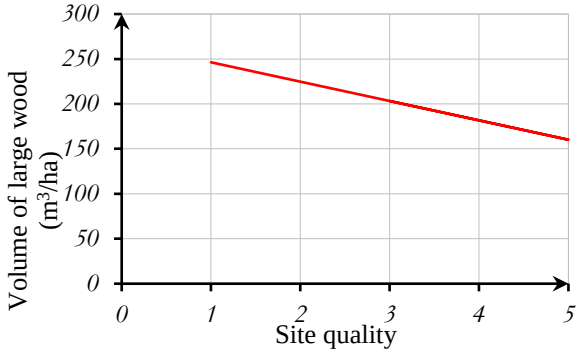
Graphical depiction of this equation is provided in Graph 3- Value of the volume of large wood of even-aged stands of Scots pine is, with average age and average site quality, larger with larger degree of land coverage by forest canopy. This is logical relation, while progressive increase in value of stand volume with increase of degree of land coverage by forest canopy points out that the larger degree is most probably the consequence of larger number of trees per unit of stand area.

Net correlation between value of volume of large wood and site quality of Scots pine even-aged stands - *Neto korelacija između veličine zapremine krupnog drveta i boniteta staništa jednodobnih sastojina bijelog bora*

Net correlation equation between value of volume of large wood and site quality is:

$$V_k = 267,84203 - 21,53694044\,\beta \quad (6)$$

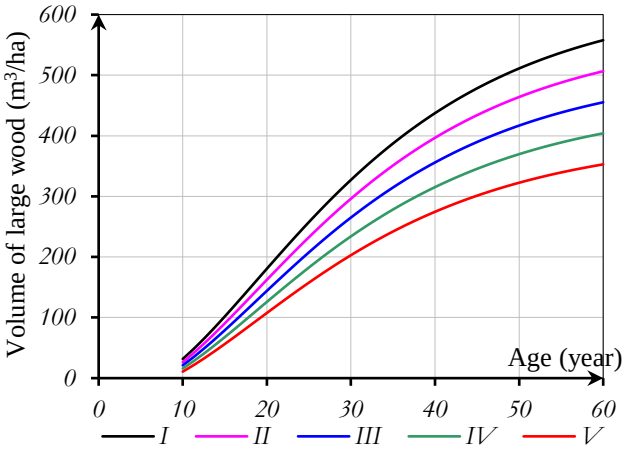
According to mathematical presentation of net correlation, values of parameters and graphical depiction (Graph 4), the value of volume of large wood of Scots pine stands is decreasing with worsening of habitat/site conditions with average age and average degree of land coverage by forest canopy.



Graph 4. - Net correlation between value of volume of large wood and site quality of Scots pine even-aged stands
Grafikon 4. - Neto korelacija između veličine zapremine krupnog drveta i boniteta staništa jednodobnih sastojina bijelog bora

That is quite understandable if one has in mind the expressed statement that the complex of all conditions for tree growth is more favourable on better habitats/sites than on bad ones and that it causes faster increase in values of all taxation elements of trees, and indirectly the volume of large wood of the stands as complex and additive taxation element.

On Graph 5 we have presented graphical presentation of dependences of assessed values of volume of large wood with the age of even-aged stands of Scots pine per site quality classes, while in Table 3 we present absolute values.



Graph 5. – Dependence of value of volume of large wood and age and site quality of even-aged stands of Scots pine
Grafikon 5. - Zavisnost veličine zapremine krupne drvne mase od starosti i boniteta staništa jednodobnih sastojina bijelog bora

Curves of growth of large wood mass volume as per site quality classes were determined by a method of equal relative changes (MATIĆ, 1980). This method is based on position that within site quality classes we cannot expect the same absolute differences in values of volume of large wood of the stands of different age, but those differences are larger in older age.

Table 3 – Assessed values of volume of large wood of even-aged not-tended forest plantations on carbonate substrates in Bosnia depending on site quality and age of plantations
Tabela 3 – Procjenjene veličine zapremina krupnog drveta jednodobnih nenjegovonih šumskih zasada na karbonatnim supstratima u Bosni u zavisnosti od boniteta staništa i starosti zasada

Age of stand (year)	Volume of large wood *(m^3/ha)*				
	Bonitet class				
	I	**II**	**III**	**IV**	**V**
10	31,6	26,4	21,2	15,9	10,7
15	101,8	90,4	79,1	67,7	56,3
20	180,5	162,2	144,0	125,8	107,5
25	257,5	232,5	207,5	182,5	157,6
30	327,2	296,1	265,0	234,0	202,9
35	387,2	350,9	314,6	278,3	241,9
40	437,4	396,7	355,9	315,2	274,5
45	478,3	434,0	389,7	345,4	301,1
50	511,1	464,0	416,8	369,6	322,5
55	537,2	487,7	438,3	388,9	339,4
60	557,7	506,5	455,2	404,0	352,8

Based on assessed values of volume of large wood of even-aged not-tended stands of Scots pine in Bosnia (Graph 5 and Table 3) one can say that existing plantations have very high productivity and their forming and growth is quite justified. High productivity is most likely the consequence of favourable conditions of the habitat/site on which these plantations were raised.

Comparison of results with data from yield and increment tables - *Upoređenje rezultata s podacima prirasno-prinosnih tablica*

In order to make close assessment on productivity of researched stands, as well as assessment of justification of their existence and future creation, the determined values in this document were compared with the data in existing increment and yield tables. For comparison we used indexes that were calculated as quotients (relations) of values of other tables and appropriate estimated values of Scots pine stands in Bosnia (appropriate age and quality class) multiplied by 100. We this we achieved that the indexes for all compared data have the same basis.

Since for even-aged stands of Scots pine in Bosnia we lack data on wood volume of cut trees since creation to the moment of stand measurement, and that we are dealing with stands that lacked application of silviculture measures, we can ask the question of soundness of mentioned comparison procedure. Because of this it is important to emphasise that this comparison for its objective has orientation knowledge on yield capabilities of habitats of even-aged forest plantations of Scots pine in Bosnia. Determined values of volume of large wood of Scots pine stands in Bosnia were compared to the appropriate data of yield tables from WIEDEMANN, (1943), LEMBCKE

et al. (2000) and GERHARDT, (1921). Table 4 represents values of indexes of comparison of value of even-aged stands for the best, medium and worst habitats/sites.

Table 4.- Indexes of comparison of value of Scots pine even-aged stands volume
Tabela 4.- Indeksi poređenja veličine zapremine jednodobnih sastojina bijelog bora

Age (year)	Indexes of volumes								
	WIEDEMANN			*GEHRHARDT*			*LEMBCKE ET AL.*		
	I	*III*	*V*	*I*	*III*	*V*	*MEN28*	*MEN20*	*MEN12*
25	**62**	**22**					**115**		
30	**68**	**34**		**72**	**45**	**-**	**104**	**61**	
35	**71**	**40**	**6**				**99**	**62**	
40	**73**	**43**	**11**	**65**	**46**	**17**	**97**	**62**	
45	**75**	**46**	**15**				**96**	**64**	
50	**77**	**49**	**18**	**61**	**45**	**21**	**97**	**66**	**26**
55	**79**	**51**	**21**				**98**	**68**	**29**
60	**81**	**53**	**24**	**60**	**46**	**24**	**100**	**70**	**31**

Values of comparison indexes, which are mainly significantly lower than 100, point out the significantly larger value of volume of large wood of Scots pine stands in Bosnia compared to used table data. The exception is comparisons with data from tables from LEMBCKE et al. (2000) for the best habitat/site conditions which points out to insignificant differences. Differences in value of volumes are smallest with better habitat/site conditions and larger age of stands. According to the results of comparison the even-aged Scots pine stands in Bosnia could be assessed as highly productive, and is most likely conditioned by habitat/site conditions on which even-aged plantations that suit the Scots pine, were created.

CONCLUSIONS - *Zaključci*

On the basis of conducted researches, we can make the following conclusions:

- For assessment of value of volume of large wood of even-aged plantations of Scots pine in Bosnia as best regression model we have chosen the model in which independent variables are the age of the stand, site quality class and degree of land coverage by forest canopy. Mathematical presentation of this model is:

$$V_7 = 40{,}6654706 + 541{,}8565479\left(1 - e^{(-0{,}0531143\alpha)}\right)^{2{,}702903811} + 7{,}592038\beta - 241{,}83288\delta + 271{,}91457\delta^2 - 33{,}426699\alpha\beta\delta$$

- For chosen regression model we have assessed that is of high quality regardless of large standard error of assessment (52.33 m^3/ha) because values of volume of large wood of even-aged plantations of Scots pine in Bosnia vary in very wide interval, from 7.88 to 512.61 m^3/ha. Besides this, selected regression model is of quality because with included independent variables in the model it explains 81% of variations in value of

volume of large wood in Scots pine stand, while the rest is attributed to other not included impact factors.

- With net correlation analysis between value of volume of large wood and age of even-aged plantations of Scots pine in Bosnia, we have determined a typical S-shaped curve of dependence between value of the volume and age of the stand.
- With net correlation between value of volume of large wood and site quality we have determined that the value of volume in linear form increases with improvement of habitat/site conditions.
- With net correlation between value of volume of large wood and degree of land coverage by forest stand canopy it has been determined that progressive increase in value of volume with increase of degree of coverage conditioned by increase of number of trees per unit of stand area.
- With determined model one can calculate the most likely (assessed) values of volume of large wood of even-aged plantations of Scots pine with existing management manner up to the age of 60 years. Having in mind that planned production periods for even-aged stands of Scots pine are longer than 60 years there is a need for new researches with samples that cover stands older than 60 years. This would check the validity and usability of created regression model.
- By comparison of results gained from this research with appropriate data of other yield tables we can conclude that even-aged stands of Scots pine in Bosnia are highly productive; that their existence is quite justified and that in the future much more attention should be focused on them. High productivity of these stands is most likely conditioned by habitat/site conditions which suit Scots pine.
- In this document we could not get the value of totally produced wood volume which is the only real indicator of yield capabilities of the habitat/site of even-aged stands, because we did not have available data on the value of harvested/cut trees. Considering that in the sample we chose stands (experimental plots) where "there was no harvest", because of which these stands were characterised as not-tended, we can assume that volume of harvested trees was not big and that only mortality was in effect.

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SAŽETAK

U radu je predstavljen regresioni model za procjenu veličine zapremine krupnog drveta jednodobnih nenjegovanih šumskih zasada bijelog bora na karbonatnim supstratima u Bosni za koji je ocijenjeno da je najbolji od više prethodno testiranih. U ovom modelu su kao nezavisne varijable korišteni starost sastojine, bonitetni razred staništa i stepen zastrtosti zemljišta sastojine krošnjama stabala. Model je ocijenjen kao kvalitetan jer se njime opisuje 81% varijabiliteta veličine zapremine krupnog drveta jednodobnih nenjegovanih šumskih zasada bijelog bora na karbonatnim supstratima u Bosni. U radu su provedene i analize neto korelacione veze između veličine zapremine krupnog drveta predmetnih zasada i odabranih nezavisnih varijabli. Utvrđeno je da se veličina zapremine krupnog drveta analiziranih zasada sa starošću povećava prvo progresivno, a zatim degresivno, sa poboljšanjem uslova staništa povećava se linearno, dok se sa povećanjem stepena zastrtosti povećava progresivno. Zaključeno je da se po utvrđenom regresionom modelu veličine zapremine krupnog drveta jednodobnih nenjegovanih šumskih zasada bijelog bora u Bosni mogu procjenjivati za starosti do 60 godina, a da su za prevazilaženje ovog ograničenja potrebna nova istraživanja na uzorcima koji obuhvataju i starije sastojine kojim bi se provjerila i valjanost utvrđenog modela. Osim toga, na osnovu poređenja rezultata utvrđenih u ovom radu sa odgovarajućim podacima drugih autora jednodobni nenjegovani šumski zasadi bijelog bora u Bosni su ocijenjeni kao visoko produktivni, da je njihovo postojanje i uzgajanje opravdano i da im u budućnosti treba posvetiti mnogo više pažnje.

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IDENTIFICATION AND MANAGEMENT OF HIGH CONSERVATION VALUE FORESTS WITHIN POTENTIAL NATURA 2000 HABITATS: CASE STUDY VRANICA MOUNTAIN

Identifikacija i upravljanje šumama visoke zaštitne vrijednosti u potencijalnim NATURA 2000 staništima: studij slučaja planina Vranica

Dženan Bećirović[1], Amila Brajić[1], Bruno Marić[1], Sabina Delić[1], Špela Pezdevšek Malovrh[2], Mersudin Avdibegović[1]

Abstract

Nature conservation and sustainable management of forest resources become more important in Bosnia and Herzegovina, driven by the accession process toward the European Union as well as other international processes directed toward responsible management of forest resources. The forest certification has been widely adopted in the forestry sector and it implies meeting the sustainable forest management standard, whereas identification and proper management of high conservation value forests are one of the basic requirements. The NATURA 2000 ecological network is to become an important driver of reforms in the field of nature protection and forestry sector, due to the designation of new sites in forest area, which are under the responsibility of forestry institutions. This paper illustrates the scientific understanding of identification and management processes related to high conservation value forests that were proposed within potential NATURA 2000 habitats. The paper is based on analysis of main guiding principles for site designation and the role of the cross-sectoral approach applied identification and management of sites with high conservation value attributes. The case study research design was selected focusing on the Vranica Mountain due to recent activities implemented in this site. The in-depth face-to-face interviewing was used to collect qualitative data containing the key stakeholders' attitudes regarding the harmonization of NATURA 2000 habitats with the high conservation value forests – (HCVF), as well as the involvement of stakeholders in the processes of cross-sectoral cooperation. Results of this paper can be useful for the key forest and nature protection policy-makers, as well as to those responsible for managing of protected areas, or other stakeholders directly or indirectly involved in the process of identification and management of HCVFs and NATURA 2000 sites. Harmonisation of guiding principles and cross-sectoral cooperation during the identification and management of HCVFs and NATURA 2000 forest habitats enables the proper implementation of conservation and management measures based on sustainable forest management activities.

Key words: *High Conservation Value Forests, NATURA 2000, harmonisation, cross-sectoral cooperation, Vranica Mountain*

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INTRODUCTION – *Uvod*

Nature protection and sustainable management of forest resources become more important alongside with accession process of Bosnia and Herzegovina (BiH) toward the European Union (EU). Some of the reforms in the field of nature protection are directed toward preparation for the implementation of the Berne Convention, as well as EU Birds and Habitats Directives (OFFICIAL WEB SITE OF THE FEDERAL MINISTRY OF ENVIRONMENT AND TOURISM(a)). The accession process is challenging both in political and institutional terms, while implementation of reforms is with small progress. A new set of rules in the field of nature protection (e.g. NATURA 2000 ecological network) is to become an important driver of reforms in this field. The Vranica mountain, due to its biodiversity richness, is proposed as one of the 122 sites for the establishment of NATURA 2000 network in BiH (OFFICIAL WEB SITE OF THE FEDERAL MINISTRY OF ENVIRONMENT AND TOURISM(b)). Having in mind that the implementation of NATURA 2000 in other EU countries was characterized by many challenges, it is recognized that effective implementation of nature conservation is dependent on cross-sectoral cooperation and mutual coordination (KATIET et al. 2014). In that sense, this paper seeks to illustrate the scientific understanding of identification and management processes related to high conservation value forests (HCVF)[1] that were proposed within potential NATURA 2000 habitats. The paper is based on analysis of main guiding principles for site designation and the role of the cross-sectoral approach applied in site identification and management. For that purposes, Vranica Mountain has been chosen as a case study due to recent activities implemented in this site related to HCVF as well as NATURA 2000 process.

The forest certification process, in line with Forest Stewardship Council standards (hereinafter: FSC), has been widely adopted in the forestry sector of BiH coveringthe environmental, social, cultural and economic aspects of forest management (PEZDEVŠEK MALOVRH et al. 2019a). Forest certification implies meeting a certain, predefined, sustainable forest management standard, whereas identification and proper management of high conservation value forests are one of the basic requirements (Principle 9). At the moment, there are9 valid SFM FSC[2] certificates issued to the public forest companies in BiH that are managing with state-owned forests (OFFICIAL WEB SITE OF THE FSC(a)). One of the public companies that holds the certificate is the "Šumskoprivredno društvo - ŠPD Srednjobosanske šume" d.o.o. Donji Vakuf that is managing with HCVFs on Vranica Mountain. During the certification process area of 1.284,52 ha was identified and designated as HCVFs (ŠPD/ŠGD

[1] The HCVF concept is a part of voluntary forest certification systems, which requires from forest managers to identify any high conservation values - HCVs that occur within their individual forest management units, to manage them in order to maintain or enhance the values identified, and to monitor the success of this management through applying the precautionary approach

[2] SFM FSC refers to Sustainable Forest Management Forest Stewardship Council

"SREDNJOBOSANSKE ŠUME"/"ŠUME SREDIŠNJE BOSNE" D.O.O. DONJI VAKUF, 2016), located within the potential NATURA 2000 habitats.

Although NATURA 2000 and HCVFs concepts origin from different sectoral policies, one can conclude that there are certain similarities in these approaches directed toward conservation of naturals values and its attributes. Having in mind that in the study area (Vranica Mountain) NATURA 2000 and HCVFs are intended toward maintenance, enhancement and promotion of identified high conservation value attribute, using the mix of policy instruments can be recommended to efficiently and effectively conserve valuable forest areas (FAO, 2010). In that sense, this research is dealing with the analysis of precondition for applying a mix of forest/nature conservation policy instruments in the identification and management processes of HCVFs within potential NATURA 2000 forest habitats. The research is focused on the process of cross-sectoral cooperation primary between forest and nature protection departments. Having in mind that the institutional cooperation between the federal and cantonal ministries is modest (COM, 2019), lack of coordinated activities related to preparation and implementation of strategic and operational framework both for forests and nature protection is present. Thus, the conflicts between these sectors are not unusual and mainly based on lack of mechanisms ensuring the exchange of information, as well as mutual coordination and consultation between relevant institutions. Therefore, cross-sectoral cooperation and harmonization of guiding principles for site designation and management are considered as effective measures for the protection of high conservation value attributes (IUCN WCPA, 2019).

