

# STOCKS OF DEAD BIOMASS OF BEECH (*FAGUS SYLVATICA* L.) FOREST ECOSYSTEMS IN WEST BALKAN RANGE, BULGARIA\*

ZALIHE BIOMASE MRTVOG DRVA U ŠUMSKIM  
EKOSUSTAVIMA BUKVE (*FAGUS SYLVATICA* L.)  
NA PODRUČJU ZAPADNOG BALKANA, BUGARSKA

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## SUMMARY

The dead trees play an important role in the functioning and productivity of the forests' ecosystems through influence over biological diversity, the accumulation of carbon dioxide, nutrient turnover and energy flux, hydrological processes, protection of the soils and the regeneration of tree species. The dead wood assures important habitats also. In historical aspect, for many years the dead wood was removed from the stands as a measure for protection against insects and fungi, which are perceived as a threat for the healthy forest status. This leads to reduction of the quantity of the dead wood in the forest ecosystems to critical low levels, which are not enough for maintaining the vital populations of many forest species. During the past years, the new settings in the national legislation, especially these related to the Natura 2000 development and management, require the quantity information about this component for the forest habitats assessment. In this regard, the objective of this study was to obtain quantitative data on stocks of dead forest biomass in beech communities in West Balkan Range.

The amount of standing dead wood was calculated with height rates tables; method of line intersect sampling was used for determination of the lying dead wood stocks. Thomas scale was used to assess the degree of decomposition of standing dead biomass (Table 2) and a 4-point harmonized scale for lying biomass and stumps (Table 3).

It was found total dead wood biomass stocks variation in the range of 14.48 - 41.8 m<sup>3</sup>.ha<sup>-1</sup> as a result of studies conducted in beech stands (Table 5). The standing dead wood biomass was 6.7-17.5 m<sup>3</sup>.ha<sup>-1</sup>, lying dead wood biomass was 3.4-26.5 m<sup>3</sup>.ha<sup>-1</sup>, stumps were 0.28-6.4 m<sup>3</sup>.ha<sup>-1</sup>. The observed standing dead trees were mainly from the fourth level of decomposition. The prevailing rate of decomposition for lying biomass was B and for stumps were C and D (Table 6).

It can be generalized from the results of current study that the percentage of the total amount of dead wood to the total forest yield was insufficient from a conservation perspective.

**KEY WORDS:** dead wood, stocks, beech communities.

## INTRODUCTION UVOD

The dead trees play an important role in the functioning and productivity of the forests' ecosystems through influ-

ence over biological diversity, the accumulation of carbon dioxide, nutrient turnover and energy flux, hydrological processes, protection of the soils and the regeneration of tree species. The dead wood assures important habitats for invertebrates' species, for small vertebrate species, fishes,

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birds as well as many lichen, mosses and fungi species (Dudley, Vallauri 2004).

In historical aspect, for many years the dead wood was removed from the stands as a measure for protection against insects and fungi, which are perceived as a threat for the healthy forest status. This leads to reduction of the quantity of the dead wood in the forest ecosystems to critical low levels, which are not enough for maintaining the vital populations of many forest species (Lazarov et al., 2012). The protection of these species and forest habitats became a priority and require a new perception of the dead wood meaning with the establishment of European ecological network Natura 2000.

Each group of organisms require different types and amount of dead wood. Characteristics of deadwood as size, tree species, type (standing or lying), duration and stage of decay are important to maintain their life cycle. It is assumed that the dead wood with larger sizes deliver more microhabitats and therefore habitats for more species. But studies show that smaller deadwood debris are important habitat for some species of fungi.

Deadwood as part of living trees (dead branches, rotten core, etc.), also has its residents. The availability of adequate supplies and diverse in their quality characteristics dead wood provides optimal conditions for the existence of organisms related to the functioning of ecosystems, but there are rare and endangered species of conservation importance, which are entirely dependent on its presence in the forests. The understanding of the importance of deadwood habitat for such organisms is constantly growing. However, the ecology of communities of dead wood is not yet well understood, making it difficult to formulate practical recommendations for their conservation.

