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Qualitative and Quantitative Characterization of Deadwood Related to the Accessibility of Managed Beech Forests of the Abruzzo, Lazio and Molise National Park †

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Abstract: Deadwood is a basic component in forest ecosystems since it supports many ecological and functional roles. Despite the importance of deadwood for assessing the sustainability of forest management, information on this fundamental parameter of forest ecosystems is documented mainly for protected areas, while for managed forests it is much scarcer. The study aims to assess the deadwood in managed beech forests of the National Park of Abruzzo, Lazio and Molise. These forests have an important socio-economic function for the local population, who collect the deadwood as allowed by the park regulation. The presence of deadwood found from inside the forest to logging roads was investigated. Three accessibility classes were established, and data analysis was performed according to this classification. The result showed that the accessibility to the forest affects the quantity and the decay class of the deadwood. In conclusion, the deadwood removal influences the quantity of deadwood in the forest and the removal is affected by the distance from the road.

Keywords: *Fagus sylvatica* L.; accessibility; sustainable management; decay classes; deadwood

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1. Introduction

Deadwood, also defined as coarse woody debris (CWD), is a basic component in forestry ecosystems, since it supports many ecological and functional roles: it provides a habitat for many organisms, contributing to the biodiversity conservation [1,2], to the soil's formation and to the nutrients' cycles [3,4]; it maintains and increases the productivity of forests providing 'nurse logs' for tree regeneration [5] and operates as a long-term carbon stock [6,7].

The importance of deadwood is recognized by the pan-European criteria which identify it as an index of sustainable management [8,9]. Currently, its assessment is considered essential for the management of forest resources both in "wild" forests and in areas managed via "close-to-nature silviculture", even if the deadwood dynamics are very interesting and more and more studied for productive forests. Despite the importance of deadwood for assessing the sustainability of forest management, information on this fundamental parameter of forest ecosystems is documented mainly for protected areas, while for managed forests it is much scarcer. Rights of local people to collect deadwood in forest, by virtue of laws or customary laws, are largely diffused in Italy even in some protected areas. The influence of this practice on close-to-nature forest management is little studied [10,11]. The aim of this study was to evaluate the quantitative and qualitative amount of deadwood in managed beech forests of the National Park of Abruzzo, Lazio and Molise (NPALM).

2. Materials and Methods

This study was carried out in a pure beech forest of the National Park of Abruzzo, Lazio and Molise in Central Italy. Three parcels located in Coda di Monte Tranquillo were selected from an area in an oriented general reserve actively managed both for the protection of natural processes and ecological, hydraulic and hydrogeological balances, and for the protection of landscapes also through the maintenance and recovery of traditional production activities. The aim was to evaluate the quantitative gradient of deadwood moving away from the roads access.

The altitude of the area is ranging between 1350 and 1650 m a.s.l. The study area is a mature beech forest resulting from the conversion of coppice to high forest from the early 1900s managed with low-intensity interventions by adopting the shelterwood cutting system, with exclusively natural regeneration and a close-to-nature silviculture. These practices are aimed mainly at guaranteeing wood for civic uses.

In addition, the beech forests of this area perform another important socio-economic function for the local populations. In fact, the collection of deadwood lying on the ground with a diameter of no more than 15 cm for firewood is freely permitted, complying with the customary law of collecting firewood on the forest ground; for larger diameters, a permit from the Park Authority is required.

Based on the slope class found (<20%, 20–40%, >40%), the slope direction towards the nearest road, the type of road, and the road distance, the study area was divided into three accessibility classes (easy—EAC, medium—MAC and difficult—DAC) [10].

Data were collected in circular sample plots (diameter 40 m). Dendrometric parameters and volume of living trees were determined using local table. The diameters of snags (standing dead trees) and stumps (defined as cut tree remains) were measured to determine volumes. Volume was calculated using Huber's formula for snags up to 4 m and for stumps:

$$V = A_m h,$$

where V was the volume (m^3), A_m was the mid-point cross-sectional area (m^2) and h was the height (m).

The lying deadwood was estimated using 4 transects 20 m long perpendicular to each other and with the center falling in the same center of the plot. Logs intersecting the transect with a diameter $\geq$ 3 cm were recorded.

