Macedonian Journal of Ecology and Environment
Vol. 25, issue 1
pp. 27 - 33
Skopje (2023)
ISSN 1857 - 8330 (on-line)
ISSN 0354-2491 (print)
Original scientific paper
Available online at www.mjee.org.mk
DOI: https://doi.org/10.59194/MJEE23251027v

Down dead wood in a montane beech forest stands on Deshat mountain. 3. Mineral composition

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Abstract

Data on chemical composition of down dead wood is important for understanding decomposition processes in soil, the interacting role of the living organisms and biogeochemical cycles in general. This paper presents the results on the content and quantity of chemical elements (K, Ca, Mg, Na, Fe, Mn, Zn, Cu and Pb) in down dead wood in five montane beech forest stands on Deshat Mountain in Mavrovo National Park. The stands were selected to represent five different types of degradation and management practices in beech forests (from highly preserved forest stands with old thick standing trees and large numbers of fallen trees with accumulated biomass, to degraded forest stands represented by a resprouting trees and small amount of coarse biomass). The contents of analyzed elements was determined by atomic absorption spectrometry. Quantities of analyzed elements were calculated based on the concentration of elements in different size fractions and decay classes of logs and branches and the corresponding values of down dead wood biomass. The contents of elements is similar to other studies in beech forests with the exception of Ca that showed higher values in the studied beech forests on Deshat mountain. Following quantities of analyzed elements are stored in the down dead wood biomass as an average of five investigates beech forest stands: K - 10.353, Mg - 5.617, Ca - 94.224, Na - 0.723, Fe - 1.101, Mn - 1.117, Zn - 0.082, Cu - 0.026 and Pb - 0.048 $kg \cdot ha^{-1}$. The highest quantities of all elements were recorded in the preserved forests. The quantities of K, Ca, Mg, Cu, Fe and Pb were generally higher in logs compared to branches. The rest of the elements (Mn, Na, Zn) showed higher quantities in branches.

Keywords: dead wood, chemical composition, elements, contents, quantities.

Introduction

Down dead wood (DDW) is an integral part of the natural forest ecosystem. It has significant role in many of the ecosystem processes, especially in decomposition, pedogenesis and erosion prevention, biogeochemical cycles of carbon and nutrients, natural regeneration, and also supports important biodiversity (Maser & Trappe 1984; Harmon et al. 1986; Ranius & Jansson 2000; Harmon 2009; Krankina & Harmon 1995; Næsset 1999; Brozek & Wanic 2002; Christensen et al. 2005). Coarse dead wood in forest ecosystems consists of standing and down dead wood. The latter is usually much more important in terms of quantity in forest ecosystems (Hottola & Siitonen 2008; Christensen et al. 2005).

The exploitation of forests in Europe lead to significant decrease in the amounts of down dead wood. DDW

Submitted: *02.11.2022;*
Accepted: *13.02.2023*

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is nowadays much higher in European upland forests compared to the lowland ones, although the natural potential is opposite (Christensen et al. 2005). For example, the increase in humidity results in larger quantities of DDW including nitrogen (Dimitrova et al. 2017; Damyanova 2017; Błońska et al. 2020).

The research on dead organic matter in Macedonian forests is very scarce. Few available studies include data on the fine litterfall in an oak forest in Galichica National Park and beech forest in Mavrovo National Park (Melovski et al. 1995, 2004; Šušlevska et al. 2001). The biomass of coarse branches in forest floor was determined in both ecosystems. Hristovski (2007) determined the standing dead wood biomass in the beech forest in Mavrovo and estimated a value of 1584,31 kg·ha^{-1}. Apart of this publications, we are not aware of any other research targeted towards the coarse down dead wood in Macedonian forest ecosystems.

In 2015 we conducted research of DDW in a montane beech forest on Deshat Mountain. The research focused on estimation of DDW biomass, carbon content and mineral composition, decomposition stages and impact of forestry practices on the amount of DDW. In the first two papers of the series we presented 1) methodology used during the field work and the results on DDW biomass (Veapi et al. 2018a) and 2) carbon sequestration in DDW (Veapi et al. 2018b). In this article we will focus on 3) mineral composition and quantities, while consequent articles will elaborate 4) decomposition patterns and 5) impact of forestry on DDW. The main goal of the presented paper is to estimate the pool of metallic cations in DDW in montane beech forests.

