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Dead wood stocks of Beech forests in Ograzhden and Osogovska Mountains in Bulgaria

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Abstract. Dead wood is a key element in forests as it plays a role in maintaining biodiversity, carbon sequestration, element cycling and fire risk. Amounts and ratios of dead wood fractions are now monitored in many countries to assess forest ecological status. In this regard, the aim of the present study is to determine the stocks of dead woody biomass in the Ograzhden and Osogovska mountains (Bulgaria) and to assess their quantity from a nature conservation point of view. The standing biomass was calculated using height rates tables, the lying biomass - using the method of intersecting lines, and the stumps - by height and diameter. Degrees of decomposition are on standard scales. The stock of dead biomass varies from 11.52 $m^3.ha^{-1}$ in Mountain Ograzhden to 5.45 $m^3.ha^{-1}$ in Mountain Osogovo. Stump biomass predominates (61-39%), and standing biomass is least in amount (14-22%). Coarse debris are absent in two of the sample areas. In the standing biomass, one of the initial stages of decomposition prevails - stage 1 (54%) and stage 2 (58%). In the lying biomass, that which decomposed to a lesser extent also prevails - A (30-50%), B (53-36%). Among the stumps, those in a more advanced stage of decomposition C (39-50%), D (26-52%) prevail. The sample plot in Ograzhden mountain is in good condition in terms of the amount of dead biomass in it. In the Osogovo mountain, the total amount of dead biomass is insufficient from an ecological point of view.

Key words: dead biomass, beech forests, decomposition.

Introduction

Dead wood is a key element in forests as it plays a role in maintaining biodiversity, carbon sequestration, element cycling and fire risk (Dudley & Vallauri, 2004; Christensen et al., 2005; Vítková et al., 2018; Veapi et al., 2018). Amounts and ratios of dead wood fractions are now monitored in many countries to assess forest ecological status (Woodall et al., 2009). Threshold values are widely used in forest management when considering biodiversity conservation issues.

Levels of 20-30 $m^3.ha^{-1}$ have been accepted for minimum amounts of dead wood for the survival of threatened saproxylic organisms (Müller & Bütler, 2010), and for the three-toed woodpecker (*Picoides tridactylus*) amounts of 15 $m^3.ha^{-1}$ (Bütler et al., 2004). Heilmann-Clausen & Christensen (2004) considered the importance of different fractions of coarse woody debris for the species diversity of wood-associated fungi. They found that the number of species increased with the increase in the size of the dead wood fractions. The same was found for representatives of arthropods by Kappes (2005). He commented that in the studied managed beech forests in Western Europe, the lying dead biomass was of the order of 3–5 $m^3.ha^{-1}$. The results show that dead wood is an important structural component for maintaining biodiversity and improves aspects of forest functioning, particularly in element cycling.

In forests that have been subject to logging for a long time, the amount of dead wood is several times smaller than in forests where no measures have been taken. This poses a threat to organisms that are associated with dead biomass (Ekbom et al., 2006). Mayer & Smidt (2011) investigated standing and lying dead biomass in beech reserves in Germany where silvicultural activities had not taken place for 28 years. The amounts of dead wood they found ranged from 9 to 18 $m^3.ha^{-1}$. Standing biomass was 40% of the total amount of dead biomass.

Some authors are working on models to estimate the biomass of standing living and standing dead trees (Smith et al., 2003). Estimating the biomass of standing trees helps to estimate the amounts of carbon, as carbon is known to be 50% of a plant's biomass.

Kueppers et al. (2004) examined dead wood as a carbon sink and the dependence of litter decomposition on climate warming in the subalpine Rocky Mountains of Colorado. With the help of a radiocarbon method, they prove that the decomposition of dead wood accelerates 2 times with the increase in temperatures of 3°C.

In our country, data on amounts of dead wood and degrees of decomposition in forests can be found in publications by Asenova et al. (2019), Dimitrova (2018), Dimitrova & Dimitrov (2023), Zlatanov et al. (2016). The chemical composition of dead wood is discussed in publications by Damyanova & Dimitrova (2023), and species of wood-destroying fungi in a publication by Bencheva et al. (2023). However, this issue is still not well studied and there is a lack of data for different forest types. In this regard, the aim of the present study is to determine the stocks of dead woody biomass in the beech forests of Ograzhden and Osogovska mountains and to assess their quantity from a nature conservation point of view according to Natura 2000.