The issues on identification and management of HCVF are insufficiently analysed in previous research in BiH. Even though several authors provided guidelines for identification and management of HCVFs (IORAS et al. 2008; AVDIBEGOVIĆ et al. 2017a), covering the aspects of adaptation toward changes of FSC criteria and indicators, the cross-sectoral cooperation did not get needed attention as a tool for effective nature conservation. Compared to previous, forest policy research is more present in BiH and Western Balkan region, dealing with the use of the policy instruments in the process of nature protection, forest management and cross-sector cooperation. The aspects of nature protection policy implementation in some EU and Non-EU countries (PEZDEVŠEK MALOVRH et al. 2019b), and forestry activities in protected areas (POSAVEC et al. 2019) indicated the need for further research regarding the cross-sector cooperation and involvement of stakeholders in the nature protection process. Also, the importance of cross-sector cooperation in nature protection (MARIĆ, 2013; AVDIBEGOVIĆ et al. 2015) andforest management activities including the identification and management of HCVFs is identified in previous research (IORAS et al. 2009; AVDIBEGOVIĆ et al. 2017a; AVDIBEGOVIĆ et al. 2012; AVDIBEGOVIĆ et al. 2017b). Besides the overview of NATURA 2000 status in BiH (MILANOVIĆ et al. 2015), the issues related to this field are not covered by many research activities.

Considering that research activities on identification and management of HCVFs within potential NATURA 2000 sites are modest, the results of this paper can be useful for the key forest and nature protection policy-makers, as well as to those

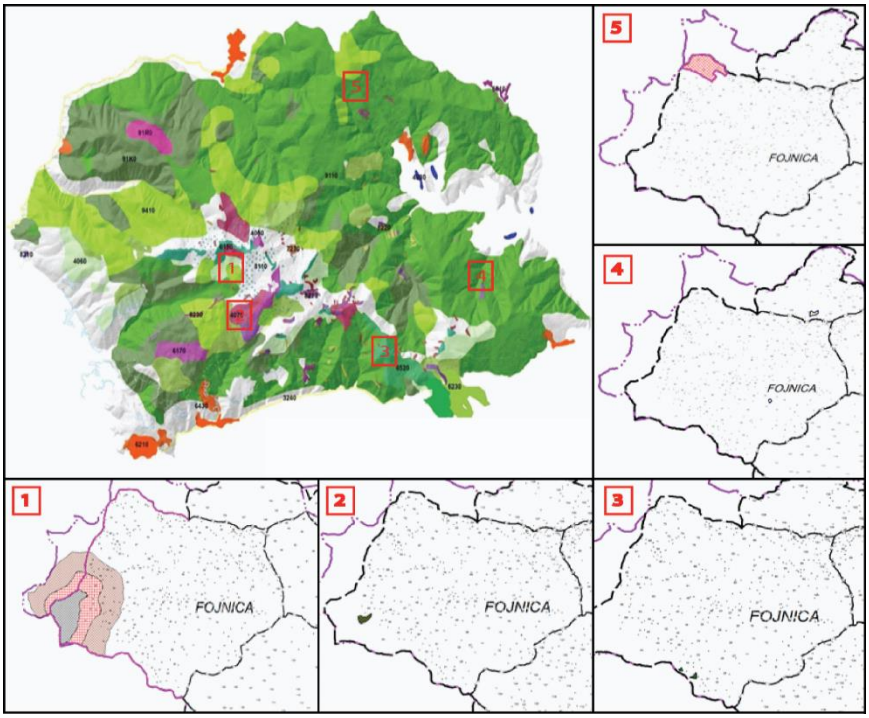
responsible for managing of protected areas. The results can be used by all actors directly or indirectly involved in the process of identification and management of HCVFs and NATURA 2000 sites, as well as scientific experts, the local communities and other non-governmental organizations. Harmonisation of guiding principles and cross-sectoral cooperation during the identification and management of HCVFs and NATURA 2000 forest habitats enable the proper implementation of conservation and management measures through sustainable forest management activities implemented by users and forest owners. In that manner, results presented in this paper can be useful for the wider public, as well as anyone interested in the process of identification and management of HCVFs within NATURA 2000 forest habitats.

RESEARCH AREA AND RESEARCH METHODS - *Područje i metode istraživanja*

Mountain Vranica is an important area for biodiversity conservation and thus it is one of the 122 sites proposed for the project NATURA 2000 in BiH (OFFICIAL WEB SITE OF THE FEDERAL MINISTRY OF ENVIRONMENT AND TOURISM(b) – Figure 1). The area incorporates many habitats and species considered endangered under the Berne Convention, as well as EU Birds and Habitats Directives. Moreover, due to extremely attractive natural and landscape values, in the recent decades, some areas (e.g. Prokoško lake) have been under extreme anthropogenic pressure, especially from the aspect of construction and continuous expansion of Prokos village. Around 87,2% of the Vranica Mountain is covered with forests (OFFICIAL WEB SITE OF THE FEDERAL MINISTRY OF ENVIRONMENT AND TOURISM(b)) and forestry plays an important role in maintenance and management. Considering that the most valuable and preserved forest ecosystems are consisting of mountain beech and its associations with spruce and fir in the northern part of the Vranica mountain, this area is of great importance not just from the economic, but also from the ecological and sociological point of view.

This research is based on case study research design that, according to YIN (2009), is common for contribution to the knowledge of individual, group, organizational, social, political and related phenomena. Therefore, the desk and field research methods have been used for data collection and analysis. The qualitative content analysis, as a technique for gathering and analysing the content of the text (NEUMAN, 2006), was used for determination of compliance (mutual harmonisation) between NATURA 2000 and HCVF principles. For that purpose, criteria for selection and designation of NATURA 2000 sites, as well as the criteria for selection of HCVFs in Vranica Mountain have been reviewed and compared. Besides, the qualitative filed research was conducted with the key stakeholders regarding the selection and designation of NATURA 2000 and HCVFs and the attitudes toward cross-sectoral cooperation in the nature conservation. During the field research, the trough in-depth face-to-face interviewing, qualitative data were collected containing the key stakeholders' attitudes regarding the harmonization of NATURA 2000 habitats with the

HCVFs, as well as the involvement of stakeholders in the processes of cross-sectoral cooperation when it comes to the identification of these sites.



1. Nature monument "Prokoško jezero"; 2. Habitat of mugo pine (Pinus mugo); 3. Habitat of green alder and yew tree (Alnus viridis and Taxus baccata); 4. Seed stand of beach and fir trees; 5. Habitat of western capercaillie (Tetrao urogallus L.)

Figure 1: The spatial distribution of NATURA 2000 and HCVFs in Vranica
Slika 1: Prostorni položaj NATURA 2000 staništa i HCVF šuma na Vranici

The initial selection of respondents was based on data gathered through the desk analysis, while during the interviewing process snowball sampling technique (NEUMAN, 2006) was used to identify missing representatives of key stakeholders. The initial interview was conducted with a representative of the Ministry of Foreign Trade and Economic Relations of BiH who was the coordinator of the project "Support to implementation of the Birds and Habitats Directives in BiH" (2012-2015). The next interview was conducted with the representative of ŠPD "Srednjobosanske šume" d.o.o. Donji Vakuf, that wasresponsible for the designation of certain areas of Vranica Mountain as HCVFs. The procedure of stakeholder nomination was followed when interviewing each new respondent, which resulted in the sample consisted of 9 respondents (Table 1).

Table 1: List of interviewed stakeholders and their abbreviations
Tabela 1: Lista intervjuisanih interesnih grupa i njihove skraćenice

Name of institution	Abbreviation
National level	
Ministry of Foreign Trade and Economic Relations of BiH	MVTiEO BIH
Entity level	
Ministry of Environment and Tourism Federation of BiH	FMOiT
Ministry of Agriculture, Water Management and Forestry of FBiH	FMPViŠ
Cantonal level	
Šumsko privredno društvo"Srednjobosanske šume"	ŠPD SBK
Ministry of Agriculture, Water Management and Forestry of the SBK	MPViŠ SBK
Ministry of Spatial Planning, Construction, Environment of the SBK	MPUGZOPiSP SBK
Cantonal forest office of the SBK	KUŠ SBK
Local level	
Municipality Fojnica	OF
Šumarija "Fojnica"	ŠF

To conduct qualitative research (i.e. collecting primary data) the guideline for structured in-depth interviews was created. It contained 13 questions divided into 3 groups: questions related to issues of harmonization between NATURA 2000 and HCVF principles, identification and management of HCVFs and NATURA 2000 forest habitats in Vranica Mountain, and attitudes related to the cross-sectoral cooperation in identification and management of these habitats. Qualitative research was conducted in the period July-December of 2018. Selected respondents expressed their positive, negative or neutral attitudes for most of the questions, therefore the results are presented in the form of opponent-advocate matrices.

RESULTS AND DISCUSSION - *Rezultati i diskusija*

Comparative analysis of NATURA 2000 and HCVF criteria for site designation - *Komparacija kriterija za identifikaciju NATURA 2000 i HCVF staništa*

NATURA 2000 network is aiming to ensure the long-term survival of Europe's most valuable and threatened species and habitats, listed under both EU Birds and Habitats Directives (OFFICIAL WEB SITE OF THE EUROPEAN COMMISSION (a)). Essentially, the network alleviates the negative consequences of habitat fragmentation, enable migration of the species, establish the functional link between protected natural resources and thus ensure the satisfactory status of species and habitats. NATURA 2000 sites are identified according to scientific criteria prescribed in the Directives to ensure that natural habitat types (listed in the directives' annexes) are maintained or, where appropriate, restored to a favourable conservation status in their natural range (OFFICIAL WEB SITE OF THE EUROPEAN COMMISSION (b)). Under the legal framework of Federation of BiH (FBiH), the government adopted REGULATION ON NATURA 2000 PROGRAM - PROTECTED AREAS IN EUROPE (2011) that prescribes

criteria for selecting sites that are in accordance to the NATURA 2000 EU Directives. According to the article 4 of the Regulation, these criteria apply to types of habitats, habitats of plant species and habitats of birds and other animal species in the FBiH listed as habitats and species whose conservation is of EU interest. Comparative analysis of criteria for designation of NATURA 2000 and HCVF sites are presented in Table 2.

Although BiH has no obligation to implement provisions prescribed with EU Habitat and Birds Directives, in recent period potential NATURA 2000 site were proposed (OFFICIAL WEB SITE OF THE FEDERAL MINISTRY OF ENVIRONMENT AND TOURISM(a)). Vranica Mountain area is one of 122 proposed NATURA 2000 sites in BiH. Approximately 25.158 ha of Vranica Mountain is designated to the NATURA 2000 (5% of the total area identified in BiH), comprising 22 habitat types from the Annex II of Habitats Directive (OFFICIAL WEB SITE OF THE FEDERAL MINISTRY OF ENVIRONMENT AND TOURISM(b)). Covering the same area, during the certification process public company ŠPD "Srednjobosanske šume" d.o.o. Donji Vakuf identified and designated 1.284,52 ha of HCVFs (ŠPD/ŠGD "SREDNJOBOSANSKE ŠUME"/"ŠUME SREDIŠNJE BOSNE" D.O.O. DONJI VAKUF, 2016). The HCVF concept is a part of voluntary forest certification systems, which requires from forest managers to identify any HCVs that occur within their forest management units, to manage them to maintain or enhance the values identified, and to monitor the success of this management through applying the precautionary approach (OFFICIAL WEB SITE OF THE FSC(b)). Considering that natural habitats possess inherent conservation values, including the presence of rare or endemic species, provision of ecosystem services, sacred sites, or resources harvested by residents, HCVs are defined by six categories (BROWN et al. 2013), while in BiH few subcategories emerges also (et al. 2008, AVDIBEGOVIĆ et al. 2017a).

Even though the NATURA 2000 and HCVFs concepts origin from different sectoral policies their overall objectives are similar. Both concepts seek to maintain, enhance, and promote the importance of identified attributes, advocating to ensure that activities in designated areas do not have a negative impact on biodiversity and the integral ecosystem, including forests as well. This means that these concepts are abutting, and moreover, since the approaches to conservation and sustainable use of areas largely rely on people working with nature rather than against it. Given that the aim of NATURA 2000 is to ensure the long-term survival of Europe's most valuable and threatened species and habitats, this concept is compact to categories of HCV 1 (Species diversity) and HCV 3 (Ecosystems and habitats), which are presented in Table 2.

Table 2: Comparative analysis of criteria for designation of NATURA 2000 and HCVF sites
Tabela 2: Komparacija kriterija za identifikaciju NATURA 2000 i HCVF staništa

NATURA 2000	HCV
Site assessment criteria for a given natural habitat type in Annex I	**Site assessment indicators for HCV 1: Species Diversity Concentrations of biological diversity including endemic species, and rare, threatened or endangered species that are significant at global, regional or national levels.**
– Degree of representativeness of the natural habitat type on the site – Area of the site covered by the natural habitat type concerning the total area covered by that natural habitat type within the national territory – Degree of conservation of the structure and functions of the natural habitat type concerned and restoration possibilities – Global assessment of the value of the site for conservation of the natural habitat type concerned	– The presence of a recognized biodiversity priority area (e.g. IUCN recognised Protected Area, Ramsar Site, UNESCO World Heritage Site etc.) – A designation by national authorities, or by reputable conservation organizations, recognizing concentrations of biodiversity – The presence of natural habitat in good condition within such designations is a strong indicator of the presence of HCV 1
Site assessment criteria for a given species in Annex II	**Site assessment indicators for HCV 3: Ecosystems and habitats Rare, threatened, or endangered ecosystems, habitats or refugia**
– Size and density of the population of the species present on the site concerning the populations present within the national territory – Degree of conservation of the features of the habitat which are important for the species concerned and restoration possibilities – Degree of isolation of the population present on the site concerning the natural range of the species – Global assessment of the value of the site for conservation of the species concerned	– In regions where many natural ecosystems or habitats have been eliminated, and others have been heavily impacted by development, remaining natural ecosystems of reasonable quality are likely to be HCV 3 – Where ecosystem proxies indicate the presence of RTE ecosystems, even if these are inaccessible or have not been confirmed on the ground.

Source: Regulation on NATURA 2000-protected areas in Europe, 2011; Brown et al. 2013; Avdibegović et al.2017

According to BROWN et al. (2013), HCV1 encompass significant concentrations of biodiversity that are recognized as unique or outstanding compared to other areas or recognized based on priority frameworks, through field assessments and consultations. In that regard following could be qualified as HCV1:

- a high overall species richness, diversity or uniqueness within a defined area when compared with other sites within the same biogeographic area;
- populations of multiple endemic or RTE (i.e. rare, threatened or endangered) species;

- important populations or a great abundance of individual endemic or RTE species, representing a substantial proportion of the regional, national or global population needed to maintain viable populations, either year-round (e.g. key habitat for a specific species) or seasonally, including migratory corridors, sites for breeding, roosting or hibernation, or refuges from disturbance;
- small populations of individual endemic or RTE species, in cases where the national, regional or global survival of that species is critically dependent on the area in question;
- sites with significant RTE species richness, or populations (including temporary concentrations) of priority species approaching those of key protected areas or other priority sites within the same biogeographic boundary;
- particularly important genetic variants, subspecies or varieties.

For the purposes of assessment, HCV1 BROWN et al. (2013) defined term 'rare', which includes naturally rare species, existing only at very low densities in undisturbed habitat, or rare because of human activities, and at the limit of their natural distribution. Threatened and endangered species include species classified by IUCN as vulnerable, endangered and critically endangered at a global or regional level, or whose trade is regulated under international agreements (e.g. CITES), as well as protected species by the national legal framework. Endemic species are those found within a restricted geographical region, which may range from a unique site or a geographical feature to a political boundary such as a province or country (BROWN et al. 2013).On the other hand, as mentioned before EU Habitats Directive defines criteria for site assessment of species listed in Annex II, which are size and density of the population of the species present on the site concerning the populations present within the national territory, degree of conservation of the features of the habitat which are important for the species concerned and restoration possibilities, degree of isolation of the population present on the site concerning the natural range of the species, global assessment of the value of the site for conservation of the species concerned (COUNCIL DIRECTIVE 92/43/EEC).

Along with HCV1, category of HCV3 is also interest in terms of harmonization with the concept NATURA 2000. According to BROWN et al. (2013), HCV 3 includes ecosystems, habitats or refugia of special importance because of their rarity or the level of threat that they face, or their rare or unique species composition or other characteristics. To define rare ecosystems, one must consider the presence of similar ecosystems in the same biogeographic region and/or country. The size, age, structure and species composition of an ecosystem may also be important criteria. Thus, the following would qualify as HCV3:

- ecosystems that are naturally rare because they depend on highly localised soil types, locations, hydrology or other climatic or physical features, such as some types of limestone karst forests, inselbergs, mountain forest, or riverine forests in arid zones;
- anthropogenically rare, because the extent of the ecosystem has been greatly reduced by human activities compared to their historic extent;

- threatened or endangered (e.g. rapidly declining) due to current or proposed operations;
- classified as threatened in national or international systems.

Within concept NATURA 2000, EU Habitats Directive defines criteria for site assessment of natural habitat type listed in Annex I. For identifying these sites degree of representativeness of the natural habitat type on the site, area of the site covered by the natural habitat type concerning the total area covered by that natural habitat type within the national territory, degree of conservation of the structure and functions of the natural habitat type concerned and restoration possibilities, and global assessment of the value of the site for conservation of the natural habitat type concerned are taking into account (COUNCIL DIRECTIVE 92/43/EEC).

Key stakeholders' attitudes on compliance of NATURA 2000 and HCVFs sites in the Vranica Mountain – *Stavovi ključnih aktera u vezi usklađenosti NATURA 2000 HCVF staništa na planini Vranici*

Along with the qualitative content analysis of the relevant documents the data about attitudes of key stakeholders regarding the compliance of NATURA 2000 and HCVFs sites in the Vranica Mountain was conducted. Special attention was dedicated to the participation process and the cross-sectoral cooperation when it comes to the identification of these sites. In that sense, all stakeholders recognized that harmonization of HCVF and NATURA 2000 sites can contribute to maintaining or improving the identified attributes. Furthermore, the harmonization level between the NATURA 2000 and HCVF principles, in terms of identification processes, attributes, management measures and managerial jurisdiction, was conducted (Table 3).