Material and methods

Field research

Deshat Mountain is situated in the western part of North Macedonia. Beech forests are the dominant forest type. Five stands were selected on 08.06.2015, based on the differences in forest management and the general structure of the stands. They were named as follows: Degraded forest (DF) – 1.15 ha, Coppice forest (CF) – 1.63 ha, Good forest (GF) – 1.76 ha, Preserved forest (PF) – 1.07 ha and Old-growth forest (OF) – 3.12 ha. The main field research was conducted in the period 28.09-01.10.2015. Coarse DDW in fallen tree logs was measured on the whole surface of the five forest stands. All of the fallen tree logs within five investigated stands were recorded. The following parameters were observed or measured: decay classes, length and three diameters (at base, in the middle and at the apex of the tree log). The biomass of fallen branches was estimated in three transect in all five investigated forest stands. Each of the 15 transects consisted of 10-20 sampling quadrats with surface of 1 m^2. Sampling quadrats were placed on 3 m distance (Veapi et al. 2018a).

All branches within the sampling quadrats were classified into three diameter classes (3-5, 5-10 and 10-20 cm), weighed on a field scale (0.5 g accuracy) and their decay classis was recorded (Veapi et al. 2018). During the field work we took samples (in average 400 g) of each diameter classis and decay class in order to measure the dry weight and water percentage.

Chemical analyses

Chemical analyses were performed for 17 logs of different decay classes as well as 39 samples of branches with different diameters and decay classes. Methods of wet digestion were used for preparation of plant material for chemical analyses. A portion of the dry powder material of DDW was digested in an oxi-acidic mixture of HNO_3/H_2O_2 (2:1, 12 ml for a 0.5 g sample and then heated up to 120 °C for 24 hours in sand bath (Soylak et al. 2004). Blanks were prepared following the same procedure. The contents of heavy metals in the solutions was determined by atomic absorption spectrometry (Agilent AAS 55A). All elements' concentrations are presented on dry matter.

Estimation of mineral quantities

The quantities of minerals were calculated based on the concentration of elements in different size fractions and decay classes of logs and branches and the corresponding values of DDW biomass (Veapi et al. 2018).

Results and discussion

Elements' contents (concentrations)

The investigated elements according to their concentration in DDW can be placed in the following order: Ca>K>Mg>Mn>Fe>Na>Zn>Pb>Cu (Table 1). The concentration of elements in logs may be compared to the results of beech logs (after 0,8 and 18 months of decomposition) in Rhine valley in Germany (Herrmann and Bauhus 2018). The concentration of K in the logs of Deshat showed higher values (0.090- 0.317%) while the aforementioned study reported values between 0.077 and 0.126%; Mg content in our study was also higher compared to 0.028 and 0.057%; Ca was considerably higher compared to 0.08-0.17%; Mn was considerably lower compared to 0.14-0.34 mg•kg-1. In four plots in a beech forest on Western Balkan Mountain in Bulgaria, comparable values were recorded: 1) Standing dead wood: 0.20-1.40% for Ca, 0.06-0.91% for K, 0.04-0.08% for Mg and 7.4-93.9 mg•kg-1 for Zn; 2) logs: 0.34-1.12% for Ca, 0.07-0.39% for K, 0.05-0.10% for Mg and 14.1-44.8 mg•kg-1 for Zn (Damyanova 2017).