Species, diameter, height and decay class were collected for each sampled snag, downed log and stump. Each snag, log and stump was attributed to one of the 5 decay classes, on the basis of conservation state following the classification provided by Behjou et al. [10], with increasing decay named DC1, DC2, DC3, DC4 and DC5.

Indices were subsequently calculated to assess the characteristics of the deadwood in the three areas (RSS = Snag volume/living tree volume; RDT = Downed log volume/Standing volume; RWD = CWD volume/living tree volume).

A statistical analysis was carried out with the software Statsoft Statistica version 7.0. After checking for data normality and homoschedasticity with Shapiro–Wilk and Levene tests, respectively, one way analysis of variance (ANOVA) was applied to check for the presence of statistically significant differences among the mean values of the experimental treatments. The Duncan test was applied as a post-hoc.

3. Results and Discussion

Deadwood volume in the accessibility classes is shown in Table 1. The total amount of CWD shows a higher volume in the easy accessibility class (EAC), statistically different from MAC and DAC.

Deadwood distribution by diameter class provides additional information. The log volume (Table 2) was 98% in the smallest diameter class (3–5 cm) in EAC. The log amount per accessibility class relative to the total log volume represented 96% in EAC, 3.8% in MAC, and 3.4% in DAC. In each accessibility class, the larger diameters were missing or absent.

Table 1. Volume of CWD (m^3 ha^{-1}) components (downed log, snag and stump) in the accessibility classes, and results of ANOVA and Duncan tests.

Accessibility Class	Log m^3 ha^{-1} (%)	Snag m^3 ha^{-1} (%)	Stump m^3 ha^{-1} (%)	CWD (Total Volume) m^3 ha^{-1}
EAC	1.38 (14.4)	1.79 (18.7)	6.41 (66.9)	9.58 a
MAC	0.06 (7.7)	0.68 (92.3)	0.00 (0.0)	0.73 b
DAC	0.05 (6.1)	0.68 (81.4)	0.10 (12.5)	0.83 b

Different lowercase letters indicate different homogeneous groups according to Duncan test considering a significance threshold of $p < 0.05$.

Table 2. Percentage distribution of log volume (%) by diameter class in the accessibility classes.

Diameter Class (cm)		EAC	MAC	DAC
3–5	%	98.41	29.77	61.83
6–10	%	0.13	40.38	38.17
11–15	%	0.43	29.85	0.00
16–20	%	1.03	0.00	0.00

Snags were found in two diameter classes in EAC, the smallest (3–5 cm) and the largest (16–20 cm), accounting for 38% and 62% by volume, respectively. In MAC and DAC snags were found only in the smallest diameter class. Stumps in the diameter class 46–60 cm were found only in EAC and DAC.

The indices of the characteristics and dynamics of CWD are shown in Figure 1. It is evident that the indices that characterize MAC and DAC are lower than those in EAC. As also suggested by the RWD index (Figure 2), which represents CWD creation, this result is probably related to the activity of collecting logs by local citizens as well as to the logging activity of the recent years, aimed either to the transition to high forest or to safety.

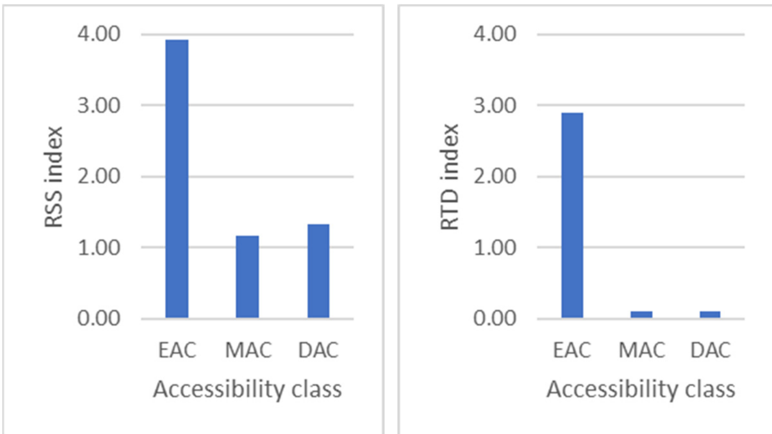

Figure 1. RSS index (Snag volume/living tree volume) and RDT index (Log volume/Standing volume), in the accessibility classes.

