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Management influence on the dead wood distribution in a Norway spruce forest from Calimani National Park, Romania

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Abstract. The research paper mainly focuses on the distribution of dead wood depending on origin and based on the specific elements analysis related to the stand. The research has been conducted in the Calimani National Park, located in the north of the Eastern Carpathians, Romania. The only identified origin of snags across the covered surface was the natural one. In the case of logs, 95.8% of the total volume is of natural origin, while 4.2% has anthropic causes. In the case of stumps, its origin is mainly natural (64.3%). As concerns the distribution of the total volume of dead wood, for each stand type, have found that its highest value (87.8 $m^3 \cdot ha^{-1}$) is recorded in forests that have undergone forestry works, but the works are currently restricted, as these are part of the permanently protected areas on surfaces outside the forest standing crop (A2), while the lowest value (30.8 $m^3 \cdot ha^{-1}$) was in pastures or wooded pastures within the park boundaries (A4). The highest amount of snags (41.7 $m^3 \cdot ha^{-1}$) and logs (40.4 $m^3 \cdot ha^{-1}$) is recorded in the stands included in the A2 category, while the highest stumps value (9.5 $m^3 \cdot ha^{-1}$) is in forests that have undergone forestry works and where certain types of works are currently allowed, while these forests are now part of the sustainable conservation area (A3). The lowest value for snags (12.3 $m^3 \cdot ha^{-1}$), logs (17.0 $m^3 \cdot ha^{-1}$) and stumps (1.5 $m^3 \cdot ha^{-1}$) is recorded in forests included in the A4 category. Our findings show that both natural phenomena and anthropic activities have had significant effects on the dynamics of dead wood and that a series of measures or a dead wood management strategy are needed in order to preserve a high biodiversity in forests, so that they can properly fulfill the complex role for which they were created.
Key Words: *Picea abies*, forest management, biodiversity, decay class, necromass.

Introduction. Dead wood is an essential sub-layer for numerous species of aerophyte or saprophyte plants (Sippola & Renvall 1999; Londsdale et al 2008). The presence of dead wood increases the range of available microclimates and microhabitats, thus allowing for the presence of a much higher number of species than what the case may have been in its absence (Bader et al 1995; Christensen & Emborg 1996; Londsdale et al 2008; Lemperiere & Marage 2010). Moreover, it provides room for nests and a wet habitat for numerous species during periods of severe draught, all the while providing shelter during periods of extreme temperatures or weather conditions (Stevens 1997; Grove & Jeff 2003).

Dead wood performs various functions in forest ecosystems and also influences biological, physical and chemical processes (Anderson et al 1986; Kirby et al 1998; Fischer 2010). It influences biodiversity, forest productivity and the geomorphology of the ecosystem (Stevens 1997; Bütler et al 2007; Pfeil et al 2007). Additionally, it helps the forest ecosystem provide various types of habitats and the long term storage of carbon (Alberti et al 2008; Woodall et al 2008; Olajuyigbe et al 2011).

The presence of dead wood in advanced states of decomposition enables the soil to be populated with mycorrhizal fungus, which is important for the health of the other trees. Moreover, a certain connection has been identified between the stages of decay that are typical of dead wood and a certain role it performs (Grove & Jeff 2003).

Based on the information presented above, the research paper has mainly focused on analyzing how the old management (before setting up Calimani National Park) were influenced the dead wood distribution, by analyzing it in terms of origin (natural and anthropic) and stand category (differentiated by the applied forestry works).

Material and method

Study area. The surface where the research has been conducted is located in the north-west of the Calimani National Park, Romania and it stretches between 47°15'-47°23' northern latitude and 25°11'-25°14' eastern longitude. It covers the upper area of the Calimani Mountains, bordering the Dorna depression to the east, the Bargau Mountains in the west, the Calimani volcanic cauldron in the south and the Dorna river valley in the north (Figure 1).