Table 1. Elements' concentration in different decay classes of down dead wood

Down dead wood	Decay class	K	Mg	Ca	Na	Fe	Mn	Zn	Cu	Pb
		%			mg·kg⁻¹					
Branches (3-5 cm)	D2	0.047	0.027	0.61	64.89	27.98	80.14	4.00	1.26	2.34
	D3	0.071	0.043	1.00	76.76	47.42	111.67	9.20	2.31	6.86
	D4	0.061	0.048	1.53	110.60	253.08	258.74	15.59	4.44	4.88
	Average	**0.061**	**0.040**	**1.09**	**86.10**	**118.07**	**157.56**	**10.18**	**2.82**	**4.94**
Branches (5-10 cm)	D2	0.049	0.021	0.80	74.25	17.29	75.98	4.25	1.24	5.65
	D3	0.078	0.040	0.84	87.87	53.81	104.67	7.89	2.94	4.19
	D4	0.105	0.126	1.78	179.74	352.29	297.62	19.35	5.32	5.99
	Average	**0.081**	**0.067**	**1.17**	**117.76**	**152.58**	**167.43**	**11.20**	**3.43**	**5.15**
Branches (10-20cm)	D3	0.127	0.029	0.78	56.80	40.74	58.27	9.81	2.21	4.53
	D4	0.127	0.029	0.78	56.80	40.74	58.27	9.81	2.21	4.75
	Average	**0.147**	**0.054**	**0.89**	**109.66**	**95.95**	**81.04**	**11.90**	**2.60**	**4.64**
Logs	D2	0.090	0.051	0.84	56.56	19.09	71.58	6.34	1.29	3.70
	D3	0.174	0.039	0.51	56.88	72.35	59.62	3.97	1.44	3.67
	D4	0.101	0.071	1.01	56.33	148.56	111.33	7.68	3.03	4.76
	D5	0.317	0.076	1.88	99.96	173.92	94.48	12.55	3.51	3.13
	Average	**0.138**	**0.060**	**1.02**	**63.37**	**90.03**	**86.49**	**7.49**	**2.20**	**3.94**
Average in DDW		**0.099**	**0.055**	**1.07**	**87.99**	**115.61**	**130.45**	**9.65**	**2.75**	**4.63**

Quantities of elements

DDW is poor in elements compared to live biomass and soil. The chemical composition of DDW changes in time due to the decomposition processes, root encroachment, litterfall, input from atmospheric precipitation and throughfall (Harmon et al. 1986).

Ca showed the greatest quantity in logs in the five investigated stands which varied between 13.1 and 102.3 kg·ha⁻¹. The lowest quantity was recorded for Pb and Cu (Table 2). The highest quantities of all elements were recorded in OF and PF and the lowest in CF in DF which is expected due to the difference in DDW biomass.

The quantities of all elements were higher in logs compared to branches in PF, GF and DF. The quantities of all elements were higher in branches of OF and CF compared to logs. The only exceptions were Fe in OF and Na in DF which had very similar quantities in logs and branches (Table 2 and 3).

The amounts on Figure 1 represent the total quantities of analyzed elements in DDW in the beech stands on Deshat mountain. The highest quantity of 94.2 kg·ha⁻¹ was recorded for Ca, followed by K, Mg, Mn, Fe, Na, Zn, Pb and Cu.

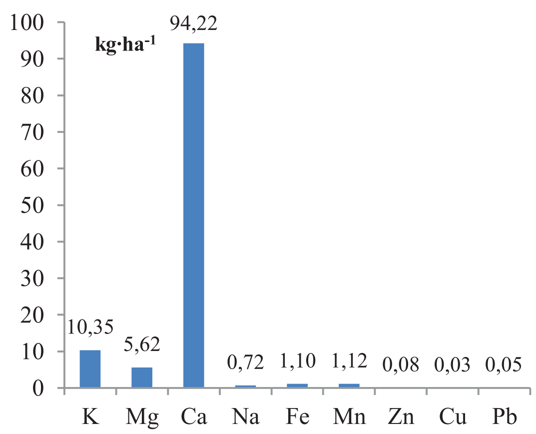

Figure 1. Average elements' quantities in DDW (logs+branches) in the five investigated beech stands

Table 2. Elements' quantities in different decay classes of fallen logs in the five investigated beech stands (kg·ha^{-1})

