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The amount of coarse dead wood and associated decay rates in forest reserves and managed forests, northwest Turkey

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Abstract

This study describes the state of coarse dead wood (CDW) in the Forest Reserve and the Managed Forest zones of northern conifer-broadleaved mixed forest. The results showed mean total CDW volumes in the ranges 30,05±11,06 m^3/ha in the Forest Reserve (6,33±2,98% of the LW volume), and 9,31±2,84 m^3/ha in the Managed Forest (1,96±0,84% of the LW volume). The total CDW volume was 3,22 times higher in the Forest Reserve than in the Managed Forest.

The CDW_{log1} and CDW_{snag1} were the most abundant CDW decay classes, whilst CDW_{log2} and CDW_{snag2} were the lowest. Comparisons of ratios between the Managed Forest and the Forest Reserve with abundant decay classes CDW_{log1} and CDW_{snag1} indicated large differences. The CDW_{log1} volume was 4,09 times higher, and the CDW_{snag1} volume was 3,68 times greater in the Forest Reserve than in the Managed Forest. The ratio of different CWD classes in the Managed Forest to CWD classes in the Reserve Forest confirms the pattern. In both Managed and Reserve Forest zones there is balance between total CDW_{logs} and total CDW_{snags}, but the differences between total CDW_{logs} and total CDW_{snags} was not statistically significant. The total CDW volume was significantly dependent on the forest management system. The system influenced amount and diversity of CDW. In commercially managed forest the abundance and structure of CDW retained is a compromise between the needs of timber production and nature conservation.

Key words: Coarse woody debris, snag, log, decay classes, forest management.

Resumen

La cantidad de madera muerta y sus tasas de descomposición asociadas en reservas forestales y bosques manejados en el noroeste de Turquía

Este estudio describe el estado de la madera muerta en la zona de reserva forestal y zonas de bosques manejados de coníferas del norte de bosques mixtos de frondosas. Los resultados mostraron que la media total de los volúmenes de madera muerta es igual a 30,05 ± 11,06 m^3 / ha en la Reserva Forestal (6,33 ± 2,98% del volumen de madera en pie), y 9,31 ± 2,84 m^3 / ha en los bosques manejados (1,96 ± 0,84% del volumen de LW). El volumen total de madera muerta fue de 3,22 veces mayor en la Reserva Forestal de que en el bosque administrado. Las clases de decaimiento de madera muerta más abundantes eran CDW_{log1} y CDW_{snag1}, mientras que CDW_{log2} y CDW_{snag2} fueron los menos abundantes. Las comparaciones de las proporciones entre el bosque manejado y la Reserva Forestal con las clases de decaimiento más abundantes (CDW_{log1} y CDW_{snag1}) indican grandes diferencias ente las dos zonas. El volumen CDW_{log1} fue 4,09 veces mayor, y el volumen CDW_{snag1} fue 3,68 veces mayor en la Reserva Forestal de que en el bosque manejado. La relación de las diferentes clases de decaimiento entre los bosques manejados y la Reserva Forestal confirma el patrón. En ambos casos, bosque manejado y zonas de reserva forestal, existe un equilibrio entre CDW_{logs} total y CDW_{snags} total, pero las diferencias entre CDW_{logs} total y CDW_{snags} total no fue estadísticamente significativa. El volumen total de madera muerta depende significativamente del sistema de gestión forestal. El sistema de manejo influye sobre la cantidad y diversidad de madera muerta. En una gestión comercial de los bosques, la abundancia y estructura de madera muerta presente es un compromiso entre las necesidades de la producción de madera y la conservación de la naturaleza.

Palabras clave: Residuos de madera muerta, tocón, leña, clases de descomposición, gestión forestal.

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Introduction

For many decades in commercially-driven forestry, coarse dead wood (CDW) (snags (CDW_{snags}) and logs (CDW_{logs})) was considered at best an inconvenience and at worst unhygienic and a problem. In recent decades it has become increasingly apparent that this is a resource of major conservation significance. It is now considered as an important indicator for sustainability and maintenance of biodiversity in both boreal and temperate forests. The volume of CDW_{snags} and CDW_{logs} is one of nine pan-European biodiversity indicators for sustainable forest management (Ranius et al., 2003; Webster and Jenkins, 2005; Bartoli and Geny, 2005; Christensen et al., 2005; Debeljak, 2006). Among other functions, CWD is important in the carbon cycle with the decomposition rate of CDW one of the major factors in C-retention in forest ecosystems (Coomes et al., 2002; Tobin et al., 2007; Beets et al., 2008). The Framework Convention on Climate Change and the Kyoto Protocol underlined the need for information on the DW pool. As the CDW component of the DW pool falls outside the remit of most C-stock change models used in reporting processes (Tobin et al., 2007).

Since most of the large-sized harvestable timber is extracted CDW quantities are normally much lower in managed forests than in unmanaged old-growth forests (Harmon et al., 1986; Kirby et al., 1998; Winter and Nowak, 2001). In addition, dead wood (DW) in managed stands typically consists of only small twigs and branches and short stumps, with few large logs or snags found (Kruys et al., 1999). The amount of CDW has been estimated in both unmanaged and managed forests in many countries (i.e. Sweden, USA, Russia, Switzerland, Scotland, UK, North America), and in managed forests is between 2% and 30% of that in unmanaged forests (Fridman and Walheim, 1999; Vallauri et al., 2003).