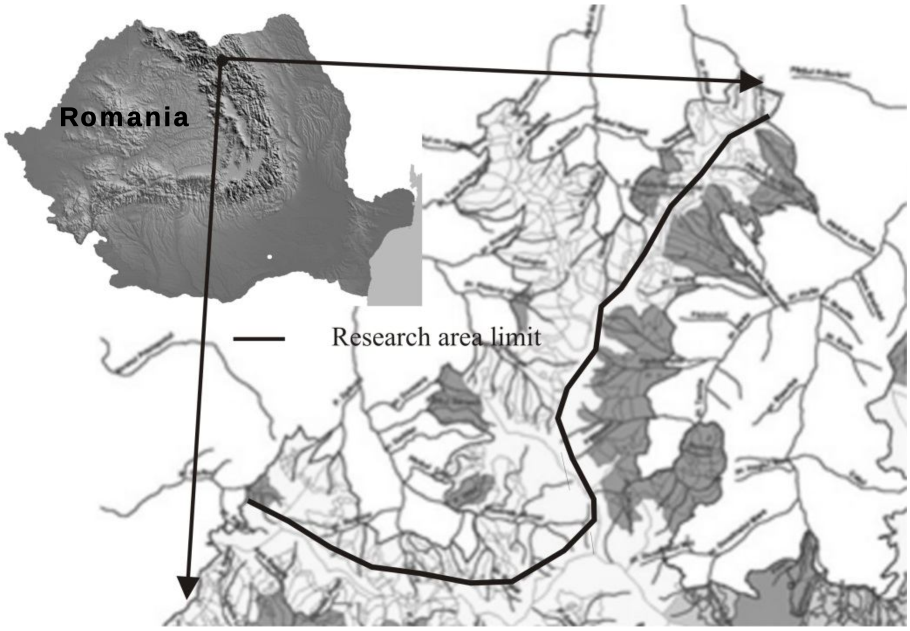

Figure 1. Study area.

Data collection. The research area was covered with a 1,000 m wide probing network; each point where the network lines intersected became the center of the sample plots. Thus, a number of 73 research points were created, each accounting for one survey area, randomly spread across the entire surface.

In order to conduct a quantitative and qualitative assessment of dead wood in terms of decay classes, the present research has resorted to the intersect method and the various types of surface sampling method, based on the types of dead wood under analysis. The intersect method was used for logs, while the surface sampling method has been used to assess snags and stumps.

Circular survey areas with a 12.62 m radius have been defined at each point. The intersect have been delineated by drawing three 50 m lines from the center of the probe, one to the north and the other two at a 120 degree angle from each other, in order to prevent the transects from overlapping or becoming parallel with the prevalent direction in which the wood has fallen and in order to ensure the accuracy of the findings (Van Wagner 1968; Densmore et al 2004; Corrow 2010).

In the field charts of each of these areas, we have measured and recorded all the physical characteristics of the snags (standing dead wood) and stump (stump dead wood), and, on each transect, the characteristics of the logs (felled dead wood) they intersected, depending on the current classifications in use (Marchetti 2004; Montes et al 2004).

Two perpendicular diameters at the height of 1.30 m have been measured for all live and dead trees (snags), as well as their height. For logs, we have measured the diameter at the thicker end, at the thinner end and the length of the piece of wood, while for stumps we have measured the diameter at the base, the diameter of the upper part and their height.

Diameter, height and length have been measured with specific forestry instruments (the caliper and the Vetrex III hypsometer). We have also used a widely system of measuring the decay stage for each separate type of dead wood. There are five stages of decay for snags and logs and six stages for stumps (Marchetti 2004; Montes et al 2004).

Data analysis. The total volume has been calculated for each category of dead wood (snags, logs and stumps) and for each decay class. The regression equation of the volume depending on the breast height diameter of the tree and its height is the most used method and, at the same time, the most recommended one, in order to calculate the volume of standing trees. For healthy trees and snags, we have used the log-log plot for Norway spruce stands (Giurgiu & Draghiciu 2004). The unit volumes have been calculated by means of the Smalian procedure (West 2009), which entails measuring the diameters at each end of the dead wood pieces, as well as the piece length. The cubic capacity of the stumps was measured using the formula of the frustum volume.

The distribution of the dead wood categories focused on measuring the average volume (%) of the dead wood categories and of the total dead wood identified in the research area.

Depending on its origin, the necromass may occur as a result of anthropic activities or under the influence of natural factors (inter or intra-specific competition, biotic or abiotic factors). Consequently, the research focused on the distribution and the analysis of the volume of dead wood categories, depending on their origin.

