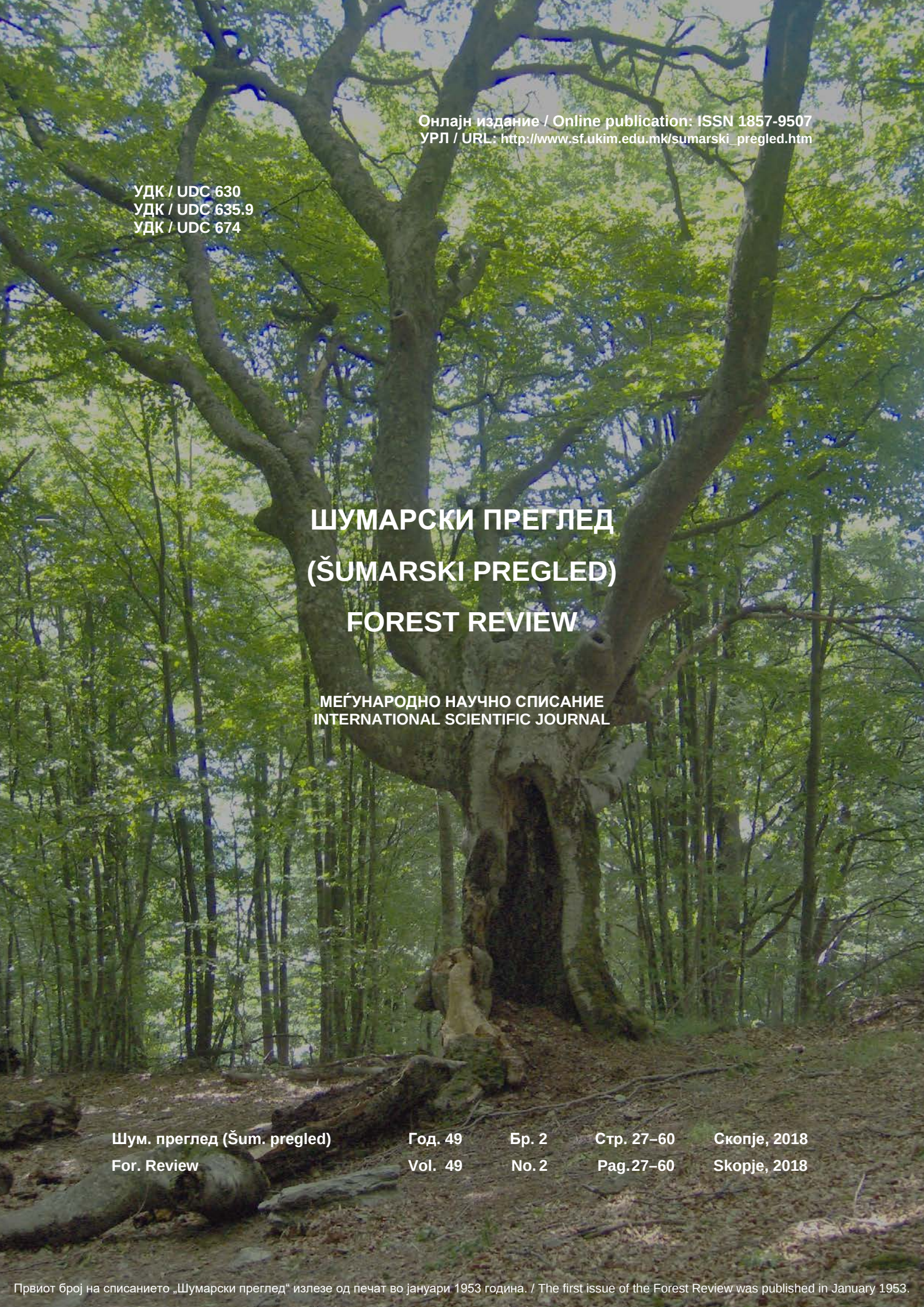

Онлајн издание / Online publication: ISSN 1857-9507
УРЛ / URL: http://www.sf.ukim.edu.mk/sumarski_pregled.htm

УДК / UDC 630
УДК / UDC 635.9
УДК / UDC 674

ШУМАРСКИ ПРЕГЛЕД
(ŠUMARSKI PREGLED)
FOREST REVIEW

МЕЃУНАРОДНО НАУЧНО СПИСАНИЕ
INTERNATIONAL SCIENTIFIC JOURNAL

Шум. преглед (Šum. pregled)	Год. 49	Бр. 2	Стр. 27–60	Скопје, 2018
For. Review	Vol. 49	No. 2	Pag. 27–60	Skopje, 2018

Првиот број на списанието „Шумарски преглед“ излезе од печат во јануари 1953 година. / The first issue of the Forest Review was published in January 1953.