Materials and methods

Object of the study

The object of research are natural beech communities in Ograzhden and Osogovska mountains in Bulgaria. The climate is moderately continental and mountainous (Georgiev, 1991). The soils are Cambisols (WRB, 2006). 3 sample plots (two in Osogovska and 1 in Ograzhden mountain) with dimensions of 50 x 50 m have been laid out. Their location is shown in Fig.1, and the main characteristics of the compartments are presented in Table 1.

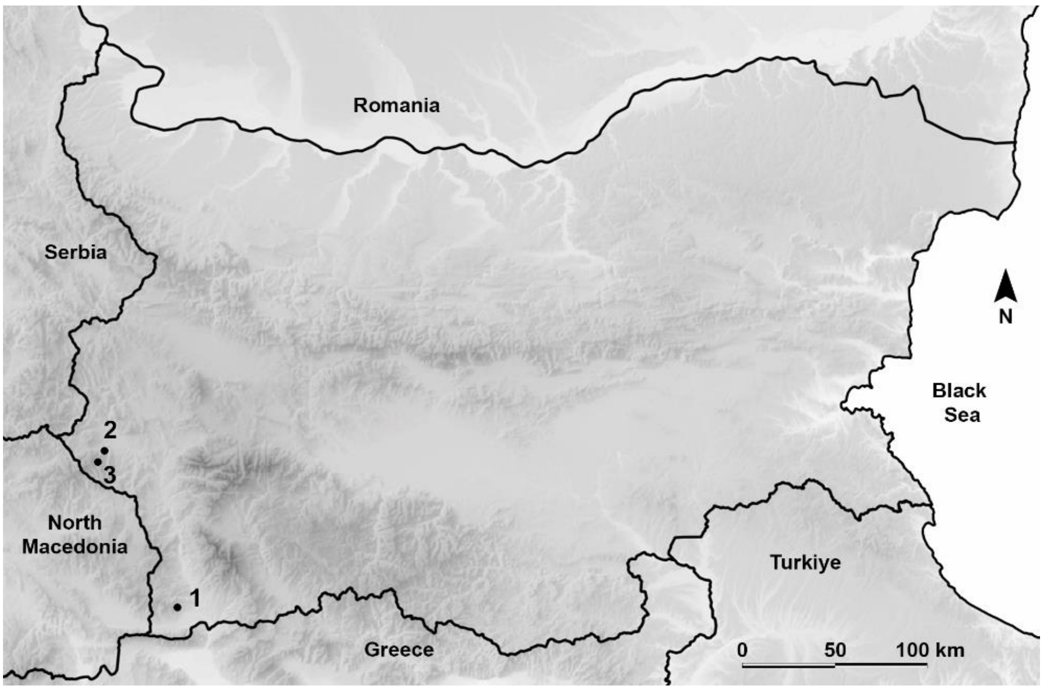

Fig. 1. Location of sample plots.

Table 1. Characteristics of the stands in the sample plots.

Sample plots	Altitude, m	Geographic coordinates	Age, years	Slope	Origin	Exposition	Average height, m	Average diameter, cm
SP 1 Ograzhden	1170	N 41° 29' 27.9" E 23° 05' 38.0"	70	18	seed	E	17	26
SP 2 Osogovo	1100	N 42° 14' 49.3" E 22° 39' 56.1"	70	18	coppice	NE	17	22
SP 3 Osogovo	1550	N 42° 12' 05.2" E 22° 37' 51.7"	170	20	seed	SE	24	46

Measuring of diameters (with caliper) at breast height (1.30 m) of all trees and their heights (with altimeter) was done in all sample plots.

SP 1 is situated in a beech phytocenosis with a tree layer with 100% total projective coverage. Dominant in it is *Fagus sylvatica* L. A shrub floor is not formed. The total projective coverage of phytocenotic horizon II is 30%, and it includes 9 plant species. More common representatives of the mixtoherbosa are: *Galium odoratum* (L.) and *Cardamine bulbifera* L. (Grantz). With low coverage are species such as *Primula veris* L. and *Aremonia agrimonoides* (L.) DC. There is a single participation of *Pteridium aquilinum* (L.) Kuhn. of the ferns, and of the gramineous group - *Melica uniflora* Retz. There are 408 living trees per ha and their biomass is 131.62 $m^3.ha^{-1}$. It was done as a sum of biomass of all living trees. Their volume was calculated with height rates tables of Duhovnikov (Poriazov et al., 2004).