The specific stand category is a filter depending on the present internal location and for each category of use of the areas encompassed by the Calimani National Park, relative to their level of anthropization. The analysis of this factor is particularly important, as it traces the dynamics of dead wood depending on one of the most important elements that equally hinder and favor it's ingoing and outgoing movement, *i.e.* the anthropic activity. The research area has been divided into four categories, depending on the forests' level of anthropization (which is highly important in terms of dead wood quantities): A1 – forests where, according to the forestry management planning conducted between 1961-2010, no forestry activities have been identified and, at present, any works have been restricted as these areas are permanently protected; A2 – forests where forestry works have been conducted and are currently restricted, as these areas are permanently protected; A3 – forests where forestry works have been conducted and where certain operations are still allowed, as these forests are currently part of the sustainable conservation area; A4 – areas outside the standing crops, pastures or wooded pastures within the park boundaries.

Lastly, the influence of the management methods on the quantitative distribution of dead wood has been identified through the analysis of the dead wood distribution relative to each stand category and differentiated for each decay class.

Results

Dead wood distribution according to origin. The distribution of the dead wood volume (%) by categories, depending on its origin, shows that snags occurred completely due to natural causes. As concerns logs and stump, the anthropic influence is identified in different degrees, with an obvious prevalence in the case of stumps (Figure 2).

The size of the average diameter at the stumps basis occurring from natural causes is 8% smaller than the one found in the case of stumps caused by anthropic activities, while the size of the average diameter measured at the upper part of the stump is 24% smaller than the one found in stumps caused by anthropic intervention. The height of the stumps occurring from natural causes is 35% higher than the one found in stumps caused by anthropic activities. The parameters under analysis have a high variability, and the variation coefficient is higher than 30%.

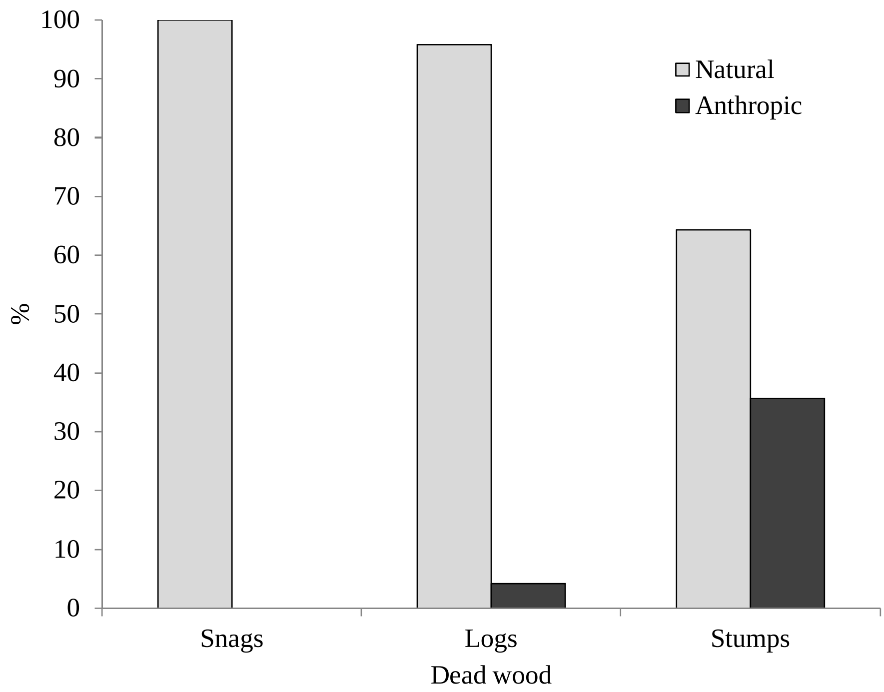

Figure 2. The distribution of the dead wood volume (%) into categories, depending on its origin.

As concerns the total number of identified stumps, note that the ones occurring from natural causes account for 58.5% of the total, and they are therefore more numerous than the ones caused by anthropic activities, which account for 41.5% (Table 1).