Elements	Forest stand	Decay classes					Total
		D1	D2	D3	D4	D5	
K	OF	0.003	1.265	4.243	5.425	0.326	**11.263**
	PF	0.108	0.995	4.394	7.971		**13.468**
	GF		0.320	2.427	3.434		**6.181**
	CF		0.075	0.768	0.638		**1.481**
	DF		0.092	1.169	0.886		**2.146**
Mg	OF	0.002	0.722	0.950	3.775	0.079	**5.528**
	PF	0.062	0.568	0.984	5.546		**7.160**
	GF		0.183	0.544	2.390		**3.116**
	CF		0.043	0.172	0.444		**0.659**
	DF		0.052	0.262	0.617		**0.931**
Ca	OF	0.026	11.879	12.501	53.798	1.939	**80.142**
	PF	1.013	9.342	12.945	79.041		**102.341**
	GF		3.003	7.149	34.055		**44.207**
	CF		0.707	2.262	6.329		**9.298**
	DF		0.860	3.443	8.786		**13.089**
Na	OF		0.080	0.139	0.301	0.010	**0.530**
	PF	0.007	0.063	0.144	0.443		**0.656**
	GF		0.020	0.079	0.191		**0.290**
	CF		0.005	0.025	0.035		**0.065**
	DF		0.006	0.038	0.049		**0.093**
Fe	OF		0.027	0.176	0.795	0.018	**1.016**
	PF	0.002	0.021	0.183	1.168		**1.374**
	GF		0.007	0.101	0.503		**0.611**
	CF		0.002	0.032	0.094		**0.127**
	DF		0.002	0.049	0.130		**0.180**
Mn	OF		0.101	0.145	0.596	0.010	**0.852**
	PF	0.009	0.079	0.151	0.875		**1.114**
	GF		0.025	0.083	0.377		**0.486**
	CF		0.006	0.026	0.070		**0.102**
	DF		0.007	0.040	0.097		**0.145**
Zn	OF		0.009	0.010	0.041	0.001	**0.061**
	PF	0.001	0.007	0.010	0.060		**0.078**
	GF		0.002	0.006	0.026		**0.034**
	CF		0.001	0.002	0.005		**0.007**
	DF		0.001	0.003	0.007		**0.010**
Cu	OF		0.002	0.004	0.016		**0.022**
	PF		0.001	0.004	0.024		**0.029**
	GF			0.002	0.010		**0.013**
	CF			0.001	0.002		**0.003**
	DF			0.001	0.003		**0.004**
Pb	OF		0.005	0.009	0.026		**0.040**
	PF		0.004	0.009	0.037		**0.051**
	GF		0.001	0.005	0.016		**0.023**
	CF			0.002	0.003		**0.005**
	DF			0.002	0.004		**0.007**

Table 3. Elements' quantities in different decay classes of fallen branches in the five investigated beech stands

