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STRUCTURAL CHARACTERISTICS OF WHITE BARK PINE (*PINUS HELDREICHII CHRIST*) FORESTS IN MONTENEGRO

Abstract: Present structure is the result of spontaneous development processes over a long time period and human activities influence. In this paper we analyzed data of the White Bark Pine (*Pinus heldreichii* Christ) forest area and average values of basic measurement elements — number of trees (N), wood volume (V) on different altitude according data of the First National forest inventory in Montenegro and 0 field research.

Analysis of the structure of those forests stands in Montenegro show diversity of growth conditions. Measuring elements present the best indicators of productivity of different areas for searched forest tree species.

The most of the White bark pine stands in Montenegro exist at altitudes ranging from 1400 m to 1800 m but the highest value of growing stock per ha shows at altitudes from 1800 m to 2000 m which undoubtedly shows that the White bark pine in Montenegro is the species of mountain regions.

Key words: *Pinus heldreichii, structure, white bark pine, Montenegro*

INTRODUCTION

Pinus heldreichii Christ (White bark pine, Bosnian pine or Munika) present subendemic, long-living high-elevation species on the Balkan Peninsula and southern Italy. It is widespread in the high mountain forest zone of the Mediterranean and sub-Mediterranean mountains (up to 2000 m above sea level, very often the upper limit of forest vegetation) of Southern Italy, Bosnia and Herzegovina, Montenegro, Serbia, Macedonia, Albania, Bulgaria and Greece (Vukićević, 1996).

According to the IUCN red list, white bark pine is not listed as endangered, but at the regional level can be included in the endangered, or even highly endangered, type (Ocokoljic et al 2013).

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White bark pine forests in Montenegro are currently classified as protective forests according to: their ecological characteristics, the area of spreading, slope on which it occurs, the forests characteristics and stand structures. Special management class is defined for these forests: management class 927 — protective forests of White barks Pine. In these stands are not planned cutting, because the felling of trees and the construction of roads (train) increased the risk of erosion because of orographic and soil conditions.

In Bosnia and Herzegovina there are 6 reserves areas of *Pinus heldreichii* with total surface of 255 ha (Pintaric 1999) and plan is that area of all protected reserves in Bosnia will be enlarged, especially in the mountain region Prenj-Čvrsnica-Čabula, which is the centre of the endemic tree species *Pinus heldreichii*.

Climate change on forest ecosystems affected primarily in moving of the vegetation vertical layout belts. In Montenegrin forests climate changes could have the greatest impact on the species with narrow ecological valence, such as spruce, fir and oak, and some endemic species such as some pines (*Pinus peuce* and *Pinus heldreichii*) (Curovic and Spalevic, 2010).

Panayotov et al. (2009) observed a relationship of the radial growth pattern of Pinus heldreichii in the Pirin Mountains (Bulgaria) to high temperatures and low precipitation in summer. Analyses of various age classes indicate younger trees (<300 years), react more sensitive to drought conditions particularly in the driest months July and August maybe due to shallow root systems. Tree ring chronologies of Albanian high elevation *Pinus heldreichii* contain a strong common signal and potential to cover at least the last millennium, although the climatic signal is still too weak for robust reconstruction (Seim et al. 2010).

Good knowledge of structural elements of stands (number of trees (N), wood volume (V), volume increment (Zv), mean diameter and high (Ds and Hs) etc.), apart from having the knowledge of biological, ecological characteristics of species and conditions in habitats, is of a special importance for reviewing the choice of the most appropriate decisions of forest management (Medarevic et al. 2004).

MATERIAL AND METHODS

Base of this research are data of the First National forest inventory in Montenegro, data of regular Inventory and field research on several locations.

In the NFI of Montenegro, information is assessed for sample plots that are distributed over the land area of Montenegro as follows:

The clusters grid with the sample plots is distributed in the entire territory of Montenegro and is based on a regular 2 x 2 *km* square raster (basic raster), set up by *Gauss-Krüger's coordinate system and projection* — zone 6. On each section of the 2 x 2 *km,* square raster there is the cluster consisting of four sample plots, positioned in the tops of the square whose leg length is 200 *m*. The sample plot consists of four concentric circles, whereat the radius of the first circle is r_1=5,64 *m* (p_1=1 *acre* on plain terrain), of the second circle r_2=7,98 *m* (p_2=2 *acres*), of the third circle r_3=12,62 *m* (p_3=5 acres) and the radius of the fourth circle r_4=17,84 *m* (p_4=10 *acres*). Diameter measurement was performed on the first concentric circle, on