Table 1

Data of the stumps occurring due to natural causes and as a consequence of anthropic activities

Statistical parameters	*Dead wood origin / Biometrical parameters*					
	Natural causes			*Anthropic*		
	Base stump diameter (cm)	*Upper stump diameter (cm)*	*Stump height (cm)*	*Base stump diameter (cm)*	*Upper stump diameter (cm)*	*Stump height (cm)*
Average	30.4±16.4	22.6±12.7	39.9±20.6	34.1±15.4	27.9±12.3	25.7±8.8
Variation coefficient (%)	54.3	56.8	50.4	44.9	43.7	34.4
Minimum	9.0	5.7	14.7	12.5	9.7	11.7
Maximum	78.8	57.0	92.7	74.7	60.5	49.2
Stumps·ha^{-1}	89	-	-	64	-	-

Dead wood distribution depending on stands category. As far as the types of stands are concerned, the dynamics of the total standing trees (healthy trees and standing dead wood) as well as that of dead wood has different aspects depending on each of the dead wood categories (Table 2).

Table 2

Values of dead wood categories on stand category

Stands type	*Snags ($m^3 \cdot ha^{-1}$)*	*Logs ($m^3 \cdot ha^{-1}$)*	*Stumps ($m^3 \cdot ha^{-1}$)*	*Total ($m^3 \cdot ha^{-1}$)*
A1	40.3	39.1	7.0	86.4
A2	41.7	41.8	4.3	87.8
A3	19.3	20.3	9.5	49.1
A4	12.3	17.0	1.5	30.8

An analysis of the snags distribution to the stands categories and related to the decay class will reveal the significant values of the parameter under analysis for the 1st and 2nd decay class. The maximum recorded value is found in the 2nd decay class, for the A2 stand category. The lowest value of the amount under analysis is found with the 3rd decay class, for the A1 stand category. The 5th class of decay has not been identified in any stand category (Figure 3A).

In terms of the distribution of logs to each category of stand and related to the decay classes, for the A2 stand category, the characteristic dynamics of the amount of dead wood is increasing, from the 1st decay class to the 2nd, and subsequently declines to the 5th decay class. The maximum recorded value in terms of amount is in the 2nd decay class with the A2 stand category. The lowest value of the amount under analysis is found with the 4th class of decay, with the A4 stand category (Figure 3B).

The analysis of the distribution of the stumps shows that the 6th decay class is mostly found, for all categories of stand included in the research. The maximum value in terms of amount, for the 6th decay class, was found with the A2 stand category. The lowest value is found with the 1st decay class and with the A1 stand category. No stump in the 1st decay class was found in the case of the A4 stand category (Figure 3C).