About a third of plants and animals in the forest are directly related to the presence of dead wood and they are also the most endangered species group in Europe (Borisov 2006). By the studies in Germany, it was found that over half of inhabiting forests beetles are saproxylic (Köhler 2000 - in Schlaghamersky 2007). Despite its great importance, the dead wood is currently critically at low level in most European countries. This applies especially to the forests, in which logging is carried out. Often the dead wood was 20 times less than that of the natural (without or with minimal human intervention) forests (Dudley, Vallauri 2004).

The dead wood is included as one of the important parameters for defining the Favourable Conservation Status of forest ecosystems in the NATURA 2000 sites. It is defined by the „Guide for assessing favorable conservation status of species and habitat types in Natura 2000 in Bulgaria“ (Zingstra et al. 2009) regulations and it is an important step for the management planning of their maintaining or improving.

The need to assess the status of biodiversity, carbon stocks, and the risk of forest fires and calamities of diseases and

pests have accelerated the need for an inventory of dead wood in forests. Depending on the goals, the assessment is made of different spatial levels, ranging from territory of states to individual habitats. In many countries the quantity and characteristics of dead wood is a part of the national forest inventories.

In the ongoing inventory, the largest volume of deadwood was reported in the forests of Switzerland (11 m<sup>3</sup>.ha<sup>-1</sup>), Czech Republic (6.5 m<sup>3</sup>.ha<sup>-1</sup>), Austria and Slovenia (6 m<sup>3</sup>.ha<sup>-1</sup>). Significantly lower volumes were recorded in Bulgaria and Slovakia (0.3 m<sup>3</sup>.ha<sup>-1</sup>), UK (0.4 m<sup>3</sup>.ha<sup>-1</sup>), Greece (0.7 m<sup>3</sup>.ha<sup>-1</sup>) and Spain (0.9 m<sup>3</sup>.ha<sup>-1</sup>) (UNECE/FAO 2000). The evaluation of dead wood in smaller spatial scales is essentially with conservation and scientific interest.

Many authors focus their attention on dead biomass. It is accepted as essential stock of biomass and carbon pool (Arthur, Fahey 1992; Bradford et al. 2009; Domke et al. 2011) that need to be considered in inventories and evaluated under the Framework Convention for UN climate change. Kueppers et al. (2004) studied the dead wood biomass and the rate of decay in altitude gradient. According to Oswalt, Brandeis (2008), the dead wood is an important part of the total biomass and should be also considered when assessing carbon stocks. In Bulgaria investigations on quantity and distribution of dead wood in representative forest plant communities are insufficient. Currently, the measurements were made within the project „Biodiversity Conservation rid of Maglenik, Eastern Rhodopes“ and „State and perspectives of the population of plain chestnut in Belasitza“ (Velichkov et al. 2011).

Zlatanov et al. (2013) suggest as an index for a complex assessment of old age forests, the „accumulation of dead wood“ to be used as an indicator. It consists in the presence of standing and fallen dead trees in varying degrees of decomposition of wood in an amount at least 80 m<sup>3</sup>.ha<sup>-1</sup> for spruce and fir, 60 m<sup>3</sup>.ha<sup>-1</sup> for common beech and European oak and 40 m<sup>3</sup>.ha<sup>-1</sup> for the remaining oaks and pines. Lower quantities around 50 m<sup>3</sup>.ha<sup>-1</sup> are typical for many old oak and beech forests in Bulgaria.

The information about the amount of dead wood in coniferous stands are found in publications of Panayotov et al. (2011), Rangelova, Panayotov (2013).

In 2013 within the project „Mapping and determination of the conservation status of habitats and species“, the amount of dead wood in some natural habitats in areas included in the Natura 2000 network was assessed.