Element	Forest stand	3-5cm				5-10cm			10-20cm		Total
		D2	D3	D4		D2	D3	D4	D3	D4	
	OF	0.124	1.307	0.084			2.335	1.765	3.313	0.335	**9.263**
	PF	0.068	1.322	0.089		0.352	0.459	0.901			**3.191**
K	GF	0.082	0.962	0.352		0.223	0.245	0.105			**1.968**
	CF	0.455	0.923	0.398				0.328			**2.104**
	DF	0.109	0.209	0.043			0.341				**0.701**
	OF	0.071	0.781	0.065			1.211	2.118	0.761	0.159	**5.166**
	PF	0.039	0.790	0.070		0.153	0.238	1.081			**2.370**
Mg	GF	0.047	0.574	0.275		0.097	0.127	0.125			**1.245**
	CF	0.259	0.551	0.310				0.393			**1.514**
	DF	0.062	0.125	0.033			0.177				**0.397**
	OF	1.601	18.267	2.092			25.216	30.054	20.348	2.011	**99.589**
	PF	0.884	18.479	2.228		5.800	4.956	15.342			**47.689**
Ca	GF	1.067	13.443	8.787		3.671	2.642	1.780			**31.390**
	CF	5.886	12.906	9.927				5.582			**34.301**
	DF	1.415	2.916	1.066			3.679				**9.076**
	OF	0.017	0.141	0.015			0.263	0.303	0.149	0.032	**0.920**
	PF	0.009	0.142	0.016		0.054	0.052	0.155			**0.428**
Na	GF	0.011	0.104	0.063		0.034	0.028	0.018			**0.258**
	CF	0.063	0.099	0.072				0.056			**0.290**
	DF	0.015	0.022	0.008			0.038				**0.084**
	OF	0.007	0.087	0.035			0.161	0.594	0.107	0.030	**1.021**
	PF	0.004	0.088	0.037		0.013	0.032	0.303			**0.476**
Fe	GF	0.005	0.064	0.145		0.008	0.017	0.035			**0.274**
	CF	0.027	0.061	0.164				0.110			**0.363**
	DF	0.007	0.014	0.018			0.023				**0.061**
	OF	0.021	0.205	0.035			0.313	0.502	0.153	0.021	**1.249**
	PF	0.012	0.207	0.038		0.055	0.062	0.256			**0.629**
Mn	GF	0.014	0.151	0.148		0.035	0.033	0.030			**0.410**
	CF	0.077	0.145	0.167				0.093			**0.483**
	DF	0.019	0.033	0.018			0.046				**0.115**
	OF	0.001	0.017	0.002			0.024	0.033	0.026	0.003	**0.105**
	PF	0.001	0.017	0.002		0.003	0.005	0.017			**0.044**
Zn	GF	0.001	0.012	0.009		0.002	0.002	0.002			**0.028**
	CF	0.004	0.012	0.010				0.006			**0.032**
	DF	0.001	0.003	0.001			0.003				**0.008**
	OF		0.004	0.001			0.009	0.009	0.006	0.001	**0.029**
	PF		0.004	0.001		0.001	0.002	0.005			**0.012**
Cu	GF		0.003	0.003		0.001	0.001	0.001			**0.008**
	CF	0.001	0.003	0.003				0.002			**0.009**
	DF		0.001				0.001				**0.003**
	OF	0.001	0.013	0.001			0.013	0.010	0.012	0.001	**0.049**
	PF		0.013	0.001		0.004	0.002	0.005			**0.025**
Pb	GF		0.009	0.003		0.003	0.001	0.001			**0.017**
	CF	0.002	0.009	0.003				0.002			**0.016**
	DF	0.001	0.002				0.002				**0.005**

K and Mg in OF have higher quantities in logs compared to branches while all of the other elements are more represented in branches. All of the elements had higher quantities in branches compared to logs in CF. In the case of other forest stands (PF, GF and DF) all of the elements had higher quantities in logs.

The amount of K in DDW on Deshat Mt was 10.4 $kg \cdot ha^{-1}$. In the Hubbard Brook forest in USA it was estimated to store K amounts of up to 70.8 $kg \cdot ha^{-1}$ and 93% of it was leached in 24-years period (Arthur et al. 1993). Two beech forest reserves in Denmark stored 70.5 and 85.8 $kg \cdot ha^{-1}$ (Christensen & Vesterdal 2004). In beech forests Rhineland-Palatinate in Germany a value of 6.4 $kg \cdot ha^{-1}$ was estimated (Wellbrock et al. 2014) while in Slovenia a value of 73.7 $kg \cdot ha^{-1}$ with annual release of 1.45 $kg \cdot ha^{-1} yr^{-1}$ was reported (Kraigher et al. 2002).

The total amount of Mg stored in DDW in the beech forests on Deshat Mt was 5.62 $kg \cdot ha^{-1}$ (Fig. 1). This value is higher although comparable to the one of 2.87 $kg \cdot ha^{-1}$ for beech forests Rhineland-Palatinate in Germany (Wellbrock et al. 2014).