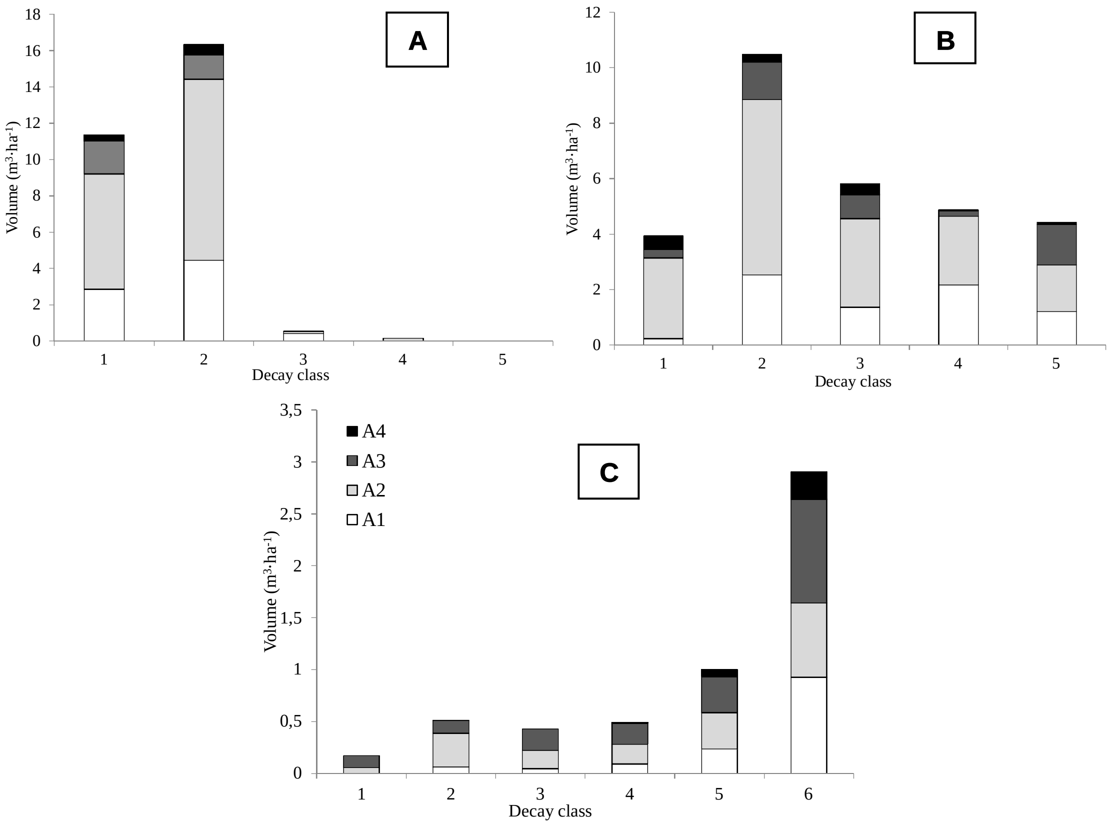

Figure 3. Distribution of the dead wood volume to decay class in relation to the stand category (A – snags, B – logs, C – stumps).

Discussion

Distribution of dead wood in terms of origin. The only identified origin for snags found across the research area was natural. In the case of logs, 98% is due to natural causes, while 2% was due to anthropic intervention. As far as stump is concerned, its origin is mainly natural (64%). Unlike the other types of dead wood, the difference from the amount due to anthropic causes (36%) is rather small. According to the research conducted by Nordén et al (2004), out of the total amount of stump dead wood, 84% consists in cut stumps (anthropic activity), while 16% was due to natural causes. As concerns the origin of stumps, note that the average values of the statistical data for dead wood occurring from natural causes, are generally higher than the figures for dead wood occurring due to anthropic activities. The research conducted abroad on stump dead wood has revealed that only 3% of the amount reaches more than 0.5 m in height (Lõhmus et al 2013).

Dead wood distribution depending on stands category. The highest amount of snags and logs for each category of the stand is found in forests that have undergone forestry works according to forest management planning, but where such works are currently restricted as these are now part of the permanently protected areas (A2) and for stump is in the forests that have undergone forestry works, according to forest management planning, and where certain types of works are allowed, as these forests are part of the sustainable conservation area (A3). The lowest amount of snags, logs and stumps was found in the stands located in areas outside the forest standing crops, pastures or wooded pastures found outside the park boundaries (A4). The research conducted on the effects of forest management on dead wood diversity in Sweden shows that the ratio of dead wood in production stands to the amount of dead wood found in stands that are exempt from cutting is of 1:2 (Ekbom et al 2006). In forests that are subjected to various management regimes, including the case of semi-natural mixtures that have previously been neglected, the amount of dead wood was generally lower, accounting for 30% of the amount found in natural stands (Green & Peterken 1997; Guby & Dobbertin 1996). Siitonen (2001) show that the effects of forest management on dead wood fount in the forests of Finland shows that, in the managed forests, the average amount of dead wood varies between 2 and 10 $m^3 \cdot ha^{-1}$, this means that the average amount of dead wood in forest ecosystems is 90-98% lower as compared to natural forests. Dead wood is found in larger amounts in stands that are subject to forestry works than in stands that have not been affected by any such of works (Blaser et al 2013). The research conducted in Sweden and Serbia, in forests currently subject to forest legislation that have undergone forestry works, show that dead wood in such forests can amount up to 20 $m^3 \cdot ha^{-1}$ (Kruys et al 1999; Koprivica et al 2013; Fridman & Walheim 2000).

Conclusions. Our research show that both natural phenomena as well as anthropic activities have had significant effects on the dynamics of dead wood and that certain measures or a dead wood management strategy is needed for preserving higher biodiversity in forests, so that these can best fulfill the complex role for which they were created. The results of the qualitative and quantitative measurement of dead wood, regardless of the stage of decay it was found in, allow for the development of a spatial distribution model of the necromass and its further extrapolation to forest ecosystems where similar conditions are observed, in order to identify coherent measures that would benefit biodiversity management.

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