During the past years, the new settings in the national legislation, especially these related to the Natura 2000 development and management, require the quantity information about this component for the forest habitats assessment of favorable nature conservational status. The inventory and dead wood monitoring are encouraged as instruments for sustainable forest management as the forest certification.

The review on the topic shows that the subject is very actual and investigated in the world, but in our country there is a lack of sufficient data, which requires the conduction of this study.

## MATERIAL AND METHODS

### MATERIJALI I METODE

#### Study sites – Područje istraživanja

The studies were conducted in four sample plots located in beech communities in the territory of Petrohan Training and Experimental Forest Range. The beech stands in the range are considered among the best in Europe. They are unique in terms of their productivity and multifunctional purpose. It is located on the north-eastern slopes of Western Balkan Range, Bulgaria. Its total area is 7192 ha. The relief of the range is typically mountainous, steep, with deeply cut river valleys and steep minor ridges. The lowest point of the range is at an altitude of 350 m; the highest point is at an altitude of 1900 m. The high proportion of the forest area (88,5%) is located in the middle-mountain forest zone, containing beech and coniferous trees (600-1800 m). The region belongs to the temperate climatic zone. The soils are mainly (Cambisols, CM, WRB, 2006).

The sample plots main characteristics are given in Table. 1. Phytocoenotic horizon I into the territory of SP 1 was mono dominant presented by common beech. Its total coverage

was 70%. Phytocoenotic horizon II was with coverage of 70%, and was also represented mainly by undergrowth of common beech. The general cover of phytocoenotic horizon III was 90%, and it included 14 plant species. This plot is a training sample plot for University of Forestry. It is special category and is part of site of community importance (SCI) of Natura 2000 network. The harvesting intensity in the stand is 0% last 10 years. The canopy is low and rotation is not foreseen.

On the territory of SP 2 *Fagus sylvatica* was a dominant in the first phytocoenotic horizon and *Acer pseudoplatanus* L. had a single participation. Overall cover was 50%. Phytocoenotic horizon II was with cover 10% as *Atropa belladonna* L. occurred in it. The total cover of phytocoenotic horizon III was 100%, as it includes 29 plant species. The harvesting intensity in the stand is 15% and the rotation period is 20 years.

On the territory of SP 3 the first phytocoenotic horizon was represented only by *Fagus sylvatica* L. Its total cover was 70%. Phytocoenotic horizon II was with coverage 30%. The total coverage of the third phytocoenotic horizon was 90%, as it includes 15 plant species. This plot is special category and is part of site of community importance (SCI) of Natura 2000 network. The harvesting intensity is 0% and rotation is not foreseen because it is a seed production stand.

*Fagus sylvatica* was a dominant in the tree layer on the territory of SP 4. The total coverage of the first phytocoenotic

**Table. 1. Stand characteristics in the sample plots.**

Tablica 1. Karakteristike staništa na pokusnim plohama.

Sample Plots pokusna ploha	Altitude, m Nadmorska visina, m	Coordinates koordinate	Age, years Dob, godine	N/ha Broj/hectar	Stock, m <sup>3</sup> /ha Zaliha, m <sup>3</sup> /ha	Origin Podrijetlo	Slope, ° nagib, °	Canopy sklop	Exposition, izlaganje	Average height, m Prosječna visina, m	Average diameter, cm Prosječni promjer, cm
SP 1 PP 1	750	N 43° 09' 19.1" S 43° 09' 19.1" E 23° 08' 50.8" / 23° 08' 50.8"	150	252	223	Seed sjeme	8	0.4	N S	29	42
SP 2 PP 2	890	N 43° 08' 53.3" S 43° 08' 53.3" E 23° 08' 16.4" / 23° 08' 16.4"	35	1192	117	Seed sjeme	21	0.9	NE SI	10	12
SP 3 PP 3	980	N 43° 08' 28.9" S 43° 08' 28.9" E 23° 08' 33.8" / 23° 08' 33.8"	160	268	330	Seed sjeme	28	0.6	SW JZ	29	48
SP 4 PP 4	1440	N 43° 07' 15.2" S 43° 07' 15.2" E 23° 07' 17.8" / 23° 07' 17.8"	130	684	164	Seed sjeme	18°	0.8	SE JI	27	32