ШУМАРСКИ ПРЕГЛЕД
Меѓународно научно списание
Год. 49, бр. 2, стр. 27–60
Скопје, 2018 година

Онлајн издание: ISSN 1857-9507
УДК: 630
УДК: 635.9
УДК: 674

Фреквенција на издавање
Се објавува двапати годишно

Издавач
Универзитет „Св. Кирил и Методиј“ во Скопје
Шумарски факултет во Скопје
Декан
проф. д-р Кирил Сотировски

Главен и одговорен уредник
доц. д-р Бојан Симовски

Технички уредник
м-р Дејан Манџуковски

Насловна страница и фотографија
доц. д-р Бојан Симовски, *Fagus sylvatica*

УРЛ-адреса (веб-страница)
http://www.sf.ukim.edu.mk/sumarski_pregled.htm

Адреса на издавачот
Универзитет „Св. Кирил и Методиј“ во Скопје
Шумарски факултет во Скопје
Редакција на „Шумарски преглед“
ул. „16 Македонска бригада“ бр. 1
(поштенски фах 235)
1000 Скопје
Република Македонија
Адреса на е-пошта: sumpregled@sf.ukim.edu.mk
Веб-локација: www.sf.ukim.edu.mk

FOREST REVIEW
International scientific journal
Vol. 49, No. 2, Pag. 27–60
Skopje, 2018

Online publication: ISSN 1857-9507
UDC 630
UDC 635.9
UDC 674

Frequency (issues per year)
Semi-annual (2)

Publisher
Ss. Cyril and Methodius University in Skopje
Faculty of Forestry in Skopje
Dean
Prof. Dr.sc Kiril Sotirovski

Editor-in-chief
Ass. Prof. Dr.sc Bojan Simovski

Technical editor
Dejan Mandžukovski, MSc

Cover page and photography
Ass. Prof. Dr.sc Bojan Simovski, *Fagus sylvatica*

URL address (webpage)
http://www.sf.ukim.edu.mk/sumarski_pregled.htm

Publisher address
Ss. Cyril and Methodius University in Skopje
Faculty of Forestry in Skopje
Editorial Board of the Forest Review
Ul. 16 Makedonska brigada br. 1
(P.O. Box 235)
MK-1000 Skopje
Republic of Macedonia
Email address: sumpregled@sf.ukim.edu.mk
Website: www.sf.ukim.edu.mk

ШУМАРСКИ ПРЕГЛЕД
Меѓународно научно списание
Год. 49, бр. 2, стр. 27–60
Скопје, 2018 година

Онлајн издание: ISSN 1857-9507
УДК: 630
УДК: 635.9
УДК: 674

Фреквенција на издавање
Се објавува двапати годишно

УРЛ-адреса (веб-страница)
http://www.sf.ukim.edu.mk/sumarski_pregled.htm

Адреса на издавачот
Универзитет „Св. Кирил и Методиј“ во Скопје
Шумарски факултет во Скопје
Редакција на „Шумарски преглед“
ул. „16 Македонска бригада“ бр. 1
(поштенски фах 235)
1000 Скопје
Република Македонија
Адреса на е-пошта: sumpregled@sf.ukim.edu.mk
Веб-локација: www.sf.ukim.edu.mk

FOREST REVIEW
International scientific journal
Vol. 49, No. 2, Pag. 27–60
Skopje, 2018

Online publication: ISSN 1857-9507
UDC 630
UDC 635.9
UDC 674

Frequency (issues per year)
Semi-annual (2)

URL address (webpage)
http://www.sf.ukim.edu.mk/sumarski_pregled.htm

Publisher address
Ss. Cyril and Methodius University in Skopje
Faculty of Forestry in Skopje
Editorial Board of the Forest Review
Ul. 16 Makedonska brigada br. 1
(P.O. Box 235)
MK-1000 Skopje
Republic of Macedonia
Email address: sumpregled@sf.ukim.edu.mk
Website: www.sf.ukim.edu.mk

Forest Review, 2018, Vol. 49, No. 2: 27–60. Issue URL: http://www.sf.ukim.mk/izdavacka_dejnost/sum_pregled/forest_review_49_2.pdf
Ss. Cyril and Methodius University in Skopje Journal URL: http://www.sf.ukim.mk/sumarski_pregled.htm
Faculty of Forestry in Skopje Online publication: ISSN 1857-9507

CONTENTS

Original scientific articles

Forest Review, 2018, Vol. 49, No. 2: 49–55.
Ss. Cyril and Methodius University in Skopje
Faculty of Forestry in Skopje
Article URL: http://www.sf.ukim.mk/izdavacka_dejnost/sum_pregled/49/2/3.pdf
UDC: 630*81:581.149]:574.36(497.7)
Original scientific article

Down dead wood in a montane beech forest stands on Deshat Mountain: Down dead wood biomass

Ekrem Veapi[1*], Daniela Jovanovska[2], Marija Trenčeva[2], Nikolčo Velkovski[3], Slavčo Hristovski[2]

[1]National Park Mavrovo, Republic of Macedonia
[2]Ss. Cyril and Methodius University in Skopje, Faculty of Natural Sciences and Mathematics in Skopje, Institute of Biology, Republic of Macedonia
[3]Ss. Cyril and Methodius University in Skopje, Faculty of Forestry in Skopje, Republic of Macedonia
Corresponding author's email address: eko-veapi@hotmail.com