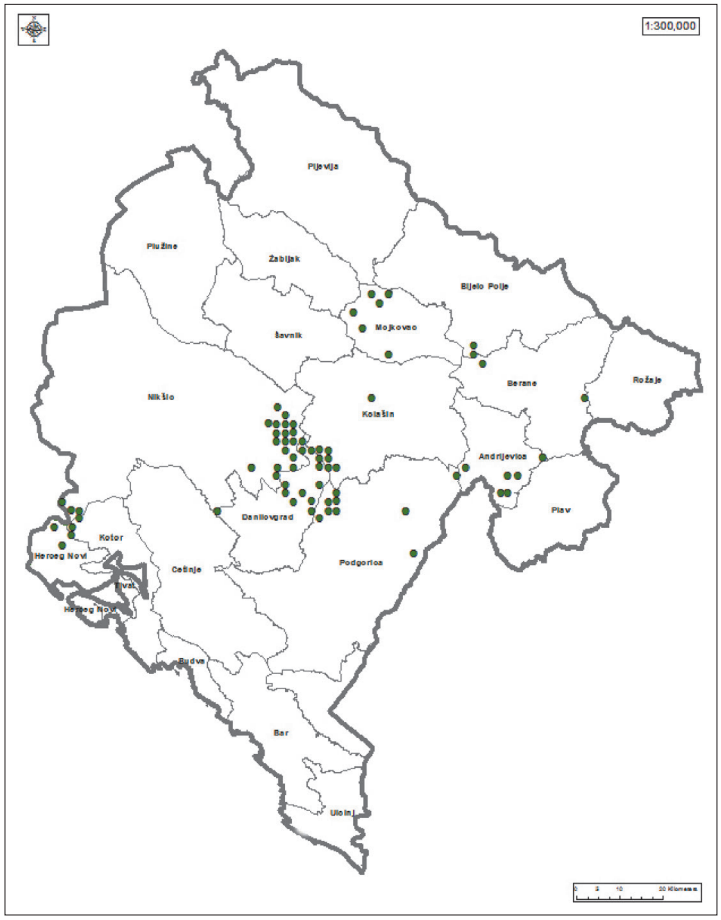

Fig. 1. Position of whitebark pine forest in Montenegro

all trees above 10 *cm at* high forests, while taxation limit for coppice forests was 5 *cm*. On the other concentric circle, diameters were measured on all trees above 15 *cm*, on the third circle diameters on all trees above 30 *cm* and on the fourth circle diameters of trees above 50 *cm*.

In a regular inventory data were obtained by collecting in a network of permanent and non permanent points which are placed on grid 100 x 100 m at a level of Management units.

Field research was done by total measurement in simple plots of 10 acres.

RESULTS AND DISCUSSION

According to the First national forests inventory of Montenegro (MARD, 2013) surface on which occurs *Pinus heldreichii* is 10.541,6 ha which means 0,0076% of the territory of Montenegro (Figure 1). White bark pine forests mainly occur on organo-mineral calcareous black soils that are less skeletal and deeper.

When we talk about the basic structural elements — Number of trees and wood volume per unit area (Table 1), the structure of Whitebark Pine Forests in Montenegro is characterized by 460 trees per hectare with an average volume of 216,9 m^3/ ha which is satisfying becouse of its occurance at high-altitude belt and characteristics of the habitat in those areas.

Also, this volume is very close to optimal volume for munika of 220 m^3 per ha (Medarevic M, 2006), which indicates that these stands fully correspond habitat.

The results of White bark pine forest structure on Mt. Cvrsnica, Croatia (Mestrovic A, 2007) show that measuring elements as indicators of productivity depend on age, development stage, habitat conditions and degrees of canopy, while the average values add up to the following figures: stands volume — 165,7 m^3/ha of the entire wooden mass, stand volume increment 2,14 m^3/ha of the entire wooden mass, base of stand — 20,0 m^2/ha, number of trees in stand- 526 piece/ha, mean stand diameter 19,6 cm, mean stand height — 7,3 m, degree of canopy — 0,44, site quality of stand — 3,5, transitional period of the trees — 24 years and relative tree age 164 years.

The average diameter of the White bark pine forest in Montenegro is 31,9 cm and is an indicator that the highest representation of middle age stands as expected because until recently were managed and cut regularly. Its cutting maturity diameter was projected at that time at 55 cm, with a rotation of 150 years and the regeneration period of 50 years.