**Table 2.** Thomas scale – degrees of decomposition for standing dead wood**Tablica 2.** Thomasova ljestvica - stupnjevi raspadanja za dubeće mrtvo drvo

Degree Stupanj	1	2	3	4	5
Bark Kora	undistorted neizobličen	50% or missing ili nedostaje	75% missing nedostaje	75% missing nedostaje	more than 75% missing više od 75% nedostaje
Branches grane	Presence prisutnost	missing nedostaje	missing nedostaje	Missing nedostaje	missing nedostaje
Decomposition of the pith Raspadanje srčike	Minimum minimum	minimum to progressive najmanje do progresivnog	minimum to progressive najmanje do progresivnog	primary to progressive primarno do progresivnog	progressive to brittle progresivno do lomljivo
Decomposition of the sap-wood Raspadanje bjeljike	no or at primary level ne ili na primarnoj razini	no or at primary level ne ili na primarnoj razini	no or to 25% ne ili do 25%	25-50% 25-50%	more than 50% više od 50%
Breaking the top Slamanje vrha	it may be broken može se slomiti	it may be broken može se slomiti	broken around 1/3 slomljen oko 1/3	broken from 1/3 to 1/2 slomljen od 1/3 do 1/2	more than 1/2 više od 1/2
Shape of the stem Oblik debla	Preserved očuvan	Preserved očuvan	mostly preserved uglavnom očuvan	lost form, unclear izgubljeni oblik, nejasno	impaired shape oštećen oblik
Age after destruction Dob nakon uništenja	1-5 years 1-5 godina	> 5 years 1-5 godina	> 5 years 1-5 godina	> 5 years 1-5 godina	> 5 years 1-5 godina

horizon was 80%. Total coverage of phytocoenotic horizon II was 30%, as it included 21 plant species. This sample plot is special category because it is in water catchment zone. The harvesting intensity is 15% and the rotation period is 120-150 years. The applied cuttings are selective.

### Dead biomass measurement – Mjerenje mrtve biomase

To take in mind all aspects of dead wood, it is necessary to define its different components. Generally dead wood can be divided into three main components:

- 1) standing dead wood – standing withered trees and broken stems, resulting from natural processes of loss;
- 2) lying dead wood - fallen and uprooted trees, stems and branches as a result of natural processes and logging activities
  - a. coarse debris - wood with a length of more than 1 m and diameter - larger than 10 cm
  - b. fine wood - wood with diameter less than 10 cm
- 3) stumps - part of the base of the stem which remains after its cutting

#### 1. Standing dead biomass – Dubeća mrtva biomasa

To establish the stock of dead wood a sample plots with square shape and size 50/50 m (2500 m<sup>2</sup>) were settled. To determine the amount of standing dead wood, the diameter of 1,30 m height and the height of all standing dead trees were measured, then their volume was calculated with height rates tables Duhovnikov (Poriazov et al. 2004). The height order was determined according the diameter of 1,30 m height and the height of each tree stem with help of tables for natural common beech stands. Then the volume (m<sup>3</sup>)

value for each tree according its diameter from each height order was taken. Then the sum of volumes of dead standing trees was given (m<sup>3</sup>.ha<sup>-1</sup>).

#### At the specific table for each height order for each tree according its diameter

#### 2. Lying dead wood – Ležeće mrtvo drvo

The method of line intersect sampling (Warren, Olsen 1964; Van Wagner 1968), adapted by Lazarov et al. (2012) and approved by Ministry of Environment and water was used for determination of the lying dead wood stocks.