The majority of respondents have similar attitudes, except for the Cantonal Forestry Administration, which gave the lowest grade to all assessed categories. Other respondents gave intermediate grades (3-4), stating that identification processes are quite harmonized, given that both processes are based on scientific criteria. On the other hand, representative of the Cantonal Forestry Administration explained the response, indicating that these processes should be harmonized due to similar outcomes. This means that certain natural values should be recognized, and cooperation between nature conservation and other stakeholders is essential.Similar grades are given for the harmonization of identified attributes with the additional explanation that these processes are not fully aligned, since HCVF encompasses a wider range of natural and cultural attributes that are considered valuable, while NATURA 2000 focuses only on the protection of habitats and endangered species of flora and fauna, with particular reference to the birds' protection. The majority of respondents rated management measures with the highest grade, explaining that for the protection of identified attributes, management activities that have a scientific background or best practice experience could be applied. On the other hand, representative of the Cantonal Forestry Administration has the opposite opinion, indicating that NATURA 2000 has management measures that are under the Law

on Nature Protection. However, the forestry sector was modestly involved in most of the nature conservation activities implemented in BiH.

Table 3: Assessment of harmonization between NATURA 2000 and HCVF principles concerning identification processes, attributes, management measures and management rights
Tabela 3: Ocjena usaglašenosti principa NATURA 2000 i HCVF kada su u pitanju procesi identifikacije, atributi, mjere gospodarenja i upravljačka nadležnost

Stakeholders	Harmonization NATURA 2000 and HCVF principles (1 - not harmonized … 5 – fully harmonized)			
	Identification processes	Attributes	Management measures	Management rights
MVTiEO BIH	-	-	-	-
FMOiT	4	4	5	-
FMPViŠ	4	4	5	4
MPUGZOPiSP SBK	3	3	-	5
MPViŠ SBK	3	4	4	2
KUŠ SBK	2	2	1	3
ŠPD SBK	4	4	4	3
OF	-	-	-	-
ŠF	3	3	4	3

Attitudes of the respondents differed when it comes to the assessment of compliance in terms of management rights. Some of them considered that management rights should be harmonised due to the fact the same area and activities are treated, and therefore the effectiveness could be improved if institutions manage the whole area. On the other hand, some stakeholders stressed out that NATURA 2000 fall under the responsibility of ministries related to nature protection, while HCVF is exclusively under the responsibility of the forestry sector and therefore the management measures, in most of the cases, are not harmonised. It is quite obvious that for the effective nature conservation cross-sectoral cooperation is needed. According to the EU Habitat Directive, there are three possible types of conservation measures for NATURA 2000 sites (OFFICIAL WEB SITE OF THE FEDERAL MINISTRY OF ENVIRONMENT AND TOURISM(b)):

- legal: protected areas established by a legal act;
- administrative: measures resulting from other regulations, e.g. solutions under the Law on Forests;
- contractual: the legal entity responsible for managing NATURA 2000 sites draws up an appropriate contract with the owner regarding specific measures in the area.

Having in mind that more than one type of measures is foreseen by NATURA 2000, it is certain that HCVF concept can be incorporated into the NATURA 2000 sites where they spatially overlap and where the valuable attributes are the same. The management activities must meet ecological requirements of target species and habitat, as well as be in accordance to the national legal framework.

The assessment of cross-sectoral cooperation in identification and management of NATURA 2000 habitats and HCVF on Vranica Mountain – *Ocjena međusektorskog pristupa prilikom identifikacije i upravljanja NATURA 2000 staništima i HCVF šumama na području planine Vranice*

The cross-sectoral cooperation, as a principle for effective nature conservation, is supported by all respondents. Respondents explained that, during the identification of sites on Vranica Mountain, there were continuous dialogue, meetings and workshops, while anyone interested could get enough information and be involved in these processes. Moreover, these processes were also present in media, whether through official sites, social networks, radio/TV stations and other types of promotional means. In that way, information was available to other groups that were not involved in these processes directly and they had the opportunity to learn about it. However, those respondents that were not directly involved in the identification of both NATURA 2000 and HCVFs stressed out that cross-sectoral cooperation should be improved. These attitudes were explained by the lack of timely provided information, while decision-making without the involvement of all stakeholders resulted with lack of cooperation during the identification process (Table 4).

Table 4: Presence of the cross-sectoral cooperation in the process of identification/designation NATURA 2000/HCVFs in the Vranica Mountain

Tabela 4: Prisustvo međusektorske saradnje u procesu identifikacije/izdvajanja NATURA 2000/HCVF na području planine Vranice

Admin. level	NATURA 2000			HCVF		
	Yes	**Neutral**	**No**	**Yes**	**Neutral**	**No**
National	MVTiEO BIH				MVTiEO BIH	
Entity	FMOiT					FMOiT
	FMPViŠ				FMPViŠ	
Cantonal			MPUGZOPiSP SBK			MPUGZOPiSP SBK
			MPViŠ SBK			MPViŠ SBK
	KUŠ SBK			KUŠ SBK		
			ŠPD SBK	ŠPD SBK		
Local			OF	OF		
			ŠF	ŠF		

Furthermore, these respondents pointed out that the involvement of all stakeholders would contribute to the wider (cross-sectoral) perspective related to nature conservation issues. There is a common understanding that cross-sectoral cooperation is required during the implementation of all measures and activities related to NATURA 2000 and HCVFs sites.

Stakeholders suggested the following key measures for improvement of the management process related to NATURA 2000 habitats and HCVFs in the Vranica Mountain:

- to establish a management structure based on transparency, and to assign management role to one of the existing institutions;
- to involve all stakeholders and interest groups in these processes through the establishment of continuous dialogue, besides the formal meetings and presentations;
- to ensure funding for conservation of identified attributes, conduct field research and detailed inventory, to determine their status.
- to organize continuous monitoring;
- to develop more comprehensive and realistic management plans, and to implement specific management measures;
- to increase inspection control and the technical and human capacities for control of the most visited tourist areas;
- to include these areas in the legislative framework, management programs and spatial planning documents, as well as to develop strategic studies at the level of FBiH, and improve management planning for overall protection of the Vranica Mountain;
- to initiate cross-sectoral policy harmonisation and cooperation.

Key stakeholders recognised and outlined the most important aspects for effective nature conservation and stressed out that cross-sectoral cooperation, transparency and participation have to be respected during identification and management processes. Furthermore, enhancement of continuous monitoring, as well as the integration of existing plans and studies into spatial documentation depends on political and financial support.

CONCLUSIONS – *Zaključci*

Natural values recognized and protected by ecological network NATURA 2000 or concept HCVFs are often perceived as protected areas in line with the national legal framework. There is increasing demand toward organizations dealing with the management of all types of protected areas, in terms of sustainable management, contribution to livelihood and rural development, as well as protection of natural ecosystems. This can be achieved by synergies between traditional nature conservation and forest policy actors and other interest groups.

Designation of HCVFs within NATURA 2000 forest habitats has many advantages and enables the institutional and legal protection since a significant share of these areas are managed by public forest management companies. The results of this research indicate that during identification and management of NATURA 2000 and HCVFs multidisciplinary and cross-sectoral approach should be promoted, alongside

with mutual harmonisation all activities. This is a precondition for cooperation of nature protection sector and forestry directed toward the protection of natural values in general. Even though Natura 2000 and HCVF concepts have the same outcomes, still there is no common framework on harmonisation between HCVFs and NATURA 2000 concepts. Collaboration between the nature protection and forestry sectors is relatively poor and uncoordinated.

Having in mind criteria for identification of Natura 2000 sites and HCVFs, it can be concluded that these concepts are compatible in terms of their use in the same area. This means that the combination of these concepts can contribute to the effective protection of natural values. It is important to emphasize that the HCVFs concept has wider application, in terms of defining high conservation values and geographical area, compared to NATURA 2000. Categories HCVF 1 (Species diversity) and HCVF 3 (Ecosystems and habitats) are in line with NATURA 2000 criteria defined by Annex III EU Habitat Directive.

All stakeholders support cross-sectoral cooperation as one of the key principles in the harmonisation of NATURA 2000 habitats and HCVFs in the Vranica Mountain. In this regard, strengthening the cross-sectoral cooperation and continuous dialogue is supported by all stakeholders. One can conclude that continuous information flow, as well as development and implementation of the communication strategy, is required for future effective cooperation. Furthermore, this should be supported by anadequatelegal framework that enhances cross-sectoral cooperation and harmonisation of the legal framework related to nature protection and forestry. Due to lack of research activities related to identification and management HCVFs within the NATURA 2000 habitats, it is recommended to create a consistent set of educational programs and training for all key stakeholders and interest groups.

The results presented in this paper may provide a useful basis for defining a consistent set of guiding principles for areas where HCVFs are overlapping with other forms of protected areas. Further analysis of these issues should be focused on understanding the institutional, policy, financial, legal and technical preconditions for institutionalisation and operationalisation of HCVF concept as a voluntary forest policy instrument for nature protection. For further research, this paper can provide guidelines for analysis of criteria for site designation, assessment of cross-sectoral cooperation and compliance in identification and management of HCVFs within NATURA 2000 habitats.

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SAŽETAK

Zaštita prirode i održivo gospodarenje šumskim resursima postaju sve važniji u Bosni i Hercegovini, podstaknuti procesom pridruživanja Evropskoj Uniji i drugim međunarodnim procesima koji su usmjereni prema odgovornom gospodarenju šumskim resursima. Certificiranje šuma je u velikoj mjeri prihvaćno u sektoru šumarstva. Ovaj proces podrazumijeva dostizanje standarda održivog gospodarenja šumskim resursima koji uključuju identifikaciju i odgovarajuće gospodarenje šumama visoke zaštitne vrijednosti. Ekološka mreža NATURA 2000 postaje važan pokretač procesa reformi u sektorima zaštite prirode i šumarstva, zbog toga što se proglašenje novih područja dešava na teritoriji koja je pod nadležnošću institucija iz sektora šumarstva. Ovim radom se prikazuje naučno razumijevanje procesa identifikacije i gospodarenja šumama visoke zaštitne vrijednosti koje su uspostavljene na potencijalnim NATURA 2000 staništima. Rad je zasnovan na analizi principa za izdvajanje područja i razumijevanju uloge međusektorskog pristupa u procesu identifikacije i gospodarenja područjima sa atributima visoke zaštitne vrijednosti. Rad je koncipiran kao studij slučaja, a odabrana je planina Vranica zbog aktivnosti koje su implementirane na ovom području. Metodom intervjuisanja su prikupljeni kvalitativni podaci o stavovima ključnih aktera u vezi sa usaglašavanjem NATURA 2000 staništa i HCVF šuma i njihovoj uključenosti u proces međusektorske saradnje. Rezultati ovog rada mogu biti od koristi ključnim donosiocima odluka u sektoru šumarstva i zaštite prirode, onima čija je odgovornost upravljanje zaštićanim područjima, kao i drugima akterima koji su direktno ili indirektno uključeni u proces identifikacije i gospodarenja NATURA 2000 staništima i HCVF šumama. Usklađivanje osnovnih principa i međusektorska saradnja tokom identifikacije i gospodarenja HCVF šumama i NATURA 2000 staništima omogućava odgovarajuću implementaciju zaštitnih i gospodarskih mjera zasnovanih na aktivnostima održivog gospodarenja šumskim resursima.

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USING DIATOMS IN BIOLOGICAL ASSESSMENT OF THE WATER QUALITY ON THE EXAMPLE OF SMALL KARSTIC RIVER IN BOSNIA AND HERZEGOVINA

Korištenje dijatomeja u biološkoj procjeni kvalitete vode na primjeru male krške rijeke u Bosni i Hercegovini

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Abstract

Research into the benthic diatoms in the Bunica River was performed during the period from 5th May 2013 to 9th January 2014 on three different sites, from the headwaters to the mouth. The Bunica River is located in the south-eastern part of the Mostar valley, in the south of Bosnia and Herzegovina. The aim of this research was to test the use of benthic diatoms as indicators and the use of diatom indices as a tool for estimating water quality in an example of a small karstic river. For that purpose, diatom indices were calculated using OMNIDIA GB 5.3 software. This was the first testing of diatom indices for a small karstic river. Diatom indices showed different results and huge variations between sites on the Bunica River. According to the results, the indices in the OMNIDIA software are not applicable for karstic rivers in Bosnia and Herzegovina and they must be modified for this purpose. This paper can be the first step towards calibration indices for karstic region. Also, it can be useful for the development of biomonitoring tool for karstic rivers in Bosnia and Herzegovina.

Keywords: diatoms, diatom indices, water quality, Bosnia and Herzegovina, OMNIDIA

INTRODUCTION - *Uvod*

Diatoms are a good environmental indicator and are often the main component of phytobenthos and phytoplankton in surface water bodies, representing an important element in aquatic ecosystems and one of the most important groups of algae for monitoring activities (KELLY et al*.,* 1998). Diatom based assessment of environmental conditions in rivers and streams has a long history and different approaches such as pollution levels on the one hand and biodiversity on the other. According to this, diatoms are being used to assess ecological conditions in streams and rivers around the world (KELLY et al., 1998; WU 1999., LOBO et al., 2004, PORTER et al., 2008). Diatoms are widespread and can be found in almost any type of running water. A combination of

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short generation time and ability to clearly designate nutrient status of their habitat, makes them a great indicator of water quality. Therefore, benthic diatoms are often used for assessing nutrient enrichment (KELLY, PENNY & WHITTON, 1995; ROTT et al., 1997, 1999; CORING, 1999), salinity (ZIEMANN, 1999) and acidity (CORING, 1993; BATTARBEE et al., 1997; VAN DAM, 1997). Consequently, several studies have addressed the tolerances and preferences of diatoms along with a number of environmental gradients; salinity, pH, trophy, saprobity (DENYS, 1991; VAN DAM, MERTEN & SINKELDAM, 1994; ROTT et al., 1997). The European Water Framework Directive (WFD; The European Parliament & European Council, 2000) establishes a framework for the protection of water resources. According to the Water Framework Directive, European Union member states and candidate states are required to achieve a good ecological status for all rivers. The European Water Framework Directive (WFD; The European Parliament & European Council, 2000) considers benthic diatoms as one of the key groups of organisms for assessing the ecological quality of rivers. Some studies show that diatom metrics detect eutrophication effects better than metrics calculated using fish, macroinvertebrates and macrophytes and they respond most strongly to land-use gradients (HERING et al., 2006). Many indices have also been developed to illustrate general water quality, mostly reflecting organic load or/and nutrient concentration level (WATANABE et al., 1986; LECLERCQ & MAGUET 1987; COSTE & AYPHASSORHO 1991; DESCY & COSTE 1991; SCHIEFELE & SCHREINER 1991; KELLY & WHITTON 1995; PRYGIEL et al. 1996; PRYGIEL, 2002). In most European countries those have been adopted as the routine monitoring method of biological quality elements for ecological status assessment in rivers.

In this study we used multimeric diatom indices calculated by OMNIDIA software as a tool for estimating the river water quality and ecological status. It presents the relationship between measured water quality variables in the Bunica River and diatom indices scores. Diatom indices scores were calculated and correlated to concurrent physical and chemical water quality data.

The aim of this study is to test diatom indices in ecological status assessment on an example of a small karstic river, Bunica, in the south of Bosnia and Herzegovina.

Study area

The Bunica River is a short, only 5.8 km long, karstic river. It flows in the south of Bosnia and Herzegovina and belongs to the Neretva river basin. Bunica River is a tributary of the Buna River. The spring of the Bunica River is of the siphon character and it is the underground extension of the Zalomka River flow. The spring depth is 73 m and it is one of the largest sources of the Dinaric karst (MILANOVIĆ, 2006). This study was conducted at three sampling stations named Bunica 1 (spring area: N: 43°13'11.81" E: 17°53' 29.95"), Bunica 2 (middle part of longitudinal flow: N: 43°14' 95" E: 17°51' 42.92") and Bunica 3 (mouth of Bunica to Buna river: N: 43°14' 39,53" E: 17°51.8' 26") (Figure 1).

Figure 1. Research area site
Slika 1: Područje istraživanja

MATERIALS AND METHODS - *Materijal i Metode*

Samples were collected from the three sites in different seasons (spring, summer, autumn and winter) in the small karstic Bunica River. Diatoms were collected using the standard procedure of scraping materials from the surface of rocks (EN 13946, 2003). The upper surface of each rock was scratched with a scalpel and carefully brushed with a toothbrush. The samples were preserved in 4% formaldehyde and stored in appropriately labelled bottles. According to standard procedure samples were cleaned of organic matter with concentrated sulphuric acid, potassium-permanganate and oxalic acid (KRAMMER & LANGE-BERTALOT, 1986). The obtained material was used for permanent diatom microscope slide preparation. The composition and relative abundance of diatoms were estimated at 1000X magnification, using a light microscope Carl Zeiss Jena. At least 400 valves were counted. Identification and nomenclature were based on relevant scientific literature and keys; KRAMMER & LANGE - BERTALOT (1986 - 1991), LANGE-BERTALOT & KRAMMER (1989), LANGE-BERTALOT & METZELTIN (1996) LANGE – BERTALOT (1993, 2001), KRAMMER (2000 - 2003), KRAMMER & LANGE – BERTALOT (1997a, 1997b, 2004) and LEVKOV (2009). The

nomenclature of taxa was determined by the nomenclature set out in algae base (GUIRY and GUIRY, 2019). Simultaneously with benthic samples, physical and chemical parameters (pH, electric conductivity, dissolved oxygen, oxygen saturation and temperature of water) were measured using a field measuring probe Hach Sension probes 156. Also, samples for nutrients analyses were taken and were processed in the standard spectrophotometric method in an accredited laboratory to valid norms, in the Laboratory of Public Health Mostar. The following chemical parameters were analyzed: chemical oxygen demand, nitrate, nitrite, total nitrogen, total phosphorus, orthophosphate and silica. The correlation between parameters and diatom indeces score was estimated with the Pearson Correlation Coefficient. Indices were calculated using OMNIDIA GB 5.3 software (LECOINTE et al., 1993). The diatom taxa counts were entered into the diatom database and indices calculation tool. Indices taken into account for the assessment of water quality are those with the highest proportion of species accounted for in the calculation. The following indices were used: EPI-D (DELL'UOMO A., 1996), IBD (LENOIR & COSTA, 1996), SHE (SCHIEFELE & SCHREINER, 1988-91), SID (ROTT et al., 1997), TID (ROTT et al., 1999), IPS (CEMAGREF, 1982), SLA (SLÁDEČEK, 1986), IDSE (LECLERCQ & MAQUET, 1987), IDG (CEMAGREF, 1982-90), CEE (DESCY et al., 1988) and TDI (KELLY & WHITTON, 1995). Indices can be divided into three different categories; indices which show global warming; saprobity and trophy indices. All values of indices in OMNIDIA software are ranged from 1 to 20 and show five different ecological statuses (Tab. 1). The software shows ecological characteristics of species: life form, pH values, salinity, dissolved nitrogen, necessary for oxygen, saprobity, trophicity and other indicators. Except for the above mentioned, it calculates diversity and distribution of species.