Table 1. Structural characteristics of white bark pine (*Pinus heldreichii*) forests per municipalities in Montenegro

	Area P (ha)	N	N/ha	V	V/ha	Zv	Zv/ha	G	G/ha	Ds	Hs
Andrijevica	708.0	239833.0	339.0	207173.0	292.6	4143.7	5.9	21021.0	29.7	38.6	17.2
Berane	35.3	27185.0	770.0	9394.0	266.0	348.2	9.9	1418.0	40.2	25.8	10
Bijelo Polje	120.3	30166.0	251.0	39885.0	331.6	274.4	2.3	2706.0	22.5	37.1	9.5
Mojkovac	307.3	54510.0	177.0	38813.0	126.3	882.6	2.9	4912.0	16.0	37.6	13.8
Kolasin	1314.1	564863.0	430.0	323823.0	246.4	5001.3	3.8	34370.0	26.2	32.6	12.7
Herceg Novi	272.1	72663.0	267.0	12685.0	46.6	398.7	1.5	2392.0	8.8	24.7	7.2
Danilovgrad	2983.4	1748765.0	586.0	562842.0	188.7	11388.9	3.8	70076.0	23.5	24.4	11.2
Niksic	3473.0	1731360.0	499.0	803474.0	231.4	12926.9	3.7	89082.0	25.7	32	12.2
Podgorica	1097.3	361001.0	329.0	251056.0	228.8	4554.3	4.2	27530.0	25.1	38.2	14.6
Total — MONTENEGRO	10541.6	4853140.0	460.0	2286334.0	216.9	40274.3	3.8	257544.0	24.4	31.9	12.6

Most of Whitebark Pine forests (73.7%) is located in the central region of Montenegro in Niksic, Danilovgrad and Kolasin.

The best productivity is achieved at the municipalities of in the northern part of Montenegro where it occurs in communities with beech and in a better habitat at: Bijelo Polje, Kolasin and Andrijevica, where the volume of Whitebark pine is above the optimum. The reason for the larger volume is not just because of the better habitat conditions but also becouse of the higher number of thicker trees at sites where the cut could not be managed in the past.

When we look at the structure according to developmental stage stands (Table 2) revealed that the volume is concentrated in co-mature stands (30–49) cm with

almost 30% or 689133 m^3. The highest volume per ha (326,5 m^3/ha) occurs in the stands with a diameter of over 50 cm which is expected, and is an indicator of good long term production potential of white-bark pine.

Table 2. Structure by development phase of white bark pine (*Pinus heldreichii*) forests in Montenegro

DHB class	Area P (ha)	N	N/ha	V	V/ha	Zv	Zv/ ha	Zv/V	G	G/ ha	Ds	Hs
Thicket, dominating DBH 5–9 cm	92.4	15791.0	171.0	3894.0	42.1	89.4	1.0	2.3	664.0	7.2	33.6	10.7
Young pole — stand DBH 10–14 cm	664.4	313220.0	471.0	47232.0	71.1	1364.9	2.1	2.9	8405.0	12.7	25.9	9.3
Old pole-stand dom. DBH 15–29 cm	3152.4	1393985.0	442.0	402188.0	127.6	9588.0	3.0	2.4	56659.0	18.0	28.5	10.4
Maturing stands dom. DBH 30–49 cm	3282.1	1484246.0	452.0	689133.0	210.0	12218.3	3.7	1.8	78803.0	24.0	30	12.5
Opened matured stands with poor regeneration DBH > 50 cm	1133.9	361944.0	319.0	370183.0	326.5	4083.2	3.6	1.1	32767.0	28.9	39.8	14.5
Opened matured stands well regenerated DBH > 50 cm	775.2	278819.0	360.0	174404.0	225.0	2406.7	3.1	1.4	17782.0	22.9	35.4	11.9
Selection stands, group selection stands and other stands	1441.1	1005135.0	697.0	599299.0	415.9	10523.8	7.3	1.8	62464.0	43.3	33.1	14.4

Observed by slopes (Table 3) it is evident that the whitebark pine forests occur on all slopes. The most common are mild to moderately steep slopes (0–20 degrees where it occurs 50.7% of these forests), but also occurs on steep (21–30 degrees Celsius to 30.1% of the area) and very steep and rugged slopes of 31 and more degrees where it occurs on 19.2% of the area.

Further analysis of the structure according to the altitude shows that whitebark pine has a wide range of occurrence, but mainly above 1000 m above sea level (asl). That fact gives an additional importance to these ecosystems as regards of protection of soil erosion in mountain regions having in mind high dependencies and interactions between hydrogeomorphic processes and vegetation (Spalevic et al 2015).