ABSTRACT**:** Down dead wood in forest ecosystems plays a very important role in major ecosystem processes such as decomposition, pedogenesis, erosion prevention, biogeochemical cycles of carbon and nutrients, natural regeneration and provides microhabitats for different organisms. Different aspects of down dead wood have received broad attention in scientific literature especially in terms of carbon sequestration and climate change, biodiversity conservation, etc. However, there are no studies on down dead wood in Macedonian forests. This paper presents the results for the amount of down dead wood biomass (dead branches and dead trees) in five montane beech forest stands in Deshat Mountain, Mavrovo National Park. The investigated forest stands represent five different types of forest in terms of degradation and forestry practices. Large branches (3-5, 5-10, and 10-20 cm) were collected by linear transect with test surfaces of 1 m². The down dead wood biomass (branches and logs) was divided into five categories according to the degree of decomposition. Following, the biomass of all fallen logs on a specific test area was assessed. The highest amount of down dead wood was estimated in the most preserved forest (19.04 $t \cdot ha^{-1}$), and the lowest in the most degraded forest (2.68 $t \cdot ha^{-1}$). Biomass of large branches ranged between 1.03 and 9.73 $t \cdot ha^{-1}$, while the biomass of fallen trees varied between 1.65 and 11.64 $t \cdot ha^{-1}$. It can be concluded that the old forests are the main accumulators of down dead wood biomass.
Keywords: Down dead wood, biomass, beech forest

1 INTRODUCTION

Aboveground coarse dead wood in forest ecosystems consists of standing and down dead wood and stumps [1]. In terms of quantity, the down deadwood (DDW) in forest ecosystems is usually much more important [2, 3].

DDW is an integral part of the natural forest ecosystem. It has a significant role in many of the ecosystem processes, especially in decomposition, pedogenesis and erosion prevention, biogeochemical cycles of carbon and nutrients, natural regeneration, etc. [4–8]. It has also a certain impact on forest microclimate and serves as an important water storage component of the forest floor [4, 9]. Down deadwood has also an important part of biodiversity in forest ecosystems. It provides key microhabitat for many species of invertebrates, fungi, birds, and mammals as well as many other species that use down dead wood as a food source or shelter [3, 9, 10]. It is well known that proper management of down dead wood in forest ecosystems (sustaining varied down dead wood or even creating dead logs by cutting of live trees) is of great importance for the survival of many species [2, 11–13]. The amount and biomass of dead trees are considered as indicators of sustainable use and management, degree of preservation of forests, and biodiversity [14]. On the other hand, DDW also supports insect outbreaks and high-severity fires [15].

The intensive and long-term exploitation of forests in Europe has lead to a decrease in the amounts of down dead wood. At present, DDW is much higher in European upland forests compared to the lowland ones, although the natural potential is opposite [3].

The research on dead organic matter in Macedonian forests is very scarce. Thus far, there are only a few studies regarding fine litterfall in an oak forest in Galichica National Park and beech forest in Mavrovo National Park [16–18]. The studies also include data on the biomass of coarse branches in the forest floor for both ecosystems. Hristovski [19] determined the standing deadwood biomass in the beech forest in Mavrovo and estimated a value of 1.58 $t \cdot ha^{-1}$. Apart from these publications, we are not aware of any other research targeted towards the coarse down dead wood in Macedonian forest ecosystems.

Therefore, there is a clear need for more comprehensive research on the amount of down deadwood in the forests, as well as determining optimal management practices that will maintain the optimal amount of down dead wood.

In response, in 2015 we researched DDW in a montane beech forest on Deshat Mountain aiming to estimate DDW biomass, carbon content and mineral composition, decomposition stages, and impact of forestry practices on the amount of DDW.

Results from the research will be presented through series of consequent papers focusing on:

- Down dead wood biomass;
- Carbon sequestration in DDW;
- Mineral composition and quantities;
- Decomposition patterns;
- Impact of forestry on DDW.

This paper is the first in the series of five and presents the results on DDW biomass (both logs and coarse branches) in natural beech forest stands on Deshat Mountain with differences in their structure and anthropogenic impact.

2 MATERIALS AND METHODS

2.1 Research area

Deshat Mountain is situated in the west part of Macedonia. Natural beech forests are the dominant forest type. The climate is mountainous with an influence from the continental climate as well as the Mediterranean climate at lower altitudes [20]. The mean annual

temperature is 7.1˚C and drops for 0.5˚C every 100 m in altitude [21]. Mean monthly temperatures during the winter months are below zero (-2.2˚C in January). The temperature during the spring months is 5.8˚C. The highest mean monthly temperature occurs in July (8.2˚C). The absolute minimal temperature (January) is -25˚C and the absolute maximum temperature (August) is 33.0˚C. Annual precipitation amounts to 1103 mm. The average duration of snow cover is 166 days.