Table. 1. Ranges of the diatom indices and ecological status (ELORANTA & SOININEN, 2002).
Tabela 1. Raspon dijatomnih indeksa i ekološki status (ELORANTA & SOININEN, 2002)

Status	**Values**	**Colour**
High	> 17	Blue
Good	15-17	Green
Moderate	12-15	Yellow
Poor	9-12	Orange
Bad	< 9	Red

RESULTS - *Rezultati*

Physico-chemical and chemical variables

The main abiotic variables measured in the Bunica River are shown in Table 2. Data of physical and chemical variables show low concentrations of nutrients, good aeration, pH typical for carbonate bed/origin and generally oligotrophic conditions. According to the measured parameters water quality in the Bunica River has a high

ecological status, corresponding to a natural status without anthropogenic influence (Official Gazette FBiH, No. 70/06). Physico-chemical and chemical conditions in water were statistically insignificant and low correlated with values of the used indeces. In contrast, the values of indices are significantly correlated with each other ($p < 0.05$) (Tab. 5). Indices showed variations in results from high to low ecological status (I-V class), completely deviating from the state of water gained on the basis of the physico-chemical parameters (I class).

Table 2. The main abiotic variables in the Bunica River (12 samples).
Tabela 2. Glavne abiotičke varijable u rijeci Bunici (12 uzoraka).

SITES	Season	Chemical oxygen demand (mg/L)	Ammonium (mg/L)	Nitrate (mg/L)	Total nitrogen (mg/L)	Silica (mg/L)	Total phosphorus (mg/L)	Orthophosphate (mg/L)	Temperature (C°)	pH	Conductivity (µs/cm)	Dissolved Oxygen (mg/L)	Oxygen saturation (%)
BUNICA 1	spring	1.15	0	0.184	0.305	2.685	0.006	0.003	13.7	7.9	313	11.98	116
	summer	1.28	0	0.34	0.42	3.0	0.011	0.004	14.2	8	390	12.25	119.3
	autumn	0.77	0	0.453	0.615	4.8	0.009	0.005	12	7.79	384	9.65	90.1
	winter	0.89	0	0.447	0.54	4.048	0.006	0.002	11.3	7.6	403	11.25	102.4
BUNICA 2	spring	1.00	0	0.180	0.3	3.1	0.005	0.003	14.1	7.8	314	12.8	120
	summer	1.28	0	0.292	0.374	3.109	0.01	0.002	15.5	7.9	384	12.77	127.9
	autumn	2.43	0.003	0.372	0.489	4.711	0.006	0.003	13.8	7.76	382	12.02	90.1
	winter	3.58	0	0.492	0.555	4.364	0.004	0.002	11.4	7.8	406	11.48	104.1
BUNICA 3	spring	1.10	0	0.182	0.31	3.15	0.005	0.003	14.7	7.86	312	13.28	132
	summer	1.28	0	0.279	0.375	3.148	0.008	0	15.3	7.9	384	12.59	125.6
	autumn	1.28	0.003	0.351	0.464	4.099	0.006	0	17	7.84	375	11.71	122.3
	winter	0.89	0	0.439	0.526	4.207	0.006	0.005	11.4	7.8	406	11.43	103.4

General taxonomic analysis

During the research period 147 diatom taxa were identified in the Bunica River. The most numerous genera were: *Gomphonema* (with 23 taxa) and *Navicula* (18 taxa). *Meridion circulare* (Greville) C. Agardh and *Ulnaria ulna* (Nitzsch) P. Comparé were recorded in all samples. All sampling stations had similar species richness in all seasons. Number of taxa at Bunica 1 ranged from 30 (in winter and summer) to 43 (in autumn), for Bunica 2 from 33 (spring) to 53 (autumn) and for Bunica 3 from 40 (summer) to 49 (autumn). The most abundant taxa at the Bunica 1 site were: *Encyonema ventricosum* (C.Agardh) Grunow, *Encyonema silesiacum* (Bleisch) D.G.Mann and *Planothidium lanceolatum* (Brébisson ex Kützing) Lange-Bertalot; at Bunica 2 *Halamphora veneta* (Kützing) Levkov, *Cocconeis euglypta* (Ehrenberg) Grunow and *Cocconeis placentula* Ehrenberg and at Bunica 3 *Gomphonema olivaceum* (Hornemann) Brébisson, *Achnanthes* sp. and *Cocconeis placentula* var. *klinoraphis* Geitler.

Diatom indices

In our study eleven (11) OMNIDIA indices were selected: EPI-D (DELL'UOMO A., 1996), IBD (LENOIR & COSTE, 1996), SHE (SCHIEFELE & SCHREINER, 1988-91), SID (ROTT et al.,1997), TID (ROTT et al.,1999), IPS (CEMAGREF, 1982), SLA (SLÁDEČEK, 1986), IDSE (LECLERCQ & MAQUET, 1987), IDG (CEMAGREF, 1982-90), CEE (DESCY et al., 1988) and TDI (KELLY & WHITTON, 1995). The values of applied indices are shown in Table 3 (Tab. 3) and the water quality classes in Table 4 (Tab. 4). The highest percentage of involved taxa was IDG (100%) and IPS (95-100%), while others had ranges between 60 and 95%.

Table 3. Values of diatom indeces for the Bunica River.
Tabela 3. Vrijednosti dijatomnih indeksa za rijeku Bunicu.

Index / Station/Season		EPI-D	IBD	SHE	SID	TID	IPS	SLA	IDSE	IDG	CEE	TDI
BUNICA 1	spring	15.6	18.6	17.6	14.5	7.1	16.2	13.1	3.9	17.9	15.8	11.5
	summer	15.2	19	14.8	13.5	7.1	17.4	12.5	4.2	16.7	17	9.4
	autumn	14.3	19.3	16.1	14.4	8.3	18.2	12.9	4.15	18.4	17	10.4
	winter	17.1	14.8	13.9	13	5.1	16.6	14.4	3.8	16.4	14.5	8.2
BUNICA 2	spring	9.6	10.5	10.5	8.3	4.9	8.9	8.5	3.01	11.7	12.4	4.6
	summer	15	16.7	15.4	13.6	7.8	16.2	12	3.65	14.5	14.5	7.5
	autumn	16.2	17.1	18.2	16.6	12.6	17.7	13.1	4.19	13.4	18.7	9.9
	winter	15.8	16.5	14.3	13.7	7.5	16.5	12.5	3.98	16.2	16.6	12.3
BUNICA 3	spring	14.5	18	13.9	12.7	6.6	17.7	11.1	3.93	15.7	15.8	6.2
	summer	15.3	13.2	14.6	18.8	11	15.1	11.3	3.03	14.2	14.5	9.1
	autumn	14.4	15.1	16.1	15.7	9.3	17.1	12	3.79	13.6	16.4	9.6
	winter	15.6	18.5	14.2	13.2	6.9	18.5	10.9	3.75	16.2	15.8	5.2

Table 4. Water quality classes according to OMNIDIA interpretation indeces.
Tabela 4. Razredi kvalitete vode prema interpretaciji OMNIDIA indeksa.

Index / Station/Season		EPI-D	IBD	SHE	SID	TID	IPS	SLA	IDSE	IDG	CEE	TDI
BUNICA 1	spring	II	I	I	III	V	II	III	II	I	II	IV
	summer	II	I	III	III	V	I	III	II	II	I	IV
	autumn	III	I	II	III	V	I	III	II	I	I	IV
	winter	I	III	III	III	V	II	III	II	1	III	V
BUNICA 2	spring	IV	IV	IV	V	V	IV	V	III	IV	III	V
	summer	II	II	II	III	V	II	III	II	III	III	V
	autumn	II	I	I	II	III	I	III	II	III	I	IV
	winter	II	II	III	III	V	II	III	II	II	II	III
BUNICA 3	spring	III	I	III	III	V	I	IV	II	II	II	V
	summer	II	III	III	I	IV	II	IV	III	III	III	IV
	autumn	III	II	II	II	IV	I	III	II	III	II	IV
	winter	II	I	III	III	V	I	IV	II	II	II	V

A significant positive correlation ($p<0.05$) was established between several indices (Tab. 5). The most significant correlation with nine indices was shown by SHE, IPS (with seven), IBD, CEE and SLA (with five). The highest correlation was established between the IBD and IDSE index, IBD and IPS, IDG, CEE, and IDSE and CEE indices.

Table 5. Pearsons correlation ($p < 0.05$) between diatom indices. (* correlation is significant)
Tabela 5. Pearson-ova korelacija ($p < 0,05$) između dijatomnih indeksa (značajna korelacija)*

	EPI-D									
IBD		IBD								
SHE	0.626*	0.612*	SHE							
SID	0.629*		0.709*	SID						
TID			0.673*	0.846*	TID					
IPS	0.800*	0.841*	0.667*			IPS				
SLA	0.843*		0.683*			0.666*	SLA			
IDSE		0.847*	0.618*			0.772*	0.678*	IDSE		
IDG		0.780*				0.624*	0.603*	0.604*	IDG	
CEE		0.719*	0.766*		0.593*	0.770*		0.854*		CEE
TDI			0.669*				0.689*			0.592*

Omnidia interpretation of Shanon-Weaver diversity index *H* were ranged between 2.42 and 3.46 for Bunica 1; 2.81-3.82 for Bunica 2; and 2.72-3.15 for Bunica 3.

Bunica 1:

According to the OMNIDIA results the Bunica 1 site showed a low degradation and antrophogenic eutrophication, and non-existent organic pollution. Values of indices were shown in the differences in results. According to IPS, IDSE and IDG indices the water quality at the Bunica 1 site is I-II class (high to good ecological status) (Tab. 3, 4). Saprobic indices showed III class (moderate ecological status), while trophic indices TDI and TID showed IV-V class water quality (poor to bad ecological status) (Tab. 3, 4). The percentage of species tolerant to pollution (% PT) is very low, in the spring was 0.3 %, and in the summer 1.8 %, while in autumn and winter presence of % PT is not recorded. Almost all taxa are neutrophile in view of pH values. One expectation was in winter when there were more alaliphilic taxa. In the summer period there were determined alpha meso-saprobic taxa with more abundant taxa sensitive on pollution (LANGE-BERTALOT, 1979, OMNIDIA). Saprobic indices values showed more alpha mesosaprobic taxa with the exception of the spring period. In the spring period there were more oligo-betamesosaprobic and betamesosaprobic taxa. According to the trophic indices values more taxa were tolerant and oligo-betamesosaprobic (HOFFMAN, 1994, OMNIDIA) or eutrophic in the winter period (VAN DAM, 1994, OMNIDIA).

Bunica 2:

According to OMNIDIA indicator values, Bunica 2 showed low degradation, organic pollution which is non-existent and antrophogenic eutrophication which is moderate in summer and low in winter time. At the station Bunica 2, depending on the season, quite a large variation was observed in water quality. The spring sample is the most different from all the other samples. According to the indices of global pollution, the spring period was moderate to poor (III-IV class) in ecological status, with communities under significant anthropogenic influence (Tab. 3, 4). The trophic state was bad according to the TID and TDI indices, while according to the SHE it was poor (Tab. 3, 4). The values of saprobic indices also present a bad ecological status, which highlights the existence of strong organic pollution. According to the percentage of pollution tolerant taxa (% PT) in that period which was 39.7%. Generally, in other seasons most indices showed good ecological status (class II) (Tab. 4). Saprobic indices present a moderate status (class III), while trophic (TID and TDI) present a poor to bad ecological status (IV-V class) (Tab. 3, 4). In the summer and winter samples % pollution tolerant taxa were 0.3 %, while in the autumn sample it was not present. Almost all taxa were alkaliphile in regard to pH values. According to saprobic and trophic indices values in spring taxa were alpha-meso-saprobic and polysaprobic (HOFFMAN, 1994, OMNIDIA) or eutrophic and saprothropic taxa (VAN DAM, 1994, HOFMANN, 1994, OMNIDIA). In other seasons at Bunica 2 there were beta-alpha-mesosaprobic taxa present (summer and winter) and oligo-beta-mesosaprobic (autumn) (VAN DAM, 1994, HOFFMAN 1994, OMNIDIA). According to LANGE-BERTALOT (1979, OMNIDIA) there were more sensible taxa recorded for pollution. Trophic indices showed oligo-alpha-mesothrophic and alpha-mesotrophic taxa (HOFFMAN, 1994) or eutrophic taxa (VAN DAM, 1994, OMNIDIA).

Bunica 3

According to OMNIDIA indicator values Bunica 3 showed low degradation (moderate only in summer); organic pollution which was non-existent (moderate only in summer) and antrophogenic eutrophication (moderate in spring and winter). According to most indices (IPS, IPD, IDSE, IDG, CEE) the water quality at Bunica 3 is II-III class and the ecological status is good to moderate (Tab. 3, 4). Saprobic indices SID and SLA indicate water quality class III - IV (moderate to poor ecological status) and the TID and TDI indicate V class (bad ecological status) (Tab. 3, 4). In spring, summer and autumn % of PT was not recorded, while in the winter it was 0.3 %. At Bunica 3 neutrophile were recorded (in spring and summer), alcaliphile (in autumn) and alcalibionte (in winter) taxa in regard of pH values. The most commonly represented were beta-mesosaprobic and eutrophic taxa (VAN DAM, 1994, OMNIDIA). The most abundant were more sensible for pollution taxa (LANGE-BERTALOT, 1979, OMNIDIA). According to saprobic and trophic indices values Bunica 3 showed beta-alpha mesosaprobic and oligosaprobic taxa present (only in autumn) (HOFFMAN, 1994,

OMNIDIA) or tolerant (spring and autumn), oligo-betamesotrophic (summer) and alpha-mesoeutrophic taxas (HOFFMAN, 1994, OMNIDIA).

DISCUSSION-Rasprava

In this paper the assessment of water quality in the Bunica River was based on diatom indices where the highest percentage of the diatom taxa were selected and incorporated into the OMNIDIA database. The results showed differences in values and indicated more variations between sites on the Bunica River. This variation has also been observed by, among others, KITNER & POULÍCKOVÁ (2003), POULÍCKOVÁ, (2004), STENGER-KOVÁCS et al. (2007), KALYONCU & ŞERBETCI (2013), BELTRAMI et al. (2012), SZCZEPOCKA & SZULC (2009). Diatom indices showed good correlations with each other, but they are not showing the real situation in the Bunica River. The variation in indicator indices has caused confusion among researchers' quality assessments. It is unclear whether there are significant differences between the results of the indices, and if so, what these differences are and what causes this variation. Probably, the cosmopolitan nature of diatoms displays a constant trophic preference. According to studies from North America (POTAPOVA & CHARLES, 2007) it has been shown that European indicator indices may need to be calibrated to regional conditions. Also, other researchers (KELLY et al*.,* 1998; PIPP, 2002; ROTT et al., 2003) have argued that indices developed in certain regions of Europe are not effective in others. European indices are designed according to a wide range of characteristics, but not according to the ecoregion and reference conditions. According to research conducted by RIMET et al. (2007) and KELLY et al. (1998, 2001) factors of each ecoregion such as geology, soil type, climate and vegetation type can cause an adjustment in water quality. Measured environmental preferences of each species can be geographically specific. Results of research conducted by SOININEN & NIEMELA (2002) showed that the reaction of species which have a wide geographic distribution area and similar ecology is still conditioned by nutrients and the conditions of the ecoregion. Therefore, the use of trophic indices that were not originally intended for a particular ecoregion can cause unmatched results. For Bosnia and Herzegovina CSANYI et al*.* (2008) calculated OMNIDIA indices and found that according to the IPS, EPI-D and CEE indices the Neretva River (Herzegovina area) and the Fojnica River (Bosnia area) had a high ecological status. They stopped just on the calculation indices. On the other hand, the results of this research disagreed and showed inapplicable values of indices and ecological status for a small karstic river. In our study any indices demonstrated expected results for all sites. Recent studies show that climate, geology, vegetation, and soil, can modify species responses to water quality characteristics (KELLY et al., 1998; RIMET et al., 2007). SOININEN & NIEMELÄ (2002) reported that although diatoms might have a wide geographical distribution and a globally similar ecology, their response to nutrient conditions may still be different between ecoregions. According to BESSE-LOTOTSKAYA et al*.* (2011) each trophic index is originally intended to be applied in the region for which it was developed and using these indices in another

region may cause uncertainty in assessment results, as happened in our study. BESSE-LOTOTSKAYA et al. (2011) considered that when assessing the trophic condition in regions for which no specific indices have been developed, it is advisable to apply several trophic indices and analyse carefully the variation in results. Some indices correlate better, whereas others appear to be completely different, and that is not always easy to explain (STENGER-KOVÁCS et al., 2007). In our study the best correlation with up to 9 indices was shown by SHE, followed by IPS (with 7), IBD, CEE and SLA (5) and EPI-D. This was expected in respect of the aims of the indices. The study of rivers in southern Poland KWANDRANS et al. (1998) concluded that the IPS has the best correlation with the IDSE and SHE index, IDSE with SHE index, and IDG also showed good results. SZCZEPOCKA & SZULC (2009) established that it is suitable for lowland rivers. Also, IPS and IDG have shown approximately good results in our study. They might serve as good indicators for planning in future research. According to all these and the results of our research, the indices in the OMNIDIA program results are not applicable without a calibration process for karstic rivers in Bosnia and Herzegovina. However, due to the fact that geographic characteristics are different, saprobity and trophy values of organisms must be modified for karstic and Bosnian-Herzegovinian conditions. This study was the first test in using diatom indices on an example of a small karstic river and can be the first starting point towards a calibration process in this karstic region.