SP 2 is in a beech phytocenosis with a tree floor with 90% total projective coverage. It is also dominated by *Fagus sylvatica* L. A shrub floor is not formed, but there is a 10% cover of undergrowth of *Fagus sylvatica* L. The total projective cover of phytocenotic horizon III is 10%, and it includes 5 plant species. A more common representative of the mixtoherbosa is *Hedera helix* L. Of the ferns, there are *Pteridium aquilinum* (L.) Kuhn. and *Polypodium vulgare* L., and from legumes - *Lathyrus niger* (L.) Bernth. There are 464 live trees per ha and their biomass is 172.5 $m^3.ha^{-1}$.

SP 3 is also in a beech phytocenosis with a tree floor with 70% total projective coverage. Dominant in it is *Fagus sylvatica* L. A shrub floor is not formed. The total projective coverage of phytocenotic horizon II is 30%, and it includes 16 plant species. A more common representative of the gramineous plants is *Festuca heterophylla* Lam., of the ferns - *Athyrium filix-femina* (L.) Roth, and of the cyperaceous grasses - *Luzula luzoloides* (Lam.) Dandy. There are 240 living trees per ha and their biomass is 283.9 $m^3.ha^{-1}$.

Methods

The dead wood was divided into three main components (Lazarov et al., 2012):

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, height less than 1 m.

Standing dead wood

To establish the volume of dead wood, three sample plots with square shape and size 50 × 50 m (2500 m^2 area) were established. The diameter of 1.30 m height and the height of all standing dead trees were measured in order to determine the amount of standing dead wood. Their volume was then calculated with height rates tables of Duhovnikov (Poriazov et al., 2004). The height order was determined according to 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^3) value for each tree according its diameter from each height order was taken and the sum of volumes of dead standing trees was given ($m^3.ha^{-1}$).

Lying dead wood

The method of line intersect sampling (Warren & Olsen, 1964), 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 of the sample plots that intersect randomly fallen and lying on the surface tree trunks and branches were outlined. The diameter of branches and stems at the intersection was measured. The volume of fallen deadwood was calculated by the formula of Warren & Olsen (1964), adapted by Lazarov et al. (2012):

$$\boldsymbol{V = \pi^2 \sum n_i = \frac{d_i^2}{8L}} \quad (1)$$

where: V – volume of lying dead wood ($m^3.ha^{-1}$); d_i – diameter of branches in the point of intersection (cm); L – length of diagonals (m).

Stumps

The diameter and height of each stump were determined. The volume of the stumps was calculated according Lazarov et al. (2012) as follows:

$$\boldsymbol{V = \pi r^2 h} \quad (2)$$

where: V – volume of dead stumps ($m^3.ha^{-1}$); r – radius (m); h – height of the stump (m).

Thomas scale (Thomas, 1979; Moussaoui et al., 2016) was used to assess the degree of decomposition of standing dead biomass and a 4-point harmonized scale (Rondeux et al., 2012) was used for lying biomass and stumps.

Class /Description (Rondeux et al., 2012):

A - hard texture 90%, no decomposition, stem completely solid;

B - hard texture 90-60%, stem slightly decomposed, the majority hard;

C - hard texture 60-30%, stem decomposed, prevailing part soft;

D - hard texture 30%, stem very decomposed, prevailing part soft.

Results and Discussion

In SP 1, the dead biomass is represented by all fractions: standing, lying and stumps (Table 2). The stumps biomass predominates (61%). The largest percentage are those of decomposition degree D, i.e. in the most advanced stage of decomposition (Table 3). The lying biomass is 25%, and the amount of coarse woody debris is greater (1.92 $m^3.ha^{-1}$) than that of fine wood (0.96 $m^3.ha^{-1}$). The predominant degree of decomposition is C. There is no lying biomass of degree D. The standing biomass is the least amount - 14%. It is dominated by dry, broken trees of the second degree of decomposition.

There is presence of standing, lying dead biomass and stumps in SP 2. The lying biomass prevails (40%), which is represented only by fine debris. It is mainly with a low degree of decomposition (A 41%), the amount of highly decomposed debris is low (2%). Stumps are (38%), those of decomposition degree C are predominant (50%), of B and D are approximately the same and the least are the slightly decomposed ones (2%). The standing dead biomass is the smallest amount (22%). It is also dominated by decomposition from initial stages (54%), and representatives from the last two stages are absent.

In SP 3, dead biomass is represented by lying biomass and stumps. Dead trees were not found (Table 2). The biomass of stumps (52%) and lying (48%) were of similar amounts. Coarse woody debris are absent. The predominant rate of decomposition of the lying biomass is A (50%) and B (43%). The stumps are equally decomposed in degree B and D (50%) (Table 3).