The selection of five stands was made on 08.06.2015, based on different differences in forest management and the general structure of the stands. These five stands were named: Old-growth forest (OF), Preserved forest (PF), Good forest (GF), Resprouting forest (RF), and Degraded forest (DF). The main field research was conducted in the period 28.09-01.10.2015.

All stands are of montane beech forest, association *Calamintho grandiflorae-Fagetum* (Em 1965) Rizovski & Džekov ex Matevski (syn: *Fagetum montanum* Em). The montane beech forest belt spreads between 1300 and 1600 m a.s.l. The dominant soil type is calcomelanosol [22].

Three plots (15 in total) were selected in each of the five forest stands. All of these plots were selected based on field observations and they represent the variability within the forest stands. Stand tree density was estimated as an average of tree density of the three sampling plots within each of the five investigated stands. The surface of the plots depended on tree density and ranged between 100 and 300 m^2 (Table I). In each of the 15 plots we recorded the number of trees and we measured the DBH (diameter at breast height) of each tree. DBH of trees ranged from 3 to 85 cm. At the same time, we recorded the number of shrubs in each of the 15 plots.

2.2 Determination of decay classes wood density

The decay classes were determined based on the different stages of wood decay assessed by visual inspection of the down deadwood. We categorized fallen tree logs and fallen branches into five categories (I-V). Most of the similar studies defined four decay classes and their description corresponds to our classification [6, 23–25]. However, we added category V which refers to deadwood in the last stages of decomposition with very low wood density (sponge-like wood).

Wood density was estimated for both logs and branches. Discs from logs were cut during the fieldwork. They were photographed and their surface (s) including bark was estimated using Photoshop CS6 v13.0. The thickness of the discs (h) was measured by calliper. The volume of the discs (v) was calculated by multiplying the surface and thickness. The discs were measured after drying at 105˚C to constant mass. The density (ρ) was calculated by dividing the mass with the volume of the discs: $\rho=m/(s \cdot h)$.

2.3 Estimation of down dead wood biomass in fallen tree logs

All of the fallen tree logs within five investigated stands were recorded. The area covered ranged from 1.07 to 3.12 ha (Table I). The following parameters were observed or measured: decay classes, length, and three diameters (at the base, in the middle, and at the apex of the tree log).

The volume (V) was calculated with mathematical formulas for truncated cone ($V=\pi r^2 l/3$) or cylinder ($V=\pi r^2 l$) depending on the general shape of the log [26] where V is volume, r is the radius and l is the length of the logs.

The biomass (b) of each tree log was calculated by multiplication of wood volume and wood density ($b=V\rho$).

2.4 Estimation of down dead wood biomass in fallen coarse branches

The biomass of fallen branches was estimated in three transects in all five investigated forest stands. Each of the 15 transects consisted of 10-20 sampling quadrats with the surface of $1m^2$. Sampling quadrats were placed on a 3m distance.

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. During the fieldwork, we took samples (on average 400 g) of each diameter classis and decay class to measure the dry weight and water percentage. In total, 37 samples were measured for the wet weight (on the field) and dry weight (in the laboratory) after drying at 105˚C to constant mass.

Table I: Main characteristics of the five investigated beech stands

Forest stand	Short description	Total stand surface (ha)	Sampling plots surface (m^2)	Number of sampling quadrats	Average DBH (cm)	Trees density (ha^{-1})	Altitude (m)	GPS coordinates	
Old forest (OF)	Presence of many old trees in good health condition and very large fallen logs. Canopy cover of ~70%. No recent human activities. Mild inclination.	3.12	300	3x10=30	12.0	1355,6	1580-1595	20.56249	41.63885
Preserved forest (PF)	Middle-aged trees are dominant with scattered old trees. Presence of a number of large fallen logs. Mild inclination.	1.07	300	3x10=30	13.5	2500	1570-1590	20.55987	41.63776
Good forest (GF)	In the vicinity of the sheepfold, next to Osmanova Livada locality. Visible signs of continuous use, mostly a collection of branches by the shepherds. Steep inclination.	1.76	200	2x10+1x20=40	9.2	2516,7	1635-1680	20.55802	41.63212
Resprouting forest (RF)	The forest consists of resprouting trees with great tree density. Intensive human use (firewood for the sheepfold that existed in the vicinity) can be observed, especially in the last 50 years. Mild inclination.	1.63	200	3x10=30	9.1	7816,7	1575-1595	20.56158	41.63655
Degraded forest (DF)	Intensive use by the inhabitants of villages Trebishte and Bitushe can be observed. Medium inclination.	1.15	100	3x15=45	11.8	2250	1305-1350	20.57627	41.62842


Old forest (OF)


Preserved forest (PF)


Good forest (GF)


Resprouting forest (RF)


Degraded forest (DF)

Figure 1: Photographs of the five investigated beech stands

3 RESULTS AND DISCUSSION

Wood density of fallen tree logs and branches varied between the decay classes (Table II). The statistical nonparametric analysis showed a significant decrease in wood density from category I to V ($p<0.05$; $r=-0.897$).