It is most prevalent in the zone 1400–1800 m where is 71.6% of the surface of observed stands and 78.7% volume mass, observed by total volume. The maximum volume and volume increment per hectare (331,5 m^3/ha; 7,1 m^3/ha) is located in the forests above 1800 m asl which shows that white bark pine forests are without doubt a forest type of mountain regions.

Table 3. Structure by slopes

Elevation in degrees	Surface (ha)
0–5	100.0
6–10	2585.4
11–15	1153.3
16–20	1506.5
21–25	1563.1
26–30	1603.9
31–35	1172.3
36–40	458.5
41–45	299.9
>45	98.7
Total	10541.6

Fig. 2 White bark pine at the top of Komovi Mountain

Fig. 3 White bark pine at Korita Kucka (Podgorica)

Table 4. The structure according to the altitude

Altitude	Area (ha)	N	N/ha	V	V/ha	V %	Zv	Zv/ha	Zv %	G	G/ha	Ds	Hs
0–200 m	6.4	4935.0	771.0	626.0	97.8	0.0	33.9	5.3	0.1	119.0	18.6	17.5	10.4
801–1000 m	129.7	81028.0	625.0	14618.0	112.7	0.6	436.8	3.4	1.1	2406.0	18.5	20.4	8.8
1001–1200 m	1024.0	339951.0	332.0	141864.0	138.5	6.2	2662.6	2.6	6.6	16160.0	15.8	28.5	12.6
1201–1400 m	1333.6	377051.0	283.0	165996.0	124.5	7.3	2754.0	2.1	6.8	19471.0	14.6	39.4	12.5
1401–1600 m	3944.1	1890031.0	479.0	868384.0	220.2	38.0	15254.9	3.9	37.9	98287.0	24.9	30.9	12.9
1601–1800 m	3609.0	1868672.0	518.0	930796.0	257.9	40.7	15624.5	4.3	38.8	102362.0	28.4	32.8	12.4
1801–2000 m	494.9	291471.0	589.0	164050.0	331.5	7.2	3507.6	7.1	8.7	18740.0	37.9	29.2	12.6
Total	10541.6	4853140.0	460.0	2286334.0	216.9	100.0	40274.3	3.8	100.0	257544.0	24.4	31.9	12.6

CONCLUSIONS

The evaluation of the structural characteristics of white bark pine (*Pinus heldreichii* Christ.) forest in Montenegro is of great importance in the process of conservation and preservation of the gene pool of this tertiary relict species. This research is the basis for further multidisciplinary research.

White bark pine (known as Bosnian pine or Munika) is sub-endemic species of the Balkan Peninsula which is widespread in the high mountain forest zone of the Mediterranean and sub-Mediterranean mountains.

The creation of a realistic information base of structural characteristics is needed condition in order to be able to adequately monitor the situation of these forests as well as for planning of short and long-term objectives of forest management and for selection of appropriate measures for their implementation. Limited spread of this species gives even greater importance of the results presented in this paper.

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STRUKTURNE KARAKTERISTIKE ŠUMA BIJELOG BORA (*PINUS HELDREICHII CHRIST*) U CRNOJ GORI

Rezime

Sadašnja struktura šume bijelog bora rezultat je spontanih razvojnih procesa tokom dugog vremenskog perioda i uticaja aktivnosti čovjeka. U ovom radu analizirani su podaci o područjima na kojima se prostire šuma bijelog (Pinus heldreichii Christ) i prosječne vrijednosti osnovnih mjernih elemenata — broj stabala (N), drvan masa (V) na različitim nadmorskim visinama, prema podacima Prve nacionalne inventare šuma u Crna Gora i na onovu terenskih istraživanja.

Analiza strukture tih šuma u Crnoj Gori pokazuje raznolikost uslova rasta. Mjerni elementi predstavljaju najbolje pokazatelje produktivnosti različitih područja za proučavane šumske drvne vrste.

Najveći dio šume bijelog bora u Crnoj Gori prostire se na nadmorskoj visini od 1400 m do 1800 m, ali najveća vrijednost rastuće površine po ha na nadmorskoj visini od 1800 m do 2000 m, što nesumnjivo pokazuje da je bor bijele kore u Crnoj Gori vrste planinskih regija.

Ključne riječi: *Pinus heldreichii, struktura, bijeli bor, Crna Gora*