The diagonals that intersect randomly fallen and lying on the surface tree trunks and branches were outlined. The diameter at the intersection was measured.

The volume of fallen deadwood was calculated as follows (1):

$$V = \pi^2 \sum_{i=1}^n d_i^2 / 8L \quad (1)$$

where:

- V – volume of lying dead wood (m<sup>3</sup>.ha<sup>-1</sup>)
- d<sub>i</sub> – diameter in the point of intersection (cm)
- L – length of transect (m)

#### 3. Stumps – Panjevi

The diameter and height of each stump were determined. The volume of the stumps was calculated as follows (2):

$$V = \pi \cdot r^2 \cdot h \quad (2)$$

where:

- V – volume of dead stumps (m<sup>3</sup>.ha<sup>-1</sup>)
- r – radius (m)
- h – height of the stump (m)

**Table 3.** Degrees of decomposition of lying dead wood and stumps  
**Tablica 2.** Stupnjevi raspadanja mrtvog drveta i panjeva

Class <i>klasa</i>	Description <i>Opis</i>
A	hard texture 90 %, no decomposition, stem completely solid <i>tvrda tekstura 90%, nema raspadanja, deblo potpuno čvrsto</i>
B	hard texture 90-60 %, stem slightly decomposed, the majority hard <i>tvrda tekstura 90-60%, deblo blago razgrađeno, većinom tvrdo</i>
C	hard texture 60-30 %, stem decomposed, prevailing part soft <i>tvrda tekstura 60-30%, deblo razgrađeno, prevladava mekani dio</i>
D	hard texture 30 %, stem very decomposed, prevailing part soft <i>tvrda tekstura 30%, deblo vrlo razgrađeno, prevladava mekani dio</i>

Additionally the following characteristics were reported, as: wood type, degree of decomposition, presence of hollows, holes, fungal bodies, reason caused the destruction of the tree and others.

Thomas scale (Thomas 1979) (Table 2) was used to assess the degree of decomposition of standing dead biomass and a 4-point harmonized scale (Rondeux et al. 2012) (Table 3) for lying biomass and stumps.

## RESULTS REZULTATI

The living standing trees were dominating at all sample plots. The dead trees represented about 3 to 8% of the total number of trees (Table. 4). Most of the observed standing dead trees were broken. The higher percentage of dead trees on the territory of SP 2 to other sample plots was due to the fact that recently there had been snow falls.

On the territory of SP 1 the lying dead biomass prevailed - 52%, standing dead biomass was represented by 46% and stumps were 2%. The fine wood fraction prevailed from lying dead wood biomass - 5,5 m<sup>3</sup>.ha<sup>-1</sup> (Table. 5). With respect to the degree of decomposition the prevailing amount of this phytomass fraction was of class B - 56%, and at least - of class A - about 3% (Table. 6). The standing biomass was represented by a small number of trees (8 per ha) of first and fourth degree of decomposition with presence of fungal fruiting bodies on them. The stumps were also not enough (8 per ha) and the degree of decomposition was C (50%) and D (50%) - significantly decomposed. There was no undergrowth of the main tree species on them, as usu-

**Table 4.** Ratio (%) between dead and alive trees at sample plots  
**Tablica 4.** Omjer (%) između mrtvih i živih stabala na pokusnim ploham

Tree state	SP 1	SP 2	SP 3	SP 4
<i>Stanje stabla</i>	<i>PP 1</i>	<i>PP 2</i>	<i>PP 3</i>	<i>PP 4</i>
standing dead dubeće mrtvo	3.2	7.7	6.0	3.5
standing alive dubeće živo	96.8	92.3	94.0	96.5

ally occurs in coniferous species, for example spruce and Macedonian pine (Panayotov 2007).