Table II: Wood density of fallen tree logs and large branches according to decay classes

Decay classis	Number of samples per decay class (discs)	Wood density
D1	38	0.72*
D2	8	0.54
D3	2	0.47
D4	10	0.32
D5	4	0.12

*The value of wood density for category I was taken from Hristovski [19]

The number of fallen tree logs varied between the forest stands. The highest number of fallen logs was recorded in PF, DF, and RF, and the lowest in OF and GF (Table III).

The length of fallen tree logs is another important measure of down dead wood since it implies the availability of microhabitat for a variety of different organisms (fungi, saproxylic insects, etc.). PF held the lengthiest fallen tree logs (Table III). DF had the lowest values when length parameters of tree logs were considered.

OF differed from the other beech stands by having the highest total volume (91.26 m^3/ha) as well as other measured volume parameters (Table IV).

The highest down dead wood biomass in fallen tree logs was recorded in PF (11.64 $t \cdot ha^{-1}$), while the lowest was recorded in RF (1.15 $t \cdot ha^{-1}$) (Table V). The average value in all investigated beech forest stands amounted to 5.78 $t \cdot ha^{-1}$.

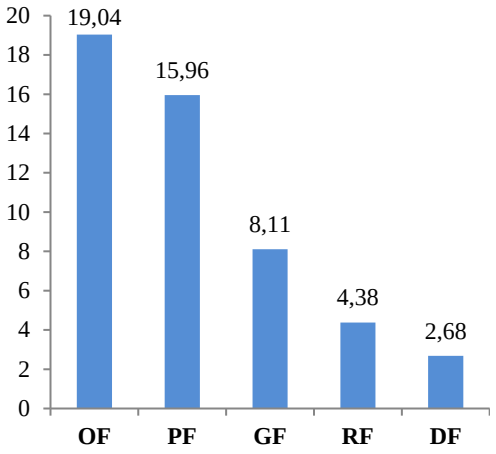

Figure 2: Total down dead wood biomass ($t \cdot ha^{-1}$) in the five investigated beech stands

The greatest biomass of fallen tree logs was recorded for category IV. The lowest biomass was recorded for category I and V (Table V). The average down dead wood biomass in fallen branches was 4.25 $t \cdot ha^{-1}$. The highest amount was recorded in OF (9.73 $t \cdot ha^{-1}$), while the lowest in DF (1.03 $t \cdot ha^{-1}$). Branches of category III were the most dominant across the investigated forest stands. According to the diameter of branches, the largest biomass was recorded in the 3-5cm category (Table VI).

The highest down dead wood biomass (fallen logs + branches) was accumulated in OF (19.04 $t \cdot ha^{-1}$) and it decreased in the following order: OF>PF>GF>RF>DF (Figure 2). The average down dead wood biomass was 10.04 $t \cdot ha^{-1}$.

The deadwood carbon pool in forests is generally similar to some other forest regions and a latitudinal gradient could not be established [6]. Values of 17-36 Mg C ha^{-1} were reported for boreal forests, 9-21 for undisturbed dry tropical forests; 2-25 for moist tropical forests, 15-25 for cold deciduous forests, and 10-12 $t \cdot ha^{-1}$ for warm temperate deciduous forests [6, 27–36].

The amount of down dead wood depends on several factors among which forest age, type of management and use, soil, climate, and decomposition are the most important [37,38]. It is known that DDW changes with the maturing of the forest and generally follows a U-shaped pattern. Mature hardwood forest stands have smaller DDW biomass compared to young and old stands. In old stands, DDW continues to accumulate as stands age from 200 to 400 years [15]. The simple U-shaped pattern is not valid for all forest ecosystems and largely depends on the forestry practices and in different forests, it can develop into J or S-shaped patterns in time [5]. Unfortunately, we did not estimate the age of the stands and this hypothesis was not tested on the investigated beech forest stands on Deshat Mountain.

Although there is no targeted research on DDW in Macedonian forests, some of the studies may help in understanding the formation of DDW. Several studies have reported data on tree mortality in forest ecosystems. The global average is 1-2% mortality [39]. The mortality in a beech forest in Mavrovo National Parl was lower [19] while the mortality of beech forests on Osogovo was assessed to 0.6-1.0% and 0.5-1.4% for beech forests on Karaorman [40,41].

The average volume of down dead wood in the investigated beech forests on Deshat was 33.63 $m^3 \cdot ha^{-1}$. Down deadwood in European beech forests ranges between 32 and 310 $m^3 \cdot ha^{-1}$ [26]. This range is broader in beech forests of Great Britain with a minimal amount of 3 m^3 and a maximum of 456 m^3 [42,43]. The amount of down dead wood in beech forest reserves has an average of about 130 $m^3 \cdot ha^{-1}$ [3, 38, 44]. Only the OF (91.26 $m^3 \cdot ha^{-1}$) approaches the European average of beech reserves while DF (5.72 $m^3 \cdot ha^{-1}$) represents highly exploited forests with a very small amount of down dead wood. The average of beech forests on Deshat is close to the average of Slovakia where 31 $m^3 \cdot ha^{-1}$ of down dead wood was estimated [45, 46], but higher than the beech forests on Stara Planina in Bulgaria which hold 3.4-26.5 $m^3 \cdot ha^{-1}$, fine wood: 3.4-6.5 and coarse debris: 0-20.1 [24]. Down dead wood in managed forests in Serbia accounts for 11.21 $m^3 \cdot ha^{-1}$ or 1.24-24.53 $m^3 \cdot ha^{-1}$ [25].