The total amount of Ca stored in DDW in the beech forests on Deshat Mt was 94.2 $kg \cdot ha^{-1}$ (Fig. 1). This quantity is smaller compared to other forest ecosystems. In a chronosequence of *Pseudotsuga* forests the amount of Ca stored in DDW ranged between 94 and 258 $kg \cdot ha^{-1}$ (Harmon et al. 1986). The value for Hubbard Brook forest was 193 $kg \cdot ha^{-1}$ and about 86% of this value was released in 24-years period (Arthur et al. 1993). Very low value of 10.27 $kg \cdot ha^{-1}$ was observed in beech forests in Rhineland-Palatinate in Germany which consist only 4.9 % of the Ca in the forest floor (Wellbrock et al. 2014).

Conclusions

The chemical composition of down dead wood in the five investigated beech forest stands on Deshat mountain is similar to other studies in beech forests in Europe. The exception is that Ca showed higher values in the studied beech forests on Deshat mountain. The quantities of analyzed elements stored in the down dead wood biomass as an average of five investigated beech forest stands are as follows: K - 10.353, Mg - 5.617, Ca - 94.224, Na - 0.723, Fe - 1.101, Mn - 1.117, Zn - 0.082, Cu - 0.026 and Pb - 0.048 $kg \cdot ha^{-1}$. The highest quantities of all elements were recorded in the preserved forests. The quantities of K, Ca, Mg, Cu, Fe and Pb were generally higher in logs compared to branches. The rest of the elements (Mn, Na, Zn) showed higher quantities in branches. The quantities of analyzed elements in the forest stands on Deshat mountain are generally lower when compared to other preserved forest ecosystems which have higher down dead wood biomass.

References

Arthur, M. A., Tritton, L. M., Fahey, T. J. (1993). Dead bole mass and nutrients remaining 23 years after clear-felling of a northern hardwood forest. *Canadian Journal of Forest Research* **23**(7): 1298–1305.

Błońska, E., Lasota, J., Piaszczyk, W. (2020). Carbon and nitrogen stock in deadwood biomass in natural temperate forest along a soil moisture gradient. *Plant Biosystems - An International Journal Dealing with all Aspects of Plant Biology* **154**(2): 213–221.

Brozek, S., Wanic, T. (2002). Impact of forest litter of *Alnus glutinosa* (L.) Gaertn, *Alnus incana* (L.) Moench, *Alnus viridis* (Chaix) Lam. Et Dc, *Abies alba* Mill., and *Fagus sylvatica* L. on chosen soil properties. *Electronic Journal of Polish Agricultural Universities* **5**(1).

Christensen, M., Hahn, K., Mountford, E. P., Ódor, P., Standovár, T., Rozenbergar, D., Diaci, J., Wijdeven, S., Meyer, P., Winter, S., Vrska, T. (2005). Dead wood in European beech (*Fagus sylvatica*) forest reserves. *Forest Ecology and Management* **210**(1–3): 267–282.

Christensen, M., Vesterdal, L. (2004). *Physical and chemical properties of decaying beech wood in two Danish forest reserves*. Nat-Man Working Report No. 24, University of Copenhagen, 16 p.

Damyanova, S. (2017). Chemical composition of a dead wood biomass in beech communities. *Journal of BioScience & Biotechnology*, Special edition/Online section “Biodiversity”: 85–88.

Dimitrova, V. G., Doychev, D., Bencheva, S., Damyanova, S., Kodjabashev, N. (2017). Dead biomass in beech (*Fagus sylvatica* L.) forest ecosystems in West Balkan Range, Bulgaria. In: Gedyo, V. M. (ed.). *II International Conference. Forests of Russia: Policy, Industry, Science and Education, Sanct Petersburg, 24-26.05.2017* pp. 38–42.

Harmon, M. E. (2009). Woody detritus its contribution to carbon dynamics of old-growth forests: the temporal context. In: *Old-Growth Forests* pp. 159–190. Springer.

Harmon, M. E., Franklin, J. F., Swanson, F. J., Sollins, P., Gregory, S. V., Lattin, J. D., Anderson, N. H., Cline, S. P., Aumen, N. G., Sedell, J. R., Lienkaemper, G. W., Cromack Jr, K., Cummins, K. W. (1986). Ecology of coarse woody debris in temperate ecosystems. In: *Advances in ecological research* pp. 133–302. Elsevier.