On the territory of SP 2 the lying dead wood biomass prevailed - 63%, the standing dead biomass was represented with 26% and stumps were - 11% of the total stocks. The coarse woody debris - 20 m<sup>3</sup>.ha<sup>-1</sup> dominated from the lying dead biomass fraction. It prevailed coarse woody debris of rate of decomposition C - 77% and A - 11%, which indicates that the processes of decomposition were still in the initial stage or were not started. Trees from the third level of decomposition with broken tops mainly have been observed from the standing dead biomass. Their quantity was 92 per ha. There were solitary trees where holes are observed. The amount of the stumps was 68 per ha, as prevailing were those of degree of decomposition D (65%) and C (24%).

In SP 3 the amount of standing (52%) and lying dead biomass (47%) were similar. The stumps were about 1%. There was a slight overrun of coarse vs (9.1 m<sup>3</sup>.ha<sup>-1</sup>) fine lying dead biomass. Rate of decomposition B - 64% prevailed. Trees of fourth level of decomposition, without branches, with broken tops and presence of small hollows were observed as standing dead biomass. The amount of standing dead trees was 16 per ha. The amount of the stumps was 12 per ha, as encountered by such a degree of decomposition D (67%) and B (33%).

SP 4 was characterized by the following distribution of dead wood biomass components: standing - 62%, lying - 13%, stumps - 25%. The lying dead biomass was represented only by fine wood (3.4 m<sup>3</sup>.ha<sup>-1</sup>). The prevailing level of decomposition was B - 81%. Only trees of fourth level of decomposition, without branches, with broken tops and presence of small hollows were observed as standing dead biomass. The amount of standing dead trees was 24 per ha. The amount of the stumps was 104 per ha, as the prevailing levels of decomposition were C (50%) and D (27%).

The obtained results were compared to those reported by other authors. The results of 50-60 m<sup>3</sup>.ha<sup>-1</sup> cited by Zlatanov et al. (2013) for Bulgaria were higher, but they were for old-age forests in some of our reserves. In some of previous investigations of common beech habitat in Natura 2000 sites the quantities between 20-45 m<sup>3</sup>.ha<sup>-1</sup> were calculated (Dimitrova, unpublished). Stocks of 12-20 m<sup>3</sup>.ha<sup>-1</sup> dead wood are pointed about Central and Northern Europe managed forests (Borisov, 2006). Meyer, Schmidt (2011) in their studies have found the quantities of 18 m<sup>3</sup>.ha<sup>-1</sup> standing and lying woody biomass for northwestern Germany common beech forests. Castagneri et al. (2010) measured the dead biomass between 31 to 47.3 m<sup>3</sup>.ha<sup>-1</sup> in Italian Alps. The results of this investigation are close to them and the differences are probably due to variations in the ecological conditions and stand characteristics.

The differences between results of this research and average values reported on the country level are due to the fact that

**Table 5.** Stocks of dead wood biomass at sample plots ( $V, m^3 \cdot ha^{-1}$ )Tablica 5. Zaliha biomase mrtvog drva na pokusnim plohama ( $V, m^3 \cdot ha^{-1}$ )

Sample Plot <i>Pokusna ploha</i>	Standing <i>Dubeće</i>	Lying <i>ležeće</i>			Stumps <i>panjevi</i>	Total <i>ukupno</i>
		coarse debris <i>grubi otpad</i>	fine wood <i>fino drvo</i>	Total <i>ukupno</i>		
SP 1 PP 1	6.7	2	5.5	7.5	0.28	14.48
SP 2 PP 2	10.9	20.1	6.4	26.5	4.4	41.8
SP 3 PP 3	17.5	9.1	6.5	15.6	0.32	33.42
SP 4 PP 4	15.8	0	3.4	3.4	6.4	25.6