The results of the study conducted in beech forests on Deshat Moutain show that the old forests are important storages of down dead wood, both logs, and branches.

Table III: Number and length of fallen tree logs in the five investigated beech stands

Forest stand	Average number of logs per hectare	Minimal length of single tree log (m)	Maximal length of single tree log (m)	Average length of tree log and standard error (m)
OF	23.4	1.70	19.20	6.54 ± 0.46
PF	43.0	1.30	18.80	7.30 ± 0.68
GF	23.9	1.10	19.50	5.22 ± 0.74
RF	38.6	0.90	12.52	4.64 ±0 0.27
DF	41.7	0.63	10.00	2.64 ± 0.27
Average	34.1	1.13	16.00	5.27 ± 0.81

Table IV: Volume (m^3) Length (m) of fallen tree logs in the five investigated beech stands

Forest stand	Minimal volume of single tree log (m^3)	Maximal volume of single tree log (m^3)	Average volume of tree logs and standard error (m^3)	Total volume of tree logs per stand (m^3/ha)
OF	0.013	23.14	1.25 ± 0.37	91.26
PF	0.013	9.78	0.88 ± 0.27	40.37
GF	0.004	9.34	0.63 ± 0.27	24.65
RF	0.005	2.75	0.09 ± 0.04	6.18
DF	0.001	0.88	0.12 ± 0.03	5.72
Average	0.007	9.18	0.59 ±	33.63

Table V: Biomass of down dead wood of fallen logs ($t \cdot ha^{-1}$)

Forest stand	Decay classes					Total
	I	**II**	**III**	**IV**	**V**	
OF	0.00	1.41	2.44	5.35	0.10	**9.31**
PF	0.12	1.11	2.53	7.86	0.00	**11.62**
GF	0.00	0.36	1.39	3.39	0.00	**5.14**
RF	0.00	0.08	0.44	0.63	0.00	**1.15**
DF	0.00	0.10	0.67	0.87	0.00	**1.65**

Table VI: Down dead wood biomass of fallen branches ($t \cdot ha^{-1}$)

Forest stand	3-5 cm				5-10 cm				10-20 cm			Total (with standard error)
	II	**III**	**IV**	**Total**	**II**	**III**	**IV**	**Total**	**III**	**IV**	**Total**	
OF	0.26	1.83	0.14	2.23	0.00	2.99	1.69	4.68	2.62	0.20	2.82	**9.73** ± 0.76
PF	0.15	1.85	0.15	2.14	0.72	0.59	0.86	2.17	0.00	0.00	0.00	**4.32** ± 1.47
GF	0.18	1.35	0.57	2.10	0.46	0.31	0.10	0.87	0.00	0.00	0.00	**3.22** ± 0.21
RF	0.97	1.29	0.65	2.91	0.00	0.00	0.31	0.31	0.00	0.00	0.00	**2.97** ± 0.16
DF	0.23	0.29	0.07	0.59	0.00	0.44	0.00	0.44	0.00	0.00	0.00	**1.03** ± 0.21

4 CONCLUSIONS

Down dead wood in a montane beech forest stands on Deshat Mountain depends directly on the quality and age of the forest. Most of the down dead wood was recorded in the old unmanaged forests, and the quantity of down dead wood decreases with decreasing quality and age of the forest. The highest amount of down dead wood biomass was estimated in the most preserved forest (19.04 $t \cdot ha^{-1}$), and the lowest in the most degraded forest (2.68 $t \cdot ha^{-1}$).

5 ACKNOWLEDGMENT

The authors would like to thank the team of students who helped and conducted the field investigation on Deshat Mountain during autumn, 2015: Aleksej Anovski, Kiril Arsovski, Maja Mladenova, and Nenad Petrovski.

We would like to express our eternal gratitude to Professor Ljupcho Melovski, an outstanding ecologist who was part of the research team but most unfortunately passed away on 29.04.2019.

6 REFERENCES

[1] M.B. Russell, S. Fraver, T. Aakala, J.H. Gove, C.W. Woodall, A.W. D'Amato, M.J. Ducey, Quantifying carbon stores and decomposition in dead wood: A review, For. Ecol. Manag. 350 (2015) 107–128. https://doi.org/10.1016/j.foreco.2015.04.033.

[2] J. Hottola, J. Siitonen, Significance of woodland key habitats for polypore diversity and red-listed species in boreal forests, Biodivers. Conserv. 17 (2008) 2559–2577. https://doi.org/10.1007/s10531-008-9317-4.