The percentage share among the different decay classes by accessibility class is reported in Table 3.

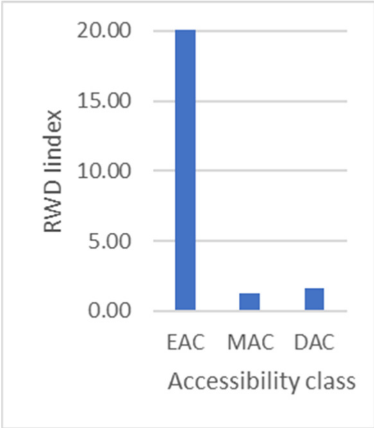

Figure 2. RWD index (CWD volume/standing volume) in the accessibility classes.

Table 3. Percentage distribution of deadwood volume by decay class in each accessibility class.

Decay Class	EAC	MAC	DAC
DC1 (%)	19.86	0.69	0.00
DC2 (%)	67.15	11.34	2.76
DC3 (%)	7.70	37.85	45.56
DC4 (%)	5.27	14.19	20.43
DC5 (%)	0.01	35.93	31.26

Distribution in decay classes indicates that fuelwood collection affected the distribution of deadwood. An active selection is carried out by local people based on the state of decay; as the DC1 is less than 20% in EAC, DC2 is much more abundant, but DC5 is lacking. Also in MAC, the DC1 class shows a low amount. In DAC the higher classes of decay are better distributed.

Literature data on deadwood from similar stands are highly variable, as a consequence of the plethora of factors which can influence the deadwood amount, such as the intensity and the way of management, the ecosystem productivity and the natural disturbance regime [12]. From the obtained results it is evident that an increase in the amount of CWD is recommended within the territory of the NPALM. In this study area, according to the Park's regulations, the collection of deadwood on the ground is allowed exclusively to native holders of civic use rights, within the limits of personal and family needs. The maximum quantity per family is established by the municipality in agreement with the Park Authority. The collection of deadwood on the ground, with a diameter of less than 15 cm, can be carried out without requiring any authorization. The collection of downed trees or branches up to 15 cm in diameter implies the accumulation at the edge of the road and then the cut to obtain firewood which leaves the thinnest elements on the ground. This explains the large accumulation of logs of the diameter class 3–5 cm in the EAC. Although it is forbidden to collect wood material from larger trees, or trees with a diameter greater than 60 cm felled by atmospheric events, unless specifically authorized by the Park Authority, large elements are rare and usually degraded. The stump number and volume reveal recent active forest interventions for the transition to high forest or for safety reasons. Furthermore, the snag number and the deadwood distribution in the decay classes indicate a recent deadwood management. In particular, it is important to encourage the accumulation of large size logs (absent), while considering with greater caution the release of permits for the collection of downed trees. It is important as well to increase the presence of snags of the larger diameter classes, and to let some large trees complete their life cycle becoming standing dead trees. It is finally recommended to manage deadwood in order to allow the achievement, over time, of the most advanced decay classes.

4. Conclusions

The influence of the forest's accessibility on the volume of deadwood was assessed in this beech forest. The result showed that the accessibility to the forest affects the amount and the distribution in the decay classes of the deadwood. Moreover, results indicated that local people collect the most suitable logs for size and soundness. In conclusion, the deadwood removal influences the quantity and the distribution of deadwood components in the forest. Furthermore, deadwood removal is influenced by the distance from the road. The results obtained indicate active forestry interventions for the transition to high forest or for safety reasons. Moreover, they indicate a recent deadwood management.These findings highlighted useful elements for an active management of the beech forests in the National Park of Abruzzo, Lazio and Molise. They can support the management decisions when aiming to the conservation and to the increase of the deadwood components in the mid-mountain forest ecosystems managed by the park. However, the practice of collecting deadwood is a social aspect that cannot be forgotten and it is necessary that forest managers adopt strategies that also allow the collection of wood. Sustainable management must also take social aspects into account.

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