When comparing the amounts of dead biomass between the two mountains, it can be seen that significantly smaller amounts were recorded in Osogovo Mountain. The stock of dead biomass varies from 11.52 $m^3.ha^{-1}$ in Ograzhden Mountain to 5.45 $m^3.ha^{-1}$ in Osogovo Mountain. Stump biomass predominates (61-39%), and standing biomass is least in amount (14-22%). Coarse debris are absent in two of the sample areas. In the standing biomass, one of the initial stages of decomposition prevails - stage 1 (54%) and stage 2 (58%). In the lying biomass, that which decomposed to a lesser extent also prevails - A (30-50%), B (53-36%). Among the stumps, those in a more advanced stage of decomposition C (39-50%), D (26-52%) prevail.

In our previous studies (Dimitrova & Dimitrov, 2023) for beech forests in Western Stara Planina Mountian and Vitosha Mountain, stocks of dead wood of the order of 32 and 12.64 $m^3.ha^{-1}$ were established, respectively. Now the results obtained for Ograzhden Mountain are similar to those of Vitosha Mountain, and they are significantly lower on Osogovo Mountain.

In other studies in the same forest type, at a similar altitude and age, amounts of 14.48-41.8 $m^3.ha^{-1}$ were observed (Dimitrova, 2018). Standing and lying biomass were significantly greater than in the present study, and stumps biomass was similar.

When comparing the results with foreign authors, there is a similarity of our results from Ograzhden Mountain with those of Mayer & Smidt (2011) - 9 to 18 $m^3.ha^{-1}$ for beech reserves in Germany, without forestry activities, as well as with part of the data of Kueppers et al. (2004). They found stocks of standing and lying dead wood of the order of 4.7 to 54 $t.ha^{-1}$.

Table 2. Dead wood biomass stocks at sample plots (V, $m^3.ha^{-1}$).

Sample plots	Standing	Lying			Stumps	Total
		Coarse woody debris	Fine wood	Total		
SP 1 Ograzhden	1.6	1.92	0.96	2.88	7.04	**11.52**
SP 2 Osogovo 1100	1.8	-	3.29	3.29	3.2	8.29
SP 3 Osogovo 1600	-	-	1.26	1.26	1.35	**2.61**

Table 3. Degrees of decomposition of different fractions of dead wood biomass (%).

Class	Standing biomass		
	SP 1	**SP 2**	**SP 3**
1	9	54	-
2	58	31	-
3	25	15	-
4	8	-	-
5	-	-	-
Class	**Lying biomass**		
	SP 1	SP 2	SP 3
A	30	41	50
B	53	36	43
C	17	21	6
D	-	2	1
Class	**Stumps**		
	SP 1	SP 2	SP 3
A	-	6	-
B	9	21	50
C	39	50	-
D	52	23	50

If we use the criteria for the presence of dead biomass in habitats from the Natura 2000 network for favorable conservation status (Zingstra et al., 2009), which are that dead wood should be 8% of the stock of the stand, with at least 10 standing dead trees of ha, we can conclude that SP 1 is in good condition according to this indicator, while at SP 2 and SP 3 the dead wood is generally not in sufficient quantities with exception that in SP 2 the dead trees are more than the required amount

(Table 4). It means that the beech forests in Ograzhden Mountain have potential to maintain the good ecological status of forest ecosystems and contribute to the protection of biological diversity by providing habitats and a food base for various species of animals and fungi.

Table 4. Ratio of deadwood stock to total stand stock.

Dead wood	SP 1	SP 2	SP 3
Standing dead trees, number per ha	48	52	-
Total dead wood, % of stand stock	8.8	4.8	0.9

Conclusions

The stock of dead biomass varies from 11.52 $m^3.ha^{-1}$ in Ograzhden Mountain to 5.45 $m^3.ha^{-1}$ in Osogovo Mountain. The beech forests in Ograzhden Mountain are in good condition in terms of the amount of dead plant biomass in it. In the Osogovo Mountain, the total amount of dead biomass is insufficient from an ecological point of view. This most likely affects the biodiversity of organisms associated with dead wood. The beech forests in Ograzhden Mountain have potential to maintain the good ecological status of forest ecosystems and contribute to the protection of biological diversity by providing habitats and a food base for various species of animals and fungi. They must continue to be managed in such a sustainable manner.

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