[3] M. Christensen, K. Hahn, E.P. Mountford, P. Ódor, T. Standovár, D. Rozenbergar, J. Diaci, S. Wijdeven, P. Meyer, S. Winter, T. Vrska, Dead wood in European beech (Fagus sylvatica) forest reserves, For. Ecol. Manag. 210 (2005) 267–282. https://doi.org/10.1016/j.foreco.2005.02.032.

[4] M.E. Harmon, J.F. Franklin, F.J. Swanson, P. Sollins, S.V. Gregory, J.D. Lattin, N.H. Anderson, S.P. Cline, N.G. Aumen, J.R. Sedell, others, Ecology of coarse woody debris in temperate ecosystems, Adv. Ecol. Res. 15 (1986) 133–302.

[5] M.E. Harmon, Woody Detritus its Contribution to Carbon Dynamics of Old-Growth Forests: the Temporal Context, in: Old-Growth For., Springer, 2009: pp. 159–190. http://link.springer.com/10.1007/978-3-540-92706-8_8 (accessed November 10, 2016).

[6] O.N. Krankina, M.E. Harmon, Dynamics of the dead wood carbon pool in northwestern Russian boreal forests, in: Boreal For. Glob. Change, Springer, 1995: pp. 227–238.

[7] E. Næsset, Relationship Between Relative Wood Density of Picea abies Logs and Simple Classification Systems of Decayed Coarse Woody Debris, Scand. J. For. Res. 14 (1999) 454–461. https://doi.org/10.1080/02827589950154159.

[8] S. Brozek, T. Wanic, 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., Electron. J. Pol. Agric. Univ. 5 (2002).

[9] C. Maser, J.M. Trappe, 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., 1984. http://digitalcommons.usu.edu/barkbeetles/165/ (accessed November 10, 2016).

[10] T. Ranius, N. Jansson, The influence of forest regrowth, original canopy cover and tree size on saproxylic beetles associated with old oaks, Biol. Conserv. 95 (2000) 85–94.

[11] P.-A. Esseen, B. Ehnström, L. Ericson, K. Sjöberg, Boreal forests—the focal habitats of Fennoscandia, in: Ecol. Princ. Nat. Conserv., Springer, 1992: pp. 252–325.

[12] M. Jonsell, J. Weslien, B. Ehnström, Substrate requirements of red-listed saproxylic invertebrates in Sweden, Biodivers. Conserv. 7 (1998) 749–764.

[13] A. Lindhe, Å. Lindelöw, N. Åsenblad, Saproxylic Beetles in Standing Dead Wood Density in Relation to Substrate Sun-exposure and Diameter, Biodivers. Conserv. 14 (2005) 3033–3053. https://doi.org/10.1007/s10531-004-0314-y.

[14] MCPFE, Improved Pan-European Indicators for Sustainable Forest Management as adopted by the MCPFE, Expert Level Meeting 7–8 October 2002., Vienna, 2003.

[15] A.M. Evans, M.J. Ducey, Carbon accounting and management of lying dead wood, White Pap. For. Guild St. Fe Httpwww For. Orgpublication sresearch20. 10 (2010).

[16] L. Melovski, L. Grupče, M. Mulev, L. Derlieva, 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 (1995) 49–66.

[17] L. Melovski, S. Hristovski, M. Šušlevska, Lj. Grupče, Dynamics of the forest floor biomass in the beech ecosystem Calamintho grandiflorae-Fagetum in Mavrovo National Park, in: Proc. 2nd Congr. Ecol. Repub. Maced. 25-29102004 Ohrid, Macedonian Ecological Society, Skopje, 2004: pp. 6–10.

[18] M. Šušlevska, L. Melovski, L. Grupche, S. Hristovski, K. Radoglou, Litter production in the ecosystem Calamintho grandiflorae-Fagetum in "Mavrovo" National Park., in: Proc. Int. Conf. For. Res. Chall. Integr. Eur. Approach Thessalon. Greece 27 August-1 Sept. 2001, NAGREF-Forest Research Institute, 2001: pp. 627–632.

[19] S. Hristovski, Phytomass and primary production in the beech ecosystem (Calamintho grandiflorae-Fagetum) in Mavrovo National Park. Doctoral dissertation, Institute of Biology, Faculty of Natural Sciences and Mathematics, Ss. Cyril and Methodius University, Skopje, 2007.

[20] G. Filipovski, R. Rizovski, P. Ristevski, The characteristics of the climate-vegetation-soil zones (regions) in the Republic of Macedonia, Macedonian Academy of Sciences and Arts, Skopje, 1996.

[21] A. Lazarevski, Climate in Macedonia, Kultura, Skopje, 1993.

[22] MASIS, Macedonian Soil Information System, (2015). http://www.maksoil.ukim.mk/masis/.

[23] S. Müller-Using, N. Bartsch, Decay dynamic of coarse and fine woody debris of a beech (Fagus sylvatica L.) forest in Central Germany, Eur. J. For. Res. 128 (2009) 287–296. https://doi.org/10.1007/s10342-009-0264-8.