CONCLUSION - *Zaključak*

Diatoms have been regularly used as bioindicators to assess water quality of surface waters. However, diatom-based indices developed for a specific geographic region may not be appropriate elsewhere. Benthic diatom assemblages in the Bunica River were sampled in different seasons to evaluate the applicability of 17 diatom-based indices used worldwide for water quality assessment. According to the physical and chemical conditions the water in the Bunica River showed high oxygen saturation and water transparency, as well as low nutrient concentrations and indicated the oligotrophic character of the river. Diatom indices showed different results and indicated more variations among sites on the Bunica River. According to the results, the indices in the OMNIDIA program, the same are not applicable for karstic rivers in Bosnia and Herzegovina. Saprobity (SID and SLA) and trophy (TID and TDI) indices showed the greatest deviations. The better result was given by EPI-D, IBD, SHE, IPS, IDG, IDSE and CEE. It is important to carry out more detailed research to determine whether they are suitable for assessing the quality of water in karstic rivers in Bosnia and Herzegovina, i.e. whether the indicator values are of a type adequate for this area. However, due to the fact that geographic characteristics are different, saprobity and trophy values of organisms must be modified for karstic and Bosnian-Herzegovinian conditions.

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SAŽETAK

Istraživanje bentoskih dijatomeja u rijeci Bunici provedeno je u razdoblju od 5. svibnja 2013. do 9. siječnja 2014. na tri različite postaje, od izvora do ušća. Rijeka Bunica je krška tekućica kratkog toka (oko 6 km), ulijeva se u rijeku Bunu, a nalazi se u jugoistočnom dijelu mostarske doline, na jugu Bosne i Hercegovine. Cilj ovog istraživanja bio je testirati korištenje bentoskih dijatomeja u svrhu praćenja kvalitete vode budući da se dijatomeje redovito koriste kao bioindikatori za ocjenu kvalitete površinskih voda. Uz bentoske dijatomeje testirano je i korištenje dijatomnih indeksa kao alata za procjenu kvalitete vode. Ukupno 17 indeksa je izračunato korištenjem softvera OMNIDIA GB 5.3. Korišteni indeksi su pokazali različite rezultate kao i varijacije između istraživanih postaja. Prema vrijednostima indeksa kvaliteta vode u rijeci je u lošijoj kategoriji (II, III, IV razred) u odnosu na kvalitetu vode prema fizikalno kemijskim čimbenicima (I razred). Prema tome indeksi u programu OMNIDIA nisu primjenjivi za krške rijeke u Bosni i Hercegovini i trebali bi se modificirati u tu svrhu. Važno bi bilo provesti detaljnija istraživanja koja bi uključivala veći broj sličnih postaja kako bi se utvrdilo koji indeks je najprimjenjiviji postajama te kako bi se napravila modifikacija indeksa koji bi odgovarao specifičnim krškim i bosanskohercegovačkim uvjetima.

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BOSNIA AND HERZEGOVINA IN THE CONTEXT OF REGIONAL AND GLOBAL COOPERATION FOR CONSERVATION AND SUSTAINABLE USE OF BIODIVERSITY

Bosna i Hercegovina u kontekstu regionalne i globalne saradnje za zaštitu i održivo korištenje biodiverziteta

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Abstract

With the geographical position and climate conditions it has, Bosnia and Herzegovinais a countryof unique life forms and biodiversity. The flora, fauna and fungi of Bosnia and Herzegovina are among the most diverse in Europe, and the high level of endemism and relict species provide for the country's significance at the global biodiversity level (UNCBD, 2019).

Since 2002, Bosnia and Herzegovina, as a party to the United Nations Convention on Biological Diversity (UNCBD), has been following global trends of conservation and sustainable use of biodiversity. Followingthe Convention, among others, six national reports were developed, as well as the Strategy and Action Plan for Protection of Biological Diversity in Bosnia and Herzegovina (NBSAP) by 2020. These documents seek to ensure that protection and sustainable use of biodiversity become inevitable principles when relevant sectoral policies, strategies and legislation at all governmental levels of Bosnia and Herzegovina are being developed. In 2013, the Bosnian-Herzegovina Clearing House Mechanism (CHM) portal for sharing information on biodiversity was established within the global network CBD CHM.

As a member country of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), Bosnia and Herzegovina actively represents and advocates for the interests of Eastern Europe. Bosnia and Herzegovina has made significant contribution to the preparation of a Regional and Sub-Regional Assessment for Biodiversity and Ecosystem Services for Europe and Central Asia, which was adopted at the Sixth Plenary Session of IPBES (Medellin, Colombia, March 2018).

In the context of regional and global cooperation, Bosnia and Herzegovina significantly contributes to the organization of the workshop and the preparation of an Eastern European Action Document on Pollinators, Food Security and Rural

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Development, within BES-Net Trialogue. Bosnia and Herzegovina reaffirmed its commitment to the status of pollinators by accessing to the global Coalition of the Willing on Pollinators at the 6th IPBES Plenary Session.

Key words: biodiversity, sustainable use, conservation, UNCBD

INTRODUCTION - *Uvod*

Biological diversity by its definition is the variety of genes, species and communities of species, ecosystems and, more broadly, the diversity of the Earth as an integrated ecosystem. It also includes all living beings, from the simplest viruses to higher plants and animals, and underlines the existence and importance of diversity (SLAVİCA and TRONTEL, 2010).

The benefits derived from ecosystem services should act as powerful incentives to conserve biodiversity (ANTON et al., 2010). Demand from ecosystem service beneficiaries and the supply of services by biodiversity operate and interact at different spatial and temporal scales. As such, gaining a basic understanding of the scales at which ecosystem services operate is integral to the development of any landscape-scale conservation programme (ANTON et al., 2010).

The extinction resulting from human activities throughout the world has caused great concern in the scientific community and among the general public (HUSTON and HUSTON, 1994). Local extinction of species can occur with a substantial delay following habitat loss or degradation (KUUSSAARİ et al., 2009). Monitoring programmes are being increasingly used to assess spatial and temporal trends of biological diversity, with an emphasis on evaluating the efficiency of management policies (YOCCOZ et al., 2001).

Conflict between biodiversity conservation and human activities is becoming increasingly evident in all European landscapes. The intensification of agricultural and silvicultural practices, land abandonment and other land uses such as recreation and hunting are all potential threats to biodiversity that can lead to conflicts between stakeholders' livelihoods and biodiversity conservation. CORINE data show that in the period from 2000-2018, changes in the land use in Bosnia and Herzegovina occurred in a total area of 71,957 ha (LJUŠA and ČUSTOVİĆ, 2019). These changes have influence on biodiversity and preservation of the nature.

Protected areas have long been one of the main for safeguarding the world`s biodiversity. But pressures on the environment caused by economic development and other human activities make it difficult to protect natural areas that are large enough to accommodate entire ecosystems. On the other hand, ecosystems need to be treated with care because they provide goods and services that are vitally important for human well-being (BENNETT, 2004).

Therefore, to address the ongoing global decline in biodiversity, identification of the main drivers responsible for conflicts between human activities and the conservation of biodiversity is much needed. In addition, promotion of management of

these conflicts is also important. The drivers of biodiversity conflicts are analysed in a European context for five habitat types: agricultural landscapes, forests, grasslands, uplands and freshwater habitats. A multi-disciplinary approach to conflict management implies active stakeholder involvement at every stage of conflict identification and management as well as a range of other approaches, including stakeholder dialogue and education, consumer education, improvement of political and legislative frameworks, financial incentives, and infrastructure planning (UNCBD, 2019).

As a member country to the UNCBD, Bosnia and Herzegovina seeks to protect its biodiversity. Following the Convention, national reports have been submitted with detailed information on the country's progress made in biodiversity protection. In addition, experts from Bosnia and Herzegovina participate in various international platforms, projects, and assessments.

The NGO sector has a major role when it comes to communication, raising public awareness, and education on environmental protection and biological diversity in Bosnia and Herzegovina. There are numerous non-governmental organizations (NGOs) that deal with this issue, and are recognized as citizens' organisations or associations of professionals / experts (IUCN, 2019).

According to the recent data provided by the Aarhus Centre of Bosnia and Herzegovina, there are 141 registered NGOs in Bosnia and Herzegovina whose work programs and activities include environmental issues, including the values of biological diversity, with an emphasis on raising public awareness and education (IUCN, 2019).

MATERIALS AND METHODOLOGY- *Materijali i metode*

Within this paper, the main objective was to reflect the work done to this date and results achieved since BiH ratified the UNCBD in 2002. The methodology used in this paper reflects the activities and concrete steps taken to meet the conditions set out in the UNCBD. This paper was prepared based on information obtained from a desk review of background documents related to biodiversity and reports that Bosnia and Herzegovina has submitted. This paper contains systematically collected, sorted and processed information about biodiversity in Bosnia and Herzegovinathat was done in accordance with the requests of the UNCBD.

Bosnia and Herzegovina, as party to the UNCBD, follows the global trends in conservation and sustainable use of biological diversity. As a result, it has brought together its potentials in actions undertaken within the Aichi Targets framework.

Although Bosnia and Herzegovina’s progress in achieving goals set up in the UNCBD is rarely visible and recognized by the public, it is important to take into account that this is a transition country with a complex political system. Its economy lacks strong actors and support, while the legal framework is still under the process of approximation to the EU jurisdiction. Bosnia and Herzegovina has made notable steps due to her status which has been presented within this paper.

Implementation of the United Nations Convention on Biological Diversity (UNCBD) in Bosnia and Herzegovina - *Primjena Konvencije Ujedinjenih Nacija o biološkoj raznolikosti u Bosni i Hercegovini*

The United Nations Convention on Biological Diversity is generally accepted as a multilateral environmental agreement that provides a framework for protection of biological diversity as an essential principle for conservation of nature. UNCBD is one of the three key multilateral environmental agreements, called the Rio conventions. This year (2020) celebrates the 27th anniversary of implementation of UNCBD and this is an important year for humankind where we need to review achievements that we have made in the past 10 years and to review future steps for the post 2020 period to achieve the objectives from the UNCBD.

The objectives of the UNCBD are the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits arising from utilization of genetic resources (CBD, 2019).

As of 2020, the UNCBD has 196 parties. Bosnia and Herzegovina ratified it on October4th2002 and became a fully-fledged party to the Convention.

So far, Bosnia and Herzegovina has developed the Strategy and Action Plan for Protection of Biological Diversity for the period 2008-2015, as a first biological diversity issues. The adoption of the Strategy and Action Plan for Protection of Biological Diversity of Bosnia and Herzegovina for the period 2015–2020 represents a continuation of the UNCBD global strategic planning and reporting.

In cooperation with other relevant institutions in Bosnia and Herzegovina, the Federation of Bosnia and Herzegovina (FBiH) Ministry of Environment and Tourism (pertaining to the entity Federation of BiH[1]), as the designated National Focal Point (NFP). NFP of Bosnia and Herzegovina for the UNCBD, has special responsibility[2] for the overall achievement of the set-out targets (NBSAP BIH, 2019).

[1]The country of BiH has been established by the Dayton Agreement, signed on 14 December 1995. BiH consists of three administrative units: the Federation of Bosnia and Herzegovina (FBiH), the Republika Srpska (RS), and the Brčko District (BD). The FBiH is made up of 10 cantons, which are divided into municipalities. In the FBiH there are 79 municipalities altogether, while in the RS there are 62 municipalities. The City of Brčko is a separate administrative unit – a district. The Bosnia and Herzegovina (BiH) Constitution states that jurisdiction in environmental issues is split between entities (Federation of Bosnia and Herzegovina - FBiH and Republika Srpska - RS), the district of Brčko (BD), and at the cantonal/municipal level. The only institution at the state level with jurisdiction in environmental issues is the Ministry of Foreign Trade and Economic Relations (MoFTER).

[2]The 'National Focal Point to the Convention on Biological Diversity' (CBD NFP) acts, on behalf of the national government, as a liaison with the international Secretariat of the Convention. The CBD NFP is in charge of the follow-up of the CBD implementation. It also acts as an umbrella structure for national focal points designated for specific thematic areas. Thematic areas already supported by an official national focal point are Access and Benefit Sharing, the Global Taxonomy Initiative, the Clearing- House Mechanism, the Global Plant Conservation Strategy and the Subsidiary Body for Scientific, Technical and Technological Advice.

Bosnia and Herzegovina's First National Report to the UNCBD was named *Bosnia and Herzegovina – Land of Diversity* and was submitted in 2008. Until today, Bosnia and Herzegovina has prepared six national reports in accordance with the UNCBD Secretariat's guidelines. In addition, Bosnia and Herzegovina has made concrete steps in implementation of the UNCBD through a number of other complex actions.

Protected areas and sustainable use of Biodiversity in Bosnia and Herzegovina - *Zaštićena područja i održiva upotreba biodiverziteta u Bosni i Hercegovini*

Bosnia and Herzegovina is characterized by its unique mosaic of biodiversity. A prerequisite for such natural wealth of the country lies in itsgeomorphologic structure, the three climatic regions (continental, alpine and mediterranean), northern plains along the Sava River to the Dinarides mountain chain and the Adriatic coast in the south. As such, biological diversity is one of the key natural resources that provides for interaction between human life and nature and creates conditions for great touristic potential.

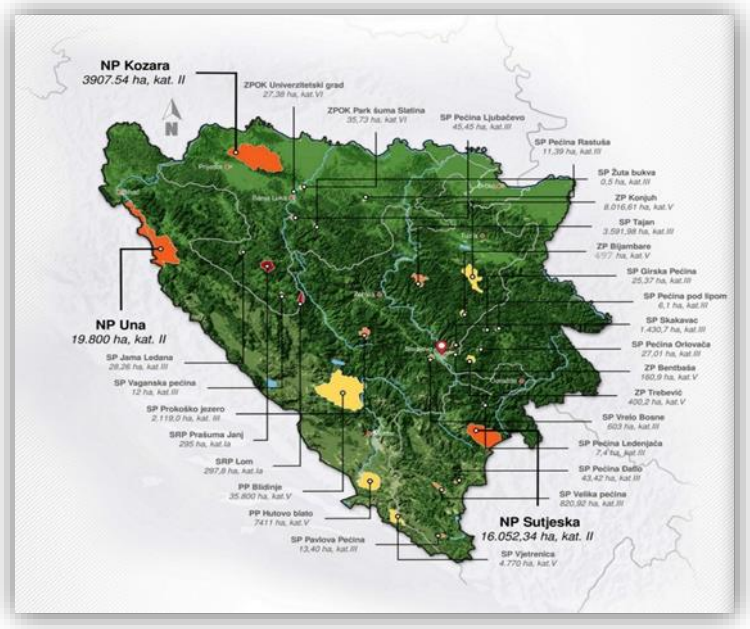
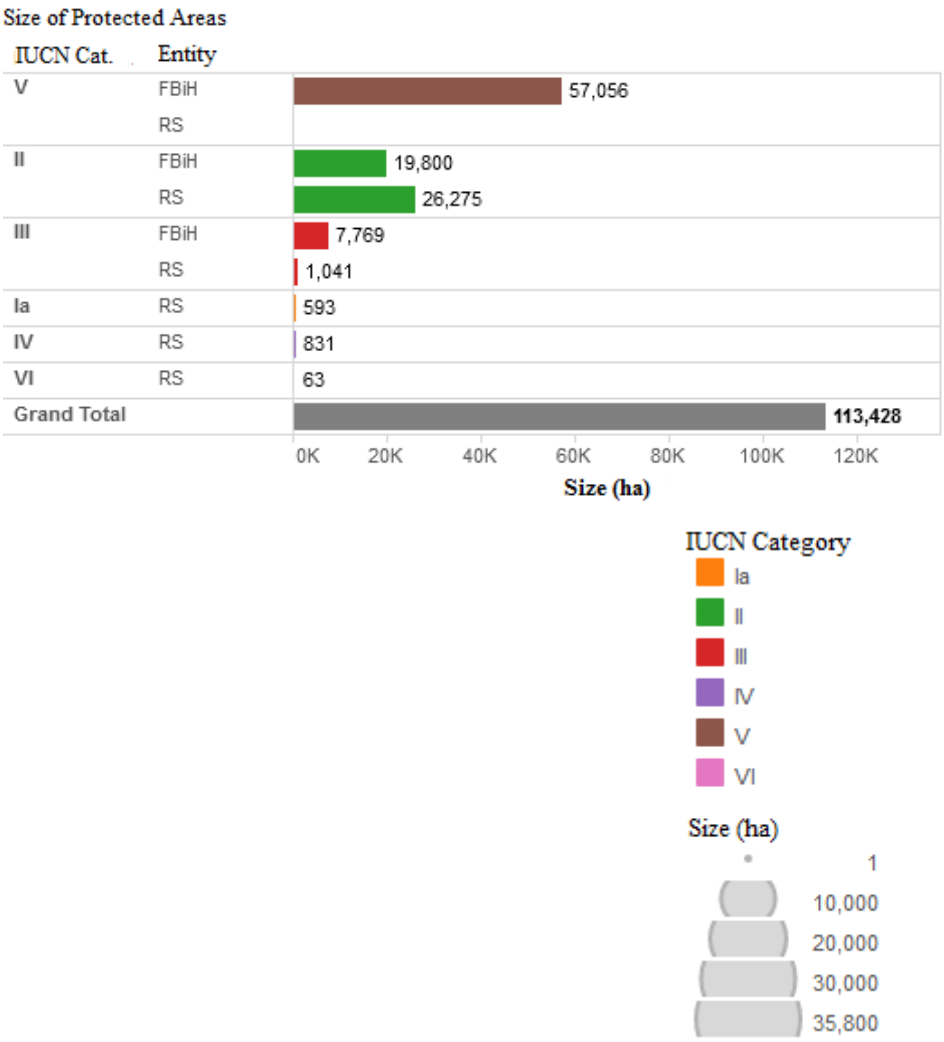


Figure 1. The map[1] of Protected Areas in Bosnia and Herzegovina with information about their size expressed in ha (USAID BIH, 2019)

Slika 1. Mapa zaštićenih područja u Bosni i Hercegovini izražena u ha (USAID BIH, 2019).