Herrmann, S., Bauhus, J. (2018). Nutrient retention and release in coarse woody debris of three important central European tree species and the use of NIRS to determine deadwood chemical properties. *Forest Ecosystems* **5**(1): 22.

Hottola, J., Siitonen, J. (2008). Significance of woodland key habitats for polypore diversity and red-listed species in boreal forests. *Biodiversity and Conservation* **17**(11): 2559–2577.

Hristovski, S. (2007). *Phytomass and primary production in the beech ecosystem (Calamintho grandiflorae-Fagetum) in Mavrovo National Park. Doctoral disserta-*

tion. Institute of Biology, Faculty of Natural Sciences and Mathematics, Ss. Cyril and Methodius University. Skopje, 297 p.

Kraigher, H., Jurc, D., Kalan, P., Kutnar, L., Levanič, T., Rupel, M., Smolej, I. (2002). Beech coarse woody debris characteristics in two virgin forest reserves in southern Slovenia. *Zbornik gozdarstva in lesarstva* **69**: 91–134.

Krankina, O. N. & Harmon, M. E. (1995). Dynamics of the dead wood carbon pool in northwestern Russian boreal forests. In: *Boreal Forests and Global Change* pp. 227–238. Springer.

Maser, C. & Trappe, J. M. (1984). *The seen and unseen world of the fallen tree*. U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, USA, 56 pp.

Melovski, L., Grupče, L., Mulev, M., Derlieva, L. (1995). Annual litter-fall in Italian and Turkey oak ecosystem on Galičica National Park. I. The litter-fall quantity and dynamics of tree layer. *God. zb. Biol.* **47**: 49–66.

Melovski, L., Hristovski, S., Šušlevska, M., Grupče, Lj. (2004). Dynamics of the forest floor biomass in the beech ecosystem Calamintho grandiflorae-Fagetum in Mavrovo National Park. In: *Proceedings of the 2nd Congress of Ecologists of the Republic of Macedonia, 25-29.10.2004, Ohrid* pp. 6–10. Macedonian Ecological Society, Skopje.

Næsset, E. (1999). Relationship Between Relative Wood Density of Picea abies Logs and Simple Classification Systems of Decayed Coarse Woody Debris. *Scandinavian Journal of Forest Research* **14**(5): 454–461.

Ranius, T. & Jansson, N. (2000). The influence of forest regrowth, original canopy cover and tree size on saproxylic beetles associated with old oaks. *Biological Conservation* **95**(1): 85–94.

Soylak, M., Tuzen, M., Narin, I., Sari, H. (2004). Comparison of Microwave, Dry and Wet Digestion Procedures for the Determination of Trace Metal. *Journal of Food and Drug Analysis* **12**(3): 254–258.

Šušlevska, M., Melovski, L., Grupche, L., Hristovski, S., Radoglou, K. (2001). Litter production in the ecosystem *Calamintho grandiflorae-Fagetum* in "Mavrovo" National Park. In: *Proceedings: International Conference Forest Research: a challenge for an integrated European approach, Thessaloniki, Greece, 27 August-1 September 2001.* pp. 627–632. NAGREF-Forest Research Institute.

Veapi, E., Jovanovska, D., Trenčeva, M., Velkovski, N., Hristovski, S. (2018a). Down dead wood in a montane beech forest stands on Deshat mountain. 1. Down dead wood biomass. *Forest Review* **49**(2): 49–55.

Veapi, E., Jovanovska, D., Trenčeva, M., Velkovski, N., Hristovski, S. (2018b). Down dead wood in a montane beech forest stands on Deshat mountain. 2. Carbon sequestration. *Forest Review* **49**(2): 56–60.

Wellbrock, N., Bielefeldt, J., Eickenscheidt, N., Bolte, A., Wolff, B., Block, J., Schröck, H.-W., Schuck, J., Moshammer, R. (2014). *Kohlenstoff-und Nährelementspeicherung von Waldflächen des forstlichen Umweltmonitorings (BZE) in Rheinland-Pfalz*. Thünen Report.