[24] V. Dimitrova, Stocks of dead biomass of Beech (*Fagus sylvatica* L.) forest ecosystems in West Balkan range, Bulgaria, Šumar. List. 142 (2018) 363–370. https://doi.org/10.31298/sl.142.7-8.2.

[25] M. Koprivica, B. Matović, S. Stajić, V. Čokeša, Đ. Jović, Dead wood in managed beech forests in Serbia, Šumar. List. 137 (2013) 173–183.

[26] M. Saniga, J.P. Schütz, Dynamics of changes in dead wood share in selected beech virgin forests in Slovakia within their development cycle, J. For. Sci. 47 (2001) 557–565.

[27] M.E. Harmon, D.F. Whigham, J. Sexton, I. Olmsted, Decomposition and mass of woody detritus in the dry tropical forests of the northeastern Yucatan Peninsula, Mexico, Biotropica. (1995) 305–316.

[28] M.E. Harmon, J.F. Franklin, F.J. Swanson, P. Sollins, S.V. Gregory, J.D. Lattin, N.H. Anderson, S.P. Cline, N.G. Aumen, J.R. Sedell, G.W. Lienkaemper, K. Cromack Jr, K.W. Cummins, Ecology of coarse woody debris in temperate ecosystems, in: Adv. Ecol. Res., Elsevier, 1986: pp. 133–302.

[29] J.B. Kauffman, C. Uhl, D.L. Cummings, Fire in the Venezuelan Amazon 1: fuel biomass and fire chemistry in the evergreen rainforest of Venezuela, Oikos. (1988) 167–175.

[30] P.J. Edwards, P.J. Grubb, Studies of mineral cycling in a montane rain forest in New Guinea: I. The distribution of organic matter in the vegetation and soil, J. Ecol. (1977) 943–969.

[31] C. Uhl, J.B. Kauffman, Deforestation, fire susceptibility, and potential tree responses to fire in the eastern Amazon, Ecology. 71 (1990) 437–449.

[32] J.A. Gore, W.A. Patterson III, Mass of downed wood in northern hardwood forests in New Hampshire: potential effects of forest management, Can. J. For. Res. 16 (1986) 335–339.

[33] T.J. Fahey, Nutrient dynamics of aboveground detritus in lodgepole pine (Pinus contorta ssp. latifolia) ecosystems, southeastern Wyoming, Ecol. Monogr. 53 (1983) 51–72.

[34] R.N. Muller, Y. Liu, Coarse woody debris in an old-growth deciduous forest on the Cumberland Plateau, southeastern Kentucky, Can. J. For. Res. 21 (1991) 1567–1572.

[35] T.L. Onega, W.G. Eickmeier, Woody detritus inputs and decomposition kinetics in a southern temperate deciduous forest, Bull. Torrey Bot. Club. (1991) 52–57.

[36] M.E. Harmon, C. Hua, Coarse woody debris dynamics in two old-growth ecosystems, BioScience. 41 (1991) 604–610.

[37] J.N. Stokland, The coarse woody debris profile: an archive of recent forest history and an important biodiversity indicator, Ecol. Bull. (2001) 71–83.

[38] K. Hahn, M. Christensen, 2. Dynamics of dead wood in European beech forests in relation to natural disturbances, in: A. Sigurgeirsson, K. Jõgiste (Eds.), Nat. Disturb. Dyn. Compon. Ecosyst. Manag. Plan., Rit Mógilsár Rannsóknastöðvar Skógræktar, 2004: pp. 5–8.

[39] S.L. Brown, P.E. Schroeder, Spatial patterns of aboveground production and mortality of woody biomass for eastern US forests, Ecol. Appl. 9 (1999) 968–980.

[40] M. Gogushevski, D. Ivanov, Structure and productivity of beecf forests on Karaorman mountain, God Zb Sum Fak. 28 (1978) 157–171.

[41] C. Ivanovski, P. Ristevski, The development and increment of intact beech forest in Osogovo, For. Rev. 1 (1987) 23–39.

[42] E.P. Mountford, G.F. Peterken, Natural developments at Scords Wood, Toy's Hill, Kent, since the Great Storm of October 1987., Engl. Nat. Res. Rep. (2000).

[43] E.P. Mountford, Natural developments in a minimum intervention area in Buckholt Wood, part of the Cotswolds Commons and Beechwoods National Nature Reserve, English Nature Research Reports (519), Peterborough, 2003.

[44] P. Ódor, J. Heilmann-Clausen, M. Christensen, E. Aude, K.W. Van Dort, A. Piltaver, I. Siller, M.T. Veerkamp, R. Walleyn, T. Standovár, Diversity of dead wood inhabiting fungi and bryophytes in semi-natural beech forests in Europe, Biol. Conserv. 131 (2006) 58–71.

[45] S. Korpel, Ergebnisse der Urwaldforschung für die Waldwirtschaft im Buchen-Ökosystem, Allg. Forstz. 47 (1992) 1148–1152.

[46] S. Korpel, Totholz in Naturwäldern und Konsequenzen für Naturschutz und Forstwirtschaft, Forst Holz. 52 (1997) 619–624.