[1]Map shows the protected areas on the territory of Bosnia and Herzegovina with information about their size (expressed in ha). The colour of spots used in Map 1. that represent the protected areas are in line with International Union for Conservation of Nature (IUCN) categories of Protected Areas (Graph 1).



Graph1.Chart[3] representing the IUCN categories of Protected Areas in Bosnia and Herzegovina in accordance with their size expressed in ha (USAID BIH, 2019).

Grafikon 1. IUCN kategorije zaštićenih područja u Bosni i Hercegovini u skladu sa njihovom veličinom izraženom u hektarima (USAID BIH, 2019).

Currently, the UNEP/GEF project „Achieving biodiversity conservation through creation, effective management and spatial designation of protected areas and capacity building (2016-2020) "is being implemented in cooperation with Bosnia and Herzegovina governmental institutions. The project' goal is to support the expansion of current national protected areas system and to encourage effective management and mainstreaming of biodiversity into production landscape. Full implementation of this

project, in accordance with the Aichi target 11 (Protected Areas), is a very importantstepin Bosnia and Herzegovina's path towards the EU. Until 2019, this project is expected to increase national protected areas network, which currently represents 2.7 percent of total Bosnia and Herzegovina's territory. The aim of the project is to proclaim eight new protected areas in Bosnia and Herzegovina: Livanjsko Polje; Orjen – Bijela Gora; Bjelašnica – Igman – the canyon of the river Rakitnica – Treskavica – Visočica; Cave of Mokranjska Miljacka spring; Tišina; Botanical-floristic Reserve Mediteranetum; Cave System Vjetrenica and Cave System Govještica.

Map 2. shows the locations of the planned new protected areas in Bosnia and Herzegovina. As it can be seen on the Graph 1., the biggest share of protected areas in hectares is declared as Category V in accordance with IUCN classification.

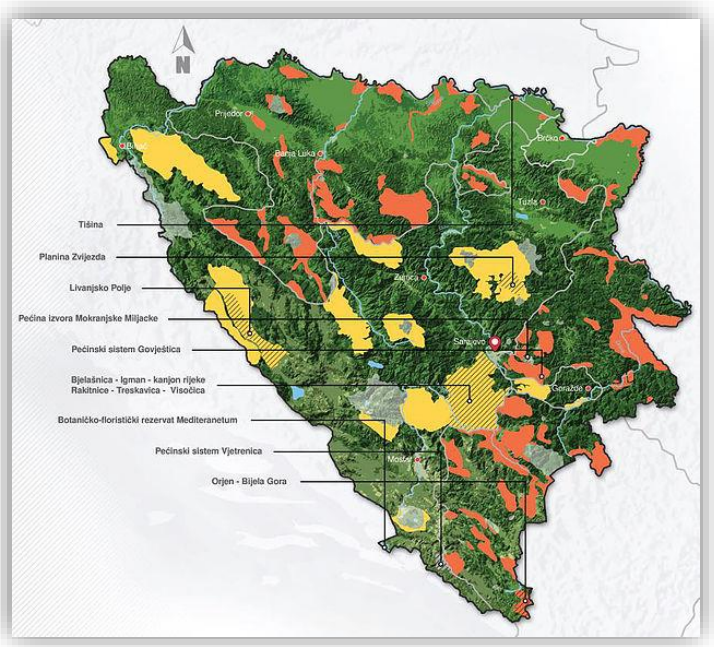


Figure 2. New planned protected nature areas in Bosnia and Herzegovina marked in yellow colour (UNEP, 2019)
Slika 2. Nova planirana zaštićena područja u Bosni i Hecegovini obilježena žutom bojom (UNEP, 2019)

Red List of Bosnia and Herzegovina - Crvena lista Bosne i Hercegovine

The IUCN Red List is regarded as an important barometer of the health of biodiversity, and is explicitly listed in the targets set by the UNCBD. The authority of the Red List lies in use of a standardized method for evaluating a defined measure of

conservation concern: a species at risk of extinction within a short period of time. This standardized system, the Red List Categories and Criteria, evaluates the available data on a species distribution, population status and threats against each of five Criteria (A-E), to determine its risk of extinction (IUCN, 2019).

In the FBiH, the "Red List of wild species and subspecies of plants, animals and fungi" was adopted in 2014, while in Republika Srpska (RS), the "Red List of Protected Species of Flora and Fauna" was adopted in 2012. These two documents were a kick starter to a fight for the preservation of rare and endangered species of plants and animals such as lynx, chamois and many various birds and plants throughout Bosnia and Herzegovina. Furthermore, the FBiH also adopted the "Red List of endangered fungi species".

According to the adopted Red lists, the situation in FBiH and RS is as follows:

- Red List of RS contains 818 species of vascular plants; 304 bird species; 46 fish species; 57 mammal species; 20 amphibian species; 25 reptile species; 273 insect species (Official Gazette of RS, No. 124/12).
- Red List of the FBiH contains 658 plant species; 27 mammal species; 40 bird species; 6 reptile species; 4 amphibian species; 36 fish species, as well as a great number of different species of invertebrates (Official Gazette of FBiH, No. 7/14).

The above data shows that in total 1,029 species have been put on the FBiH Red List and 1,545 species on the RS Red List. Bosnia and Herzegovina as a state has not yet developed a Red Data Book of threatened species, which creates a conflict situation in terms of protection and conservation of species.

Regional and global cooperation - *Regionalna i globalna suradnja*

In the context of recent regional and global cooperation, Bosnia and Herzegovina continues to be an active member of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), and was host to the BES-Net Trialogue on Pollinators, Food Security and Rural Development.

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)- *Međunarodna platforma za biodiverzitet i ekosistemske servise (IPBES)*

The IPBES Platform is primarily established to be used as scientific support to the UNCBD as well as support to other international conventions that are in relation with the UNCBD. The Platform aims to achieve its goals through the assessments which are being prepared by the experts.

As one of the member countries of the IPBES, Bosnia and Herzegovina and its team of experts participate in the development of the regional biodiversity assessment for Europe and Central Asia region. Bosnia and Herzegovina actively represent and advocates the interests of the Eastern Europe UN region, especially regarding the

capacity building needs and the status/availability of data and knowledge on biodiversity. Bosnia and Herzegovina's experts have made a significant contribution to the preparation of a Regional and Sub-Regional Assessment for Biodiversity and Ecosystem Services for Europe and Central Asia, which was adopted at the Sixth Plenary Session of IPBES held in Medellin (Colombia) in March 2018. During this Plenary Session, Bosnia and Herzegovina also joined to the global Coalition of the Willing on Pollinators.

BES-Net Trialogue on Pollinators, Food Security and Rural Development - *BES-Net Trialog o polinatorima, sigurnosti hrane i ruralnom razvoju*

The Biodiversity and Ecosystem Services Network (BES-Net) is a capacity sharing "network of networks" that promotes dialogue among science, policy, and practice for more effective management of biodiversity and ecosystems, contributing to the long-term human well-being and sustainable development (IUCN, 2019).

The first BES-Net Trialogue was held in Sarajevo, Bosnia and Herzegovina on 18-20 October 2017 and involved 52 stakeholders from Albania, Bosnia and Herzegovina, Georgia, Moldova and Montenegro.

During the Eastern European BES-Net Trialogue, the stakeholders identified and collectively agreed upon the strategic regional and national actions to address the problems that pollinators face.

Bosnia and Herzegovina has more than half of its surface area (63 percent) covered with forest and forestland (WWF, 2019), and 106,300 ha or 2.7 percent of the country's territory under protected areas (UNEP BiH, 2019). These areas are important for the BES Net Trioalog due to traditional agricultural activities including grazing, honey production and more recent tourism. Tourism is seen as a big opportunity for recovering economy of the country and is an important development driver (IUCN, 2019) especially rural tourism.

The BiH internet portal Clearing House Mechanism - CHM BiH - *Internet portal Clearing House Mechanism u Bosni i Hercegovini – CHM BIH*

The BiH internet portal with the mechanism for exchange of information on biological diversity – Clearing House Mechanism (CHMBiH), was established in 2013. The goal of the CHM is to provide comprehensive information on biological diversity through effective information services not only for the general public, but also for all stakeholders. The internet portal also allows for technical and scientific cooperation, exchange of knowledge and information flow which helps all decisionmakers and all stakeholders in meeting their obligations defined by the UNCBD (NBSAP BIH, 2019).

The CHM BiH is a platform that contains many relevant data, strategic plans, national reports, legislation and other documents of Bosnia and Herzegovina relevant for the overall portfolio of the UNCBD and its Protocols. It has a significant role in

the implementation of the UNCBDand its Global Strategic Biodiversity Plan (2010-2020), through the exchange of information, data, experience, scientific achievements and other relevant content with the aim to make an interaction of all member countries and other stakeholders.

At the 13th Conference of the States Parties to the UNCBD, by a decision of a special jury established by the UNCBD Secretariat, and in competition among all 196 members of the UNCBD, Bosnia and Herzegovina received the award for the best newly established national CHM.The CHM BiH is available at: *www.bih-chm-cbd.ba*.

CONCLUSION - *Zaključak*

Nature conservation is crucial for the coexistence of all species that reside in it and depend on natural resources. Throughout its entire history, nature has played a crucial role for human kind existence and we need to leave it in the best possible condition to the future generations.

Bosnia and Herzegovina is fortunate enough to be a country rich in biodiversity. For this purpose, development of various action plans, legislative initiatives, and project activities remains crucial for protection of its natural wealth.

Bosnia and Herzegovina, as a member country to the UNCBD and an active member of platforms of international significance for biodiversity and nature protection (such as IPBES, BES-Net and others), significantly contributes to the development of regional and global efforts of nature and the best ways of preserving it.

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SAŽETAK

Bosna i Hercegovina je,zahvaljujući svojim geografskim položajem i klimatskim uslovima, zemlja bioraznolikosti, zemlja jedinstvenih životnih oblika. Flora, fauna i gljive Bosne i Hercegovine su među najraznolikijim u Europi, a visok nivo broja endema i reliktnih vrsta osigurava značaj zemlje na globalnom nivousa stanovišta biološke raznolikosti (UNCBD, 2019).

Bosna i Hercegovina, kao članica Konvencije Ujedinjenih nacija za biološku raznolikost (UNCBD) od 2002. godine slijedi globalne svjetske trendove o očuvanju i održivom korištenju biološke raznolikosti. Prema Konvenciji, između ostalog do sada je urađeno šest nacionalnih izvještaja, kao i Strategija i akcioni plan za zaštitu biološke raznolikosti Bosne i Hercegovine (NBSAP) do 2020. godine. Ovim dokumentima se nastoji postići da zaštita i održivo korištenje biološke raznolikosti bude nezaobilazna oblast u izradi relevantnih sektorskih politika, strategija i legislative na svim nivoima vlasti u državi Bosni i Hercegovini. U 2013. godini uspostavljen je bosanskohercegovački internet portal CHM BiH (engl. Clearing House Mechanism) za razmjenu informacija o biološkoj raznolikosti u okviru globalne mreže CBD CHM.

Kao jedna od zemalja članica Međuvladine naučno-političke platforme za biološku raznolikost i usluge ekosistema (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services - IPBES), Bosna i Hercegovina aktivno predstavlja i zastupa interese regiona Istočne Europe. Bosna i Hercegovina je dala značajan doprinos pripremi Regionalne i subregionalne procjene za biodiverzitet i ekosistemske servise Europe i Centralne Azije, koja je prihvaćena na Šestoj plenarnoj sjednici IPBES-a, održanoj u Medellinu (Kolumbija) u martu 2018. godine.

U kontekstu regionalne i globalne saradnje važan je doprinos Bosne i Hercegovine u organizaciji radionice i pripremi regionalnog Akcijskog dokumenta o oprašivačima, sigurnosti hrane i ruralnom razvoju za istočnu Europu, u okviru Prvog BES-Net trijaloga. Posvećenost stanju oprašivača Bosna i Hercegovina je potvrdila pristupom globalnoj Koaliciji za polinatore, upriličenoj na 6. plenarnoj sjednici IPBES-a.

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NEW OBSERVATIONS OF STOAT (*Mustela erminea* L.) IN BOSNIA AND HERZEGOVINA

Nova zapažanja velike lasice – hermelina (*Mustela erminea* L.) u Bosni i Hercegovini

Željko Sekulić[1], Saša Kunovac[2]

Abstract

The Stoat occupies a wide range of habitats. It is often found in successional or forest-edge habitats, in the scrub, alpine meadows, marshes, riparian woodlands, hedgerows, and riverbanks that have high densities of small mammals, especially *Microtus* and *Arvicola* voles (KİNG, 1983). PULLİAİNEN, (1999) stated that coniferous and mixed woodlands are preferred, but that many other habitats are used including tundra and the summits of fells and mountains. Dense forests and deserts are avoided (KİNG, 1983). Although mentioned in all to-day's Laws on Hunting (1893 – 2014) in Bosnia-Herzegovina, there are not so many records of this species or official reports in hunting bag. Considering its geographic range (IUCN 2020), in Bosnia-Herzegovina, the stoat is recorded only in the western and northern parts of the country. İn this paper, we presented new localities where the stoat was observed in Bosnia-Herzegovina, as well as types of habitats where it was recorded.

Key words: *stoat, observation, habitat*

INTRODUCTION - *Uvod*

Mustela erminea (stoat) is a small carnivorous mammal, belonging to the *Mustelidae* family. In Bosnia-Herzegovina, the stoat is a game species. Its status is determined by Laws on Hunting that were proclaimed for or in Bosnia-Herzegovina since 1893 till nowadays (ANONYMOUS, 1893, 1931, 1947, 1948, 1955, 1977, 2006, 2009 and 2014). Also, the stoat is unprotected game species. It looks weird that in the last few decades we don't have a single confirmation of the presence of this species at certain locality (photo, corp, skeleton, etc.). According to King, 1983., the stoat occupies a variety of habitats. But, in Bosnia-Herzegovina, there is no confirmed presence below (southern and eastern) city of Banja Luka (Chart 1).

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METHODS - *Metode rada*

After observing the stoat at some locality, we collected coordinates and altitudes using the Mobile Mapper CE instrument. Further, we made a detailed analysis of habitat at each locality and wider surrounding (vegetation, anthropogenic influence, etc.). Coordinates later were transferred at the IUCN map of the geographic range of *Mustela erminea*.

RESULTS - *Rezultati*

The stoat was observed at one locality in Central Bosnia and two localities in eastern Bosnia. All three localities are outside of the known and confirmed presence of the Stoat in Bosnia-Herzegovina. Coordinates and habitat types are presented in table 1:

Table 1. Localities, coordinates, altitude and habitat types where the stoat was observed

Tabela 1: Lokaliteti, koordinate, nadmorska visina i tipovi staništa u kojima je opažena velika lasica

Locality	Coordinates	Habitat type	Altitude
Kopčić, Bugojno Municipality	44° 5'19.37"N 17°25'21.55"E	Meliorated marshland with remains of Pedunculate Oak forests	599 m.a.s.l.
Trogir (Presjenica), Trnovo Municipality	43°43'52.72"N 18°20'8.68"E	Forest (Beech-Sessile Oak)	792 m.a.s.l.
Husad (Jeleč, Miljevina), Foča Municipality	43°28'15.90"N 18°34'44.50"E	Forest (Beech-Silver fir with Spruce)	1430 m.a.s.l.

The Kopčić locality is a plain between the city of Bugojno and Donji Vakuf in Central Bosnia. This former marshland originally had forests from association *Alno – Quercion roboris* (STEFANOVIĆ et al, 1983), with pedunculate oak as a dominant tree species. Today it has only remains of these forests and rest is cultivated land. This locality belongs to the region of Lowland continental hunting grounds in Bosnia-Herzegovina (KUNOVAC et al, 2009).

Locality Trogir is a typical forest habitat, belonging to the region of Hilly hunting grounds of internal Dinaric mountains (KUNOVAC et al, 2009) with Sessile Oak stands which occupy eastern and southern expositions, while Beech (*Fagus sylvatica*) stands are at northern and western sides of slopes (STEFANOVIĆ et al, 1983).

Third locality, Husad plateau near Foča, belongs to Mountainous hunting grounds of internal Dinaric mountains (Kunovac et al, 2009), with typical forest association for this region *Fago-Abietetum*, beech-silver fir (with spruce) (STEFANOVIĆ et al, 1983).