**Table 6.** Degrees of decomposition of different fractions of dead wood biomass (%)

Tablica 6. Stupnjevi raspadanja različitih frakcija biomase mrtvog drva (%)

	degree of decomposition - standing dead biomass <i>stupanj raspadanja - dubeća mrtva biomasa</i>			
	SP 1	SP 2	SP 3	SP 4
	PP 1	PP 2	PP 3	PP 4
1		8.7		
2	50	4.3		
3		78		
4	50	8.7	100	100
5				
	degree of decomposition - lying wood biomass <i>stupanj raspadanja - biomasa ležećeg mrtvog drva</i>			
	SP 1	SP 2	SP 3	SP 4
	PP 1	PP 2	PP 3	PP 4
A	2.6	11.24	14.8	12.4
B	55.6	77.5	64.2	80.82
C	32.5	7.9	12.3	2.7
D	9.4	3.4	8.6	4.1
	degree of decomposition – stumps <i>stupanj raspadanja - panjevi</i>			
	SP 1	SP 2	SP 3	SP 4
	PP 1	PP 2	PP 3	PP 4
A			33.3	11.5
B		11.8		11.5
C	50	23.5	66.7	50
D	50	64.7		27

the data at national level are not specific to beech forests, but they are an average result for the quantity of deadwood in different types of forests in the country, and in some of them there is very low quantity.

The comparison of the data obtained from the four sample areas showed that the dead wood biomass prevailed in SP 2, which was logical, since it recently has suffered from snow falls. This was the youngest stand, which was the most unstable in respect of such abiotic factors. The quantity of the lying dead biomass was the highest in it also. The harvesting intensity is low because there is no economic profit

as the foresters have machinery only for big trees so the quantities of dead wood are highest.

In SP 4 the quantity of the lying dead wood was least. Due to accessible and convenient road network, small slope and proximity to anthropogenic object (restaurant) the fallen wood was the most probably exported from the staff of the adjacent industrial sites. But because of prolonged entry periods for felling, low logging intensity we can expect higher total deadwood stocks in the future.

In SP 3 the big slope, and the distance from settlements determined the presence of larger quantities lying dead wood biomass, which were inconvenient to be transported. Also because of lack of harvesting last 60 years the total stocks of dead wood are high.

The stumps dominated in SP 4, as in this stand more intensive silvicultural activities have been conducted over the last 20 years. Their quantity was the lowest in SP 3 (seed base), due to the lack of forestry measures because of the special regime.

The standing dead trees were least at SP 1. There the density was the lowest and it probably lead to a reduction of competition between individuals, which in turn was the reason for the presence of a more vital trees. And also because of lack of disturbances, harvesting at last 18 years and fact that rotation is not foreseen the total stocks of dead mass in this sample plot are lower.

In the other sampling areas, the density was higher, which leads to an increased competition and consequently to suppression of certain individuals. As a result, it was observed subsequent worsening, easier brittleness of the stems, and a higher susceptibility to attack from diseases and pests, leading to drying.

## CONCLUSION ZAKLJUČAK

The dead wood is included as one of the important parameters for defining the Favourable Conservation Status (FCS) of forest ecosystems in the NATURA 2000 sites. It is

defined by the „Guide for assessing favorable conservation status of species and habitat types in Natura 2000 in Bulgaria“ regulations and it is an important step for the management planning of their maintaining or improving. According to the parameter 2.5 of methodology adopted, the presence of certain quantities of dead wood is considered as a key indicator to assess the status of forest habitats.

For example, in natural beech habitats the dead wood must be not less than 8% of the stock of the stand from which at least 10 trees per ha have to be standing according to parameter 2.5 „Quantity of dead wood“. To achieve the favorable conservation status for this component, 60% of the habitat has to meet the indicator. The amount of dead wood less this rate is presume for “unfavourable - unsatisfactory” state of habitat. Depending on the evaluation of FCS, forestry activities should be planned and implemented in a way that ensures the achievement and maintenance of this status.

In relation with abovementioned, a possible areas of application of the research results are assessment of conservation status of the forest habitats and giving recommendations for environmentally oriented management of the stands.