All three localities of new observations of the stoat are presented at chart 1:

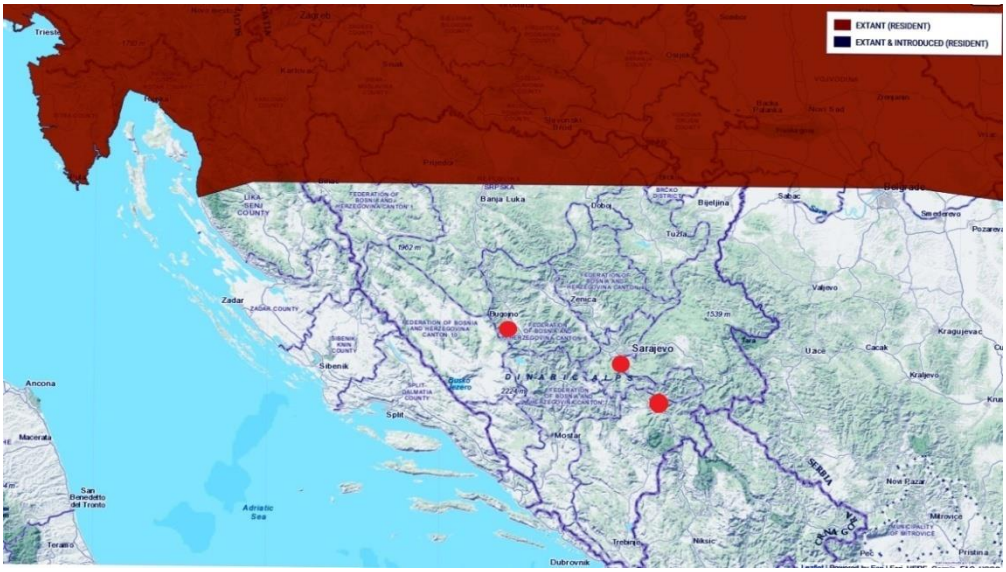

Chart 1. New localities of observations of the Stoat in Bosnia-Herzegovina, within chart of its geographic range according to IUCN 2020.

Karta 1. Lokaliteti novih opažanja hermelina u Bosni i Hercegovini, uz kartu areala ove vrste prema IUCN 2020.

From Chart 1, we can see that all three localities are far outside of the known geographic range of the stoat in Bosnia-Herzegovina. The known geographic range covers only northern and western parts of Bosnia-Herzegovina, mainly lowlands, except some mountainous terrain in western Bosnia-Herzegovina.

New localities are placed in central and eastern Bosnia-Herzegovina, each of them has different habitat structure. Localities in eastern Bosnia are typical forest habitats, but with different forest types. In Central Bosnia, locality is placed in valley of river Vrbas, in typical meliorated land.

Figures 1-2. *Mustela erminea* at Husad plateau; Photo: Željko Sekulić;
Slike 1-2. Mustela erminea na platou Husada; Foto: Željko Sekulić;

DISCUSSION AND CONCLUSIONS – *Diskusija i zaključci*

New observations of the Stoat (*Mustela erminea* L.) in Bosnia-Herzegovina go in favor of KING'S (1983), statements about types of habitats which Stoat occupy. In Bosnia-Herzegovina, the stoat is recently registered in three different types of habitats. Those habitats don't differ only in altitude, but in vegetation cover too. However, al habitats have one significant characteristic: an abundance of prey. Small rodents are very common in cultivated land, where they feed on crops, as well in oak and beech forests, where the main food is beech and oak mast. Even at higher altitudes (Husad 1430 m.a.s.l), mixed forests of beech and silver fir (with spruce) provide plenty of food for small rodents, and by them, indirectly to predators such as *Mustela erminea*.

Because the Stoat isn't protected species in Bosnia-Herzegovina, and intensive fur trade till the 70s of last century, it is quite odd that we did not have some observations or confirmations of its presence.

The results of this work suggest that species inventory in Bosnia-Herzegovina needs new revision and much more effort in the future to complete and create detailed maps for each species that inhabit this country.

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SAŽETAK

Hermelin, velika lasica (*Mustela erminea* L.), naseljava različita staništa u Evroaziji. Od četinarskih, mješovitih i listopadnih šuma, šikara, polja, močvara pa do riječnih obala, sve u zavisnosti od prisustva plijena, što su najvećim dijelom miševi i voluharice. Pa ipak, iako se pominje u svim zakonima o lovstvu (1893-2014), koji su donošeni za područje Bosne i Hercegovine, skoro da uopšte nema zvaničnih nalaza ove vrste u našoj zemlji, kao ni prijava odstrela. Ovo čudi kada se uzme u obzir da je hermelin nezaštićena vrsta divljači, te lov na ovu vrstu nije zabranjen. Ako pogledamo kartu rasprostranjenja hermelina (IUCN 2020), u Bosni i Hercegovini, vidi se da je potvrđeno njegovo prisustvo samo sjeverno i zapadno od Banja Luke. U ovom radu smo prezentirali tri nova lokaliteta opažanja hermelina u Bosni i Hercegovini, a sva tri su daleko van areala prema IUCN, (Karta 1). Lokalitet Kopčić, na 599 m.n.v., predstavlja polje i dijelom brežuljaksti dio između Donjeg Vakufa i Bugojna. Ova nekadašnja močvara, danas meliorisana, predstavlja tipičan agrobiotop sa ostacima nekadašnjih šuma lužnjaka i nizijskog brijesta koje pripadaju svezi: *Alno – Quercion roboris*. Dok se, ovaj lokalitet, prema KUNOVAC et al, 2009, nalazi u rejonu kontinentalnih nizijskih lovišta.

Lokalitet Trogir, na 792 m.n.v., u rejonu brdskih lovišta unutrašnjih Dinarida (KUNOVAC et al, 2009), je pod sastojinama zajednice šuma kitnjaka i cera (*Quercetum petraeae - cerris*) iz sveze *Quercion petraeae-cerris* , a alternira sa šumama bukve na hladnijim ekspozicijama.

Treći lokalitet (plato Husada), na 1430 m.n.v, je pod acidofilnim šumama bukve i jele (sa smrčom) (*Fago-Abietetum*), a pripada planinskim lovištima unutrašnjih Dinarida (KUNOVAC et al, 2009). Ova, nova nalazišta hermelina u našoj zemlji, od kojih su dva tipična šumska staništa, ali različitog sastava, a treći predstavlja antropogeno izmijenjeno stanište, zapravo potvrđuju navode KİNG, 1983., prema kojem hermelin naseljava najrazličitije tipove staništa sa dovoljno plijena.

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THE EFFECT OF MECHANICAL BARK DAMAGE ON THE VOLUME INCREMENT OF TREES

Uticaj mehaničkih oštećenja kore na zapreminski prirast stabala

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Abstract

It is well known that mechanical damage to trees, caused by felling and removal of timber from the forest, has multiple negative effects on the quality of the stock and the health of the forests as well as the volume increment. In Bosnia and Herzegovina there were no significant analises of volume increment loss due to bark damage of the trees. In this paper, a direct relationship between the significant damage to the bark of the stem and the size of the volume increment of individual trees was determined. Original data recorded during the Second National Forest Inventory in Bosnia and Herzegovina (2006-2009), within the accesible high economical forests was used. These forests cover a total area of 1.329.500 ha.

Data on measured trees was taken from every fourth sample plot (one from cluster). 18.546 trees were selected, on which the 10-year increment of brest diameter (DBH) was measured and significant mechanical damage was recorded (LOJO et al., 2008). Of the total number of selected trees, 2.635 or 14.21% were mechanically damaged.

The results of the study showed that the volume increment of trees, with significant bark damage of all tree species and thickness, was lower from 4,9% to 19,4% in average, compared to undamaged trees.

Based on registered damage the bark of the stem, during second NFI BiH and determined the average losses increment on individual trees, it was estimated how much these losses are on an annual basis in, productive high forests in Bosnia and Herzegovina.

The volume increment of mechanically damaged trees is statistically significantly lower compare to the increment of undamaged trees, resulting in a total loss of about 200.000 m^3 / year / 1.329.500 ha.

Key words: *Mechanical tree bark damage, tree volume increment*

INTRODUCTION- *Uvod*

Efforts to increase labor productivity, reduce unit costs, and facilitate extremely difficult and demanding forestry work have resulted in a significant mechanization of forest operations in the 1960s. To this end, the development of the management system is also directed, especially in the part of the internal spatial planning of stands, which

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primarily aims at creating the preconditions for the use of mechanization and mechanized means in carrying out work operations of forest utilization with as little damage as possible.

However, it quickly became clear that every application of machinery in the forest, certainly has certain negative consequences for the forest ecosystem (emission of harmful substances, extinguishing and compresssion of soil, damage to the young and older standing trees, etc.). The negative impacts of machinery on the forest ecosystem have been the subject of ongoing and numerous studies with often different results and thus conclusions regarding the measures necessary to reduce them. This is first and foremost conditioned by different research methodologies, but also by the significant heterogeneity of the means and techniques of work, field and stand conditions, the manner of forests care and restoration, management systems, etc. Among the numerous authors dealing with forest damage, there is general agreement that, due to the nature of the work, forest operations cannot be carried out without some damage to the forest ecosystem, despite the protection measures implemented.

Also, most researchers believe that the number of mechanically damaged trees is a good indicator of overall damage to the stand (TOMANIĆ et al. 1989; REISINGER and POPE 1991; ATHANASSIADIS, 1997; SIRÉN, 2001). These damages can be determined relatively easily and accurately, and their environmental and economic consequences (decline in value, decrease in growth, tree dieback) are better known than those caused by damage to the young trees or soil (MARTINIĆ, 2000).

PROBLEMATIC ISSUES AND GOAL OF WORK - *Problematika rada i cilj rada*

The significant heterogeneity level of of trees in our forests, in terms of quality and technical usability, necessitated the development and binding application of quality classification of trees (MATIĆ et al., 1971; MUSIĆ and LOJO, 2006), with a greater number of different parameters being evaluated and / or measured on the tree. For the evaluation of trees in terms of their quality and health status and monitoring changes in this regard, a relatively small number of quality classes is sufficient, so that the silvicultural-technical classification of trees is divided into three quality classes, with the criteria defined for classes I and III.

The first (I) class thus includes healthy, normally formed trees of good quality, which are potentially able to provide logs of excellent or good quality, or there are chances that it will be possible when the tree grows up.

In class III, trees are generally classified as the ones that do not supposed to be in a commercial forest. These are badly injured, diseased, rotten trees or healthy trees whose stems can only be used for firewood and pulpwood due to quality defects. All other trees that do belong in either of these classes (I and III) are classified as trees of second (II) quality class.

Due to the need to plan forestry production and use, or to carry out cultivation operations, the classification criteria are defined according to certain thickness classes

and tolerate the corresponding quality errors whereby these tolerances increase with the increase in the breast diameter (DBH) of the tree.

Mechanical damage is one of the essential parameters for the assessment of the quality of trees and for the subsequent analysis of the quality of forest management as well as for the evaluation of the effects of applied forest utilization technologies.When recording mechanical damage, only significant damage is recorded, that is, those that reduce the quality of trees in silvicultural view and classify them as second or third quality class, depending on the width (size) of the stem and/or tree canopy injury. In addition, damage is also recorded by its location and the cause of it.

Mechanical damage is considered to be a tree stem injury incidentally caused by a means of work, or some other biotic and abiotic factors. Most of these are usually a collateral damage that happens during the execution of forestry operations, and their type, size and severity depend on the following factors:

- framework factors (slope of terrain, distance between upright trees, intensity and types of felling, dimensions of trees and assortments, canopy size, season of operation, etc.),
- working methods and techniques,
- spatial plan of the harvesting area (cutting system),
- human factor (skills and motivation).

The magnitude of the impact of these factors is precisely proportional to their orderin which they were listed priorly. This practically means that with adequate motivation of trained workers, a good spatial plan of logging and the application of working methods and techniques in accordance with the field and stand conditions, negative consequences can be reduced to a minimum or "acceptable" level.

Mechanical damage to trees is most commonly classified according to the site of occurrence of the tree (Figure 1) and the degree of damage (Figure 2), with most authors using the MENG, (1978) classification.

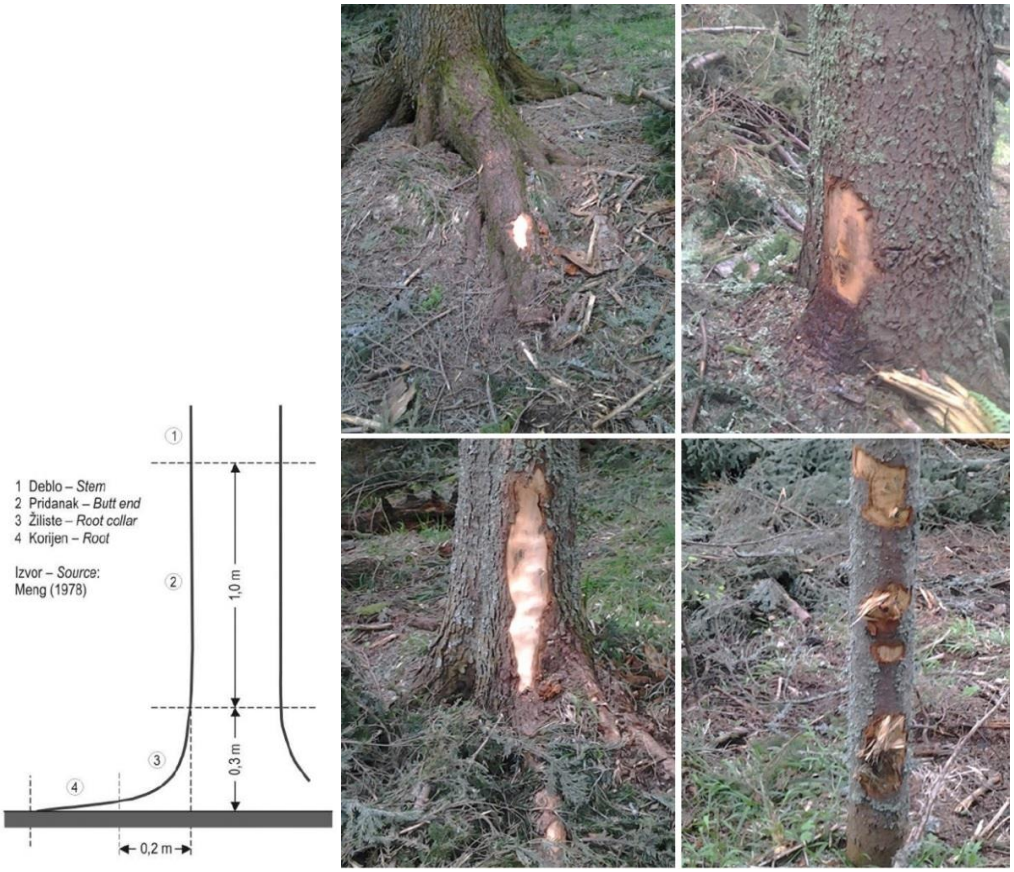


Figure 1. Classification and representation of tree damage position
Slika 1. Klasifikacija i prikaz mjesta oštećenja stabla

The location and extent of the damage depend on the work technologies used, the type and dimensions of the tree, the season of work and other influencing factors. For example, according to a study by SOLGI and NAJAFI (2007) in beech and hornbeam forests in Iran, while pulling a tree with a skidder, the most common damage appears on the roots of the remaining trees, taking up 41% of the total damage.On the other hand, TSORIAS and LIAMAS (2010), investigating mechanical damage in mixed beech and oak forests when pulling logs with an adapted agricultural tractor, registered the most damage on the stems of the trees, while KNEŽEVIĆ et al. (2018) registered the most damage on base of the trunk and root collar when pulling logs by oxen. It is important to emphasize that any injury to a tree does not a priori mean itsimpairment.

I) Squashed bark

I) Nagnječena kora

II) Debarked tree with relevant width of damage for classification (MATIĆ et al., 1971)

II) Oguljena kora sa relevantnom širinom za klasifikaciju (MATIĆ i dr., 1971)

III) Debarked and damaged tree

III) Oguljena kora i oštećeno stablo

Figure 2. Classification of trees according to the degree of damage

Slika 2. Klasifikacija stabala prema stepenu oštećenja

The appearance of decaying fungi and their development depend on the size and age of the injury, the type of tree, the time and place of injury (VASILIAUSKAS, 2001). The possibility of infection being less in the case of the squashed relative to the peeled bark of the tree (LIMBECK-LILIENAU, 2003), while BETTINGER and KELLOG (1993) find that trees with stem bark injuries closer to ground level are more likely to develop mycosis of tree destroyers. Although the literature does not specify which area or size of the injury has an impact and with what consequences on the damaged tree (PORŠINSKY and OŽURA, 2006), there are certain findings, of which the most relevant to us are those related to the local climatic and vegetation conditions.

So MATIĆ et al. (1971), in the silvicultural-technical classification of trees, of our most important tree species, specify the injury width of 10 cm as critical, that is, which classifies beech, fir and spruce trees in III silvicultural-technical quality class

(Figure 2-II). For pines slightly larger injuries are allowed and range from 10 to 20 cm, depending on the type and breast diameter. KRPAN et al., (1993) state that tree infestation and rot development depend on the size of the injury and its position on the stem. Mycosis development has not been established on injuries below 100 cm^2, so they believe that the tree can heal such injury.

In addition to the real possibility of infestation of damaged trees with rotting fungi and their subsequent decay, and the established degradation of the quality of cut and damaged trees (VANDERBERG, 2002), the negative impact of mechanical damage on the volume increment of standing trees is also very significant. ISOMÄKI and KALLIO (1974) state that root damage reduced spruce diameter increment by 35% and height increment by 25%, and stem damage reduced these increments by 15%. In doing so, the width and depth of injuries correlate positively with the decrease in increment. TAVANKAR et al., (2015) found a 8.1% decrease in the diameter incrementof damaged beech trees, citing as significant factors the decrease in the growth of damaged trees: distance of damage from the soil, area of injury and age of the tree. Analyzing the width of the year-rings of damaged pedunculate oak and beech trees KRPAN et al. (1993) found a volume incrementloss of 1 to 4.7%. According to research by REBULA, (1991), about 15% of trees are damaged in Slovenia due to the construction of tractor roads and tree pulling.1/3 of damaged trees do great damage, which diminishes their use value and reduces diameter increment.A number of studies have also shown that damage to the spruce stem results in a 14-25% reduction in increment (BAADER, 1956; VANEK, 1957). In contrast, a number of authors have not identified a significant effect of stem injury on the reduction of spruce increment (STAINES and WELCH, 1984), spruce and white pine (MÄKINEN et al., 2007) and oak (VASILIAUSKAS, 1998).

The main motives of this paper, which aim to determine the degree of mechanical damage to the trees and their effect on the volume increment, arise from the explained problems.