In our research as orientation we could use these criteria to assess the quantity of dead wood by stating that it has not been evaluated within the entire habitat. The results obtained showed ratio between stocks of dead wood and total stand stock as follows: standing dead trees (number per ha): SP 1 - 8, SP 2 - 92, SP 3 -16, SP 4 -24; total dead wood (% of the stand stock): SP 1 - 3%, SP 2 - 26%, SP 3 - 4%, SP 4 - 2%.

This shows that the percentage of the total amount of dead wood to the total forest yield was insufficient from a conservation perspective in sample areas 1, 3, 4, although the standing dead trees in SP 2, 3, 4 as number reached the criterion specified in the methodology for assessment of the favorable conservation status.

An increase in dead wood volumes must be carried out in accordance with the forest type. Thus, in order to fulfil the requirements of Natura 2000 network and as many wood-dependent organisms as possible, it is important to preserve not only larger amounts of dead wood, but also dead wood of different types and dimensions. This can be achieved as after the logging, part of the dead wood (not less than 8% of the stock of the stand) was left in the clearings.

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## SAŽETAK

Mrtva stabla imaju važnu ulogu u funkcioniranju i produktivnosti šumskih ekosustava kroz utjecaj na biološku raznolikost, akumulaciju ugljičnog dioksida, promet hranjivih tvari i tok energije, hidrološke procese, zaštitu tla te regeneraciju šumskih vrsta. Isto tako, mrtvo drvo osigurava uvijete za očuvanje važnih staništa. Povijesno gledano, uklanjanje mrtvog drva iz sastojine provodi se već dugi niz godina kao mjera zaštite od štetnih insekata i gljiva koji se smatraju prijetnjom zdravoj šumi. Takva praksa dovodi do smanjenja količine mrtvog drveta u šumskim ekosustavima do kritično niskih razina, koje nisu dovoljne za održavanje vitalnih populacija mnogih šumskih vrsta. Tijekom zadnjih godina, nacionalno zakonodavstvo uvelo je nove postavke, posebno one koje se odnose na razvoj i upravljanje Natura 2000 područjima, a kojima se, za procjenu stanja šumskih staništa, zahtijeva informacija o količini ove komponente. U tom smislu, cilj ovog istraživanja bio je dobiti kvantitativne podatke o zalihama mrtve šumske biomase u bukovim zajednicama u zapadnom Balkanu.

Količina dubećeg mrtvog drva izračunata je pomoću tablice visinskih klasa i promjer; metoda uzorkovanje na linijskim transektima korištena je za određivanje zalihe ležećeg mrtvog drva. Thomasova ljestvica korištena je za procjenu stupnja raspadanja dubeće mrtve biomase a 4-stupanjska harmonizirana ljestvica ležeće mrtvo drvo (Tablica 2) i panjeve (Tablica 3). Kao rezultat istraživanja provedenih u bukovim zajednicama, utvrđeno je da ukupna zaliha biomase mrtvog drva varira u rasponu od 14,48 do 41,8 m<sup>3</sup> ha<sup>-1</sup>. Biomasa dubećeg mrtvog drva bila je 6,7-17,5 m<sup>3</sup> ha<sup>-1</sup>, a biomasa ležećeg mrtvog drva bila je 3,4-26,5 m<sup>3</sup> ha<sup>-1</sup>, dok je biomasa panjeva bila 0,28-6,4 m<sup>3</sup> ha<sup>-1</sup> (Tablica 5). Promatrano dubeće mrtvo drvo bilo je uglavnom u četvrtom stupnju razgradnje. Pretežna stopa razgradnje za ležeću biomasu bila je B, a za panjeve C i D (Tablica 6).

Prema rezultatima ovih istraživanja može se generalizirati da je postotak ukupne količine mrtvog drva u ukupnoj šumskoj zalihi nedostatan iz perspektive povoljnog stanja očuvanja.

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**KLJUČNE RIJEČI:** mrtvo drvo, zaliha, zajednice bukve.