MATERIAL AND METHODS OF WORK - *Materijal i metod rada*

The basic material for this work is the data on mechanical damage and DBH[1] breast height diameter increment of trees, collected by inventory recordings during the implementation of the Second National Forest Inventory in BiH (NFI) from 2006 to 2009.

Specifically, for the needs of NFIs, a number of taxation elements, including mechanical damage of the trees, according to their location (stem or canopy) and the extent of damage, were recorded on every fourth sample plot (LOJO et al., 2008). Recorded tree data from sample plots within all "available high production character forests" were extracted from the formed database.

According to the NFI data processed, the total area of these forests in BiH was

[1]Diameter of the tree at the breast height
Prečnik stabla na prsnoj visini

1,329,500 ha. Of these, 1,063,400 ha (79.98%) are state forests and 266,100 ha are private (20.02%). The volume increment of large wood[1] of these forests and its structure by groups of tree species is shown in Table 1.

Table 1: Volume increment[1] (by groups of tree species) of high economic forests in BiH according to second NFI (2006-2009)

Tabela 1: Zapreminskog prirasta krupnog drveta (po grupama vrstama drveća) visokih šuma proizvodnog karaktera u BiH prema drugoj NFI (2006.-2009.)

Area *Površina* (ha)	Groups of tree species *Grupe vrsta drveća*	Volume increment[1] *Zapreminski prirast*		Share in increment *Udio u prirastu*
		(m^3/god.)	(m^3/ha)	(%)
1.329.500	Coniferous - *Četinari*	4.149.465	3,1	45,8
	Broadlaves - deciduous _ *Lišćari*	4.920.196	3,7	54,2
	All species - *Sve vrste*	9.069.660	6,8	100,0

The recorded significant mechanical bark damage to trees on the sample plots is classified as follows:

0 - undamaged tree;

1 - mechanically damaged tree (criterion - II silvicultural-technical class);

2 - mechanical damage to the tree (criterion - III silvicultural-technical class).

„Statgraphics Centurion“ computer software was used for statistical data processing and interpretation of results. The verification of the normality of the original data (distribution analysis) and their transformation were prepeared by the Box-Cox procedure (BOX and COX, 1964).

RESULTS AND DISCUSSIONS - *Rezultati rada i diskusija*

Based on data from 2.319 sample plots and 18.545 measured trees, average size of annual DBH increment and average size of annual volume increment of trees in total wood mass[2] were calculated, and the number of mechanically damaged trees per degree of bark damage was determined (Table 2).

[1] Volume increment of tree sections thicker than 7 cm
Zapreminski prirast dijelova stabla debljih od 7 cm

Table 2: Average size of annual diameter (DBH) and volume increment of one tree and the number and proportion of damaged trees by degree of bark damage (source NFI-BiH)

Tabela 2: Prosječne veličine godišnjeg debljinskog i zapreminskog prirasta[1]jednog stabla te broj i udio oštećenih stabala po stepenu oštećenja kore (izvor NFI-BiH)

Bark damage – type *Oštećenje kore - tip*	Tree number *Broj stabala*	Average brest tree diameter (DBH) *Prosječan prsni prečnik stabla*	Percentage share *Procentualni udio*	Average diameter (DBH) increment *Prirast prečnika stabla*	Volume increment of the tree[2] *Zapreminski prirast stabla[2]*
		(cm)	(%)	(mm/god.)	(m^3/god.)
0	15.911	31,7	85,79	3,63839	0,0294139
1	1.445	38,0	7,79	3,53135	0,0355895
2	1.190	38,8	6,42	3,18874	0,0318412
Total - *Ukupno*	18.546	32,6	100,00	3,60120	0,0300509

Higher diameter increment and smaller volume increment of undamaged trees (table 2) is conditioned by the structure of the tree sample per DBH.

Namely, there are many more damaged trees in the higher diameter classes (1.636 or 16,8% in diameter above 30 cm) than in the lower ones (1.035 or 11,7% in diameter below 30 cm). On average, thicker trees and smaller diameter increments have larger volume increment due to the greater height and basal area (or incremental rings area).

Of the total number of trees, 2.635 or 14,21% were mechanically damaged. Considering that these are only significant damages, we can conclude that this is an extremely large proportion. Comparatively, in extensive studies of tree damage during felling, fabrication and hauling logs, MARTINIĆ, (1991) found a total damage rate of 8,2%, indicating that the most frequent damage was squashed and peeled bark. That the level of forest damage in BiH is far higher is confirmed by the results of ZAHIROVIĆ et al. (2016) who, in their research, determined an overall damage of 35.1%, with root and trunk damage the most common (71.6%) and HALILOVIĆ et al. (2020) who determined overall damage of 30.6% in their research.

Determining the statistical significance of the effect of mechanical damage on the volume increment of trees was performed by multivariate analysis of variance. Prior to analysis, the normality of the volume increment value distribution was checked by

[1]Volume increment of trees of total wood mass (without stump)
Zapreminski prirast ukupne drvne mase stabala (bez panja)

Box-Cox procedure (BOX and Cox 1964). The distribution of the original data (Iv) was found to deviate from the normal, so an exponent of 0.2 was determined for their optimal transformation to the normal distribution ($Iv^{0,2}$).

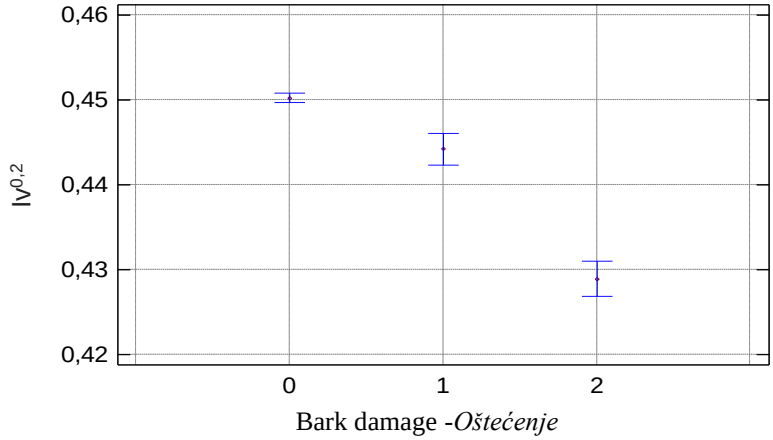
The independent categorical variables that were taken into account are: damage type ("Bark damage") and group of tree species ("Group sp."), with trees being classified into conifer and broadleaves species groups.

To exclude the stated influence on volume increment, DBHwas included as a covariate. Due to needed normality of the DBH data value, transformation with appropriate exponent of 0,5 was applied. The result of the multifactorial analysis of the variance of the volume increment of the trees is shown in Table 3.

Table 3. Analysis of Variance for$Iv^{0,2}$
Tabela 3: Analiza varijanse za $Iv^{0,2}$

The source of variation *Izvor variranja*	Sum of squares *Suma kvadrata*	Degrees of freedom *Stepeni slobode*	Mean SquareSredina kvarata	F- ratio *F- odnos*	"P" probability *"P" vjerovatnoća*
Covariate -*Kovarijabla*					
$DBH^{0,5}$	184,252	1	184,252	71428,75	0,0000
Main effects - *Kategorijske varijable*					
A: Group sp. - *Grupa vrsta*	1,72505	1	1,72505	668,75	0,0000
B: Bark damage *Oštećenje*	0,519276	2	0,259638	100,65	0,0000
Residual *Rezidual*	47,8244	18540	0,00257952		
Total (corrected) *Ukupno*	236,306	18544			

According to the variance ratio (F-ratio) and error probability (P-value), it is clear that all the analyzed factors have a statistically significant effect on the tree's volume increment. Nevertheless, starting from the research objective, an analysis of the effect of mechanical damage type on the volume increment of trees was performed, and the results are presented in Chart 1 and Table 4



Graph 1. Average values of $Iv^{0,2}$and Fisher's LSD intervalper type of damage, 95% probability
Grafikon 1. Prosječne veličine $Iv^{0,2}$ i Fisherov LSD interval po tipovima oštećenja, pri vjerovatnoći od 95%

Table 4.Multiple Range Tests for $Iv^{0,2}$) by „Oštećenje“ (LSD -the least significant difference Fisher test, 95 % probability)
Tabela 4: Višestruki rang test za prosječne veličine$Iv^{0,2}$, najmanja značajna razlika (LSD Fisher test) i formirane homogene grupe uz vjerovatnoću 95%

Bark damage - *Oštećenje*	Count *Broj podataka*	LS Mean *Srednja veličina zapreminskog prirasta*[1]	LS Sigma *Značajna razlika*	Homogeneous Groups *Homogene grupe*		
				1	2	*3*
2	1190	0,428922	0,00148837	X		
1	1445	0,444234	0,00134368		X	
0	15911	0,450248	0,000403914			X

Graph 1 and Table 4 show average tranformed value ($Iv^{0,2}$)of the tree volume incrementand least significant differences (LSD interval) at 95% probability per bark damage degree. It is observed that $Iv^{0,2}$ is the highest in undamaged trees and decreases towards trees with greater mechanical damage. The test showed that the differences in the volume increment between all groups formed (by type of damage) were statistically significant (Table 5).

Table 5. Multiple Range Test comparison of means ($Iv^{0,2}$) by type of damage
Tabela 5. Multipli Rang Testpoređenje sredina ($Iv^{0,2}$) po tipu oštećenja

Contrast *Poređenje*	Significance *Značajnost*	Difference *Razlike*	+/- Limits *+/-Limiti*
0 - 1	*	0,0060140	0,00250496
0 - 2	*	0,0213257	0,00409521
1 - 2	*	0,0153116	0,00214048

* denotes a statistically significant difference.
** označava statistički značajnu razliku*

The confirmation of the correctness of the performed analysis is clearly evident from the graph 2, which shows the distribution of residuals of estimated size ($Iv^{0,2}$) around the categories of the independent variable ("Bark damage"). It can be seen that the positive and negative values of the residuals are equally distributed around the estimated value of the $Iv^{0,2}$.

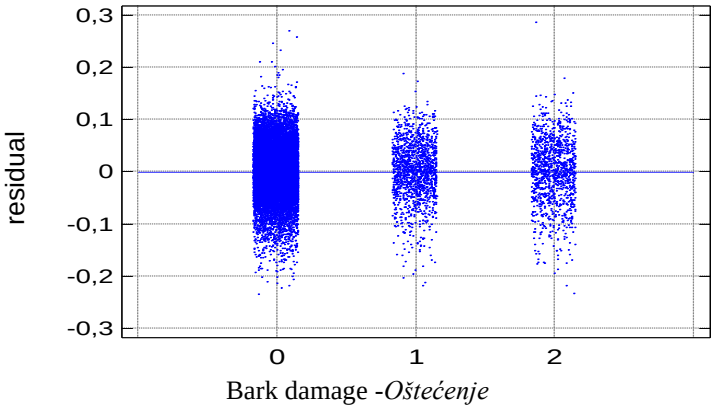


Chart 2. Distribution of residuals estimated value of $Iv^{0,2}$per independent variable categories („Bark damage")
Grafikon 2. Raspored reziduala procijenjene veličine $Iv^{0,2}$po kategorijama nezavisne varijable („Oštećenje")

Based on the obtained results, we can conclude that the mean volume increment of undamaged trees is 1.35% higher than trees with less mechanical damage (type 1) and 4.97% compared to trees with more mechanical damage (type 2). The results obtained are highly correlated with the results obtained by KRPAN et al. (1993). They found a loss in volume increment of mechanically damaged trees from 1 to 4.7%. This is especially important as these are studies in areas where the same forest utilization technologies are applied with approximately similar length of vegetation period.

The obtained data on the mean volume increment of one tree and the average number of trees per sample plot were used to calculate the average annual volume increment per hectare of forest area and its percentage reduction due to mechanical damage. The results are shown in Table 6.

Table 6. Decrease in volume increment of damaged trees, calculated on 1 ha of high forests in B&H
Tabela 6. Smanjenje zapreminskog prirasta[3] oštećenih stabala preračunato na 1 ha visokih šuma u BiH

Bark damage - *Oštećenje*	Tree number *Broj stabala*	Average volume increment of one tree[3] *Prosječan zapreminski prirast jednog stabla[3]*	Average number of trees per plot *Prosječan broj stabala na jednoj plohi*	Average volume increment[3] *Prosječan zapreminski prirast*[1]	Increment reduction *Umanjenje prirasta*
		m^3/ha/tree/year. *m^3/ha/stablo/god.*		m^3/ha/year. *m^3/ha/god.*	%
0	15911	1,18956	7,997413	9,5	0,00
1	1445	1,13108		9,0	4,92
2	1190	0,959044		7,7	19,38

The average reduction in volume increment is from 0,5 to 1,8 m^3 / ha / year, which for a ten-year period amounts to 5-18 m^3 per hectare of area, assuming the stands of only damaged or undamaged trees.

By comparison, KARDEL, (1978) found a loss of growth in spruce stands due to damage from hauling trees by tractors, from 5 to 15 m^3 in the same period (10 years). If the data on average volume increments determined on the sample plots and calculated on 1 ha (Table 6) are calculated on the total area of high forests in BiH (1,329,500 ha), we obtain data on the total volume increments. Based on the share of barke damaged trees (type 1 and 2) in the total number of trees, a total annual loss in volume increment of 205,713 m^3/year was calculated, only due to mechanical damage to the trunks of trees.

CONCLUSIONS - *Zaključci*

- Mechanical damage to trees has multiple negative impacts, which is reflected in the reduction of vitality, productivity and value of trees as well as other components of the forest ecosystem. However, this very important and complex problem in BiH's forestry practice and science, has unfortunately not received adequate attention.
- The share of damaged trees with significant decrease in quality and their value in BiH forests is high 14,21%.

[1] Zapreminski prirast ukupne drvne mase stabala (bez panja)
Volume increment of trees of total wood mass (without stump)

- The volume increase of mechanically damaged trees is statistically significantly lower than that of non-damaged trees resulting in a total loss of about 200,000 m^3/year. which at the current average prices of wood assortments represents a financial loss, only on the basis of volume increment, of about 18 mil. BAM.
- Mechanical damage to trees is an unavoidable risk when applying prescribed management systems and applied forest harvesting technologies. However, it is necessary and cost-effective to take all possible measures that would result in their reduction and increase in the volume increment, quality and value of the trees in the future.

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SAŽETAK

Poznato je da mehanička oštećenja stabala, koja nastaju pri izvođenju sječa i izvlačenju drvne mase iz šume, imaju višestruko negativne posljedice po kvalitet zalihe i zdravstveno stanje šuma kao i zapreminski prirast. U Bosni i Hercegovini značajnih mjerenja gubitaka u veličini zapreminskog prirasta usljed oštećivanja stabala nije bilo. U ovom radu je utvrđivanje uticaja mehaničkih oštećenja na veličinu zapreminskog prirasta stabala postavljeno kao cilj istraživanja. Pri tome su korišteni originalni podaci snimanja provedenog tokom II državne inventure šuma na velikim površinama (NFI) u Bosni i Hercegovini (2006-2009). U obzir su uzete sve dostupne visoke šume proizvodnog karaktera. Ove šume zauzimaju ukupnu površinu od 1.329.500 ha.Zapreminski prirast krupnog drveta, po grupama vrstama drveća, svih dostupnih visokih šuma proizvodnog karaktera u BiH, prema snimljenim podacima, prikazan je u tabeli 1.

Za potrebe ovog istraživanja, iz podataka snimljenih tokom druge NFI, u uzorak je odabrano 18.546 stabala premjernih na detaljnim plohama (svaka četvrta) na kojima je, među ostalim podacima, izmjeren 10-godišnji debljinski prirast stabala i vršena evidencija značajnih mehaničkih oštećenja (LOJO et al., 2008).

Evidentirana mehanička oštećenja stabala na primjernim plohama razvrstavana su na sljedeće tipove oštećenja:

0 - neoštećeno stablo
1 - mehanički oštećeno stablo (kriterij - II uzgojno-tehnička klasa)
2 - mehaničko oštećeno stablo (kriterij - III uzgojno-tehnička klasa)

U analizama podataka primjenjena je višefaktorijalna analiza varijanse, gdje su kao nezavisne kategorijske varijable uzete grupe vrsta drveća (četinari i lišćari) i tip mehaničkog oštećenja, da bi se izbjegao jak uticaj prsnog prečnika stabala (DBH) na veličinu zapreminskog prirasta stabla, ovaj faktor (DBH) je uključen kao kovarijabla u analizu. Rezultati su prikazani u tabeli 3, a značaj pojedinih tipova oštećenja kore debala stabala je prikazan u tabeli 4 i grafikonu 1,

Od ukupnog broja stabala njih 2.635 ili 14,21% je bilo mehanički oštećenih. S obzirom da je riječ samo o značajnim oštećenjima možemo konstatovati da je ovo izuzetno veliki udio.

Utvrđena je direktna zavisnost između značajnih oštećenja kore debla i veličine zapreminskog prirasta pojedinačnih stabala. Zapreminski prirast oštećenih stabala je manji od 4,9 % (tip 1) do 19.4% (tip 2), u odnosu na neoštećena stabla (tabela 6).

To rezultira ukupnim gubitkom od oko 200.000 m^3/god. Na ukupnoj površini visokih šuma proizvodnog karaktera u BiH, što pri aktuelnim prosječnim cijenama drvnih sortimenata predstavlja finansijski gubitak, samo po osnovu prirasta, od oko 18 mil. BAM.

Mehanička oštećenja stabala imaju višestruki negativan utjecaj koji se ogleda u smanjenju vitaliteta, poduktivnosti i vrijednosti stabala ali i drugih komponenti šumskog ekosistema. Ipak, ovom veoma bitnom i složenom problemu u bosanskohercegovačkoj šumarskoj praksi i nauci nije, nažalost, posvećena adekvatna pažnja.

Mehanička oštećenja stabala predstavljaju neizbježan rizik pri primjeni propisanih sistema gazdovanja i primjenjivanih tehnologija iskorištavanja šuma. Međutim, neophodno je i isplativo poduzeti sve moguće mjere, koje bi rezultirale njihovim smanjivanjem, te povećanjem prirasta, kvaliteta i vrijednosti stabala u budućnosti.

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