Current CDW resources are affected human activities (anthropogenic disturbances), forest characteristics, climate, and natural disturbances, and these must be considered together with stand history and management system (Fridman and Walheim, 1999; Webster and Jenkins, 2005). An assessment of forest management history suggests that the current impoverished nature of managed forests is unsurprising, with little CDW to be found. The consequence of intensive forestry policies applied over decades or in some cases centuries has cause a massive depletion of the resource and serious declines in associated biodiversity. Such forest management systems always treat removal of CDW as a priority (Bartoli and Geny, 2005) and have operated from the late eighteenth century to the present day. Forest management based mostly on age classes has been applied extensively in formely uneven-aged old-growth forests in Turkish silviculture since 1963. A result is that uneven-aged old-growth forests have been to converted to even-aged forest stands and CDW has decreased dramatically.

The main aims of this research were to quantify abundance (volume) of CWD and structure (decay stages; CDW_{logs} and CDW_{snags}) of CWD in selected plots within the Managed Forest and the Forest Reserve. This study provides useful information on the management and conservation practices of ancient or primary forests and shed lights on restoration of secondary forests.

Material and Methods

Study area

This study was conducted in Büyükdüz Research Forest, which is located in the Black Sea Mountains of northwest Turkey (latitude between 41º19'15"-41º15'03", longitude between 32º30'54"-32º34'41"; Figure 1). The region is dominated by naturally regenerated forest and lies within the central broadleaved-conifer region of the northern mixed forest. The altitude of the study area ranges from 650 m to 1645 m a.s.l. and the soils are typically loam or sandy-loam. This forest is characterized by a very wet climate, there is heavy precipitation throughout the year and mists are frequent particularly in the summer. The winters are cool and humid and the summers sub-humid with mean annual precipitation 1372 mm (Aksoy, 1978). The research area consists of 2341 ha, nearly half as Forest Reserve (pure protection without any silvicultural treatments) and half as Managed Forest (shelterwood-harvested high forest; periodical selective thinning operations).

Abies bornmülleriana Mattf., *Pinus sylvestris* L., *Pinus nigra* Arnold., *Fagus orientalis* Lipsky and *Quercus petrea* subsp. *iberica* (Steven ex M.Bieb.) Krassiln are the dominant tree species. *Acer platonoides* L., *Acer trautvetteri* Medw., *Sorbus torminalis* (L.) Crantz and *Populus tremula* L. are present but rare in both zones.

Archives date from 1911 record management activities from an early date formerly in the Büyükdüz Forest case study (Savran, 1954). The first management plan was prepared in 1928 (Alemdag, 1959) and it was con-

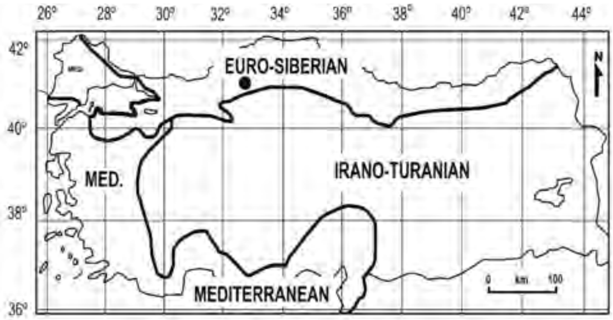


Figure 1. Research area (●) and flora regions in Turkey.

verted to a "Research Forest" in 1952 (Aksoy, 1978). From 1962 to 1965, the Bolu Forest Research Institute established thirty of sixty-five forest compartments in Büyükdüz Research Forest as Forest Reserves. Despite all the twentieth century management the natural likeness classes of the forest are near-natural and semi-natural (Aksoy, 1978).

Selection of sample plots

CWD abundance and structure of were analysed with 250m x 250m sample area in plots from a simple random grid sampling method (Christensen et al., 2005). This covered the full range of the Büyükdüz Research Forest. Ten sample plots were in the Managed Forest and ten in the Forest Reserve. Generally in CDW research, sample plots with an area of 0,10 ha (20m x 50m) are use (e.g. Webster and Jenkins, 2005). However, in this case the sample plots followed Atici et al., (2008) and were 0,25 ha (50m x 50m).

The dead wood inventory

There is no accepted standard for definitions and inventory format for dead wood sampling (e.g. decay classification, minimum diameter, volume functions, and sampling methods) (Fridman and Walheim, 2000; Debeljak, 2006). Dead wood (DW), including CDW and fine dead wood (FDW), is considered to be the major component in forests and it is primarily composed of logs and snags. FDW mainly consists of small twigs and is much less important in ecological function compared with CDW (Lipan et al., 2008). In practice, CDW is generally classified as snags (standing dead wood: CDW_{snags}) and logs (fallen dead wood: CDW_{logs}) (von Oheimb et al., 2005; Mark et al., 2006; Atici et al., 2008) rather than with a more detailed level of classification. Two types of CDW were recorded in this work. These were as defined by Fridman and Walheim (2000), Harmon et al., (1986), Mark et al. (2006), McComb and Lindenmayer (1999), Wanderwel et al., (2006), and Lipan et al., (2008) are shown in Figure 2. Both CDW_{snags} and CDW_{logs}, were identified to one of two logs or snags decay classes, as CDW_{log1}, CDW_{log2}, CDW_{snag1} and, CDW_{snag2} (Figure 2).

The CDW volumes were standardised with a minimum diameter used to measure CDW of ≥10 cm (Ranius et al., 2003; and Norden et al., 2004; Webster and Jenkins, 2005; Lipan et al., 2008; Atici et al., 2008; Beets et al., 2008). As in previous studies no data were collected from stem or branch FDW <10 cm diameter (Coomes et al., 2002; Norden et al., 2004; Beets et al., 2008).

Field procedures and volume estimation

For each sample plot for CDW volume estimation the following parameters were measured: height of snags, height of breakage on snags, the length large-end diameter of CDW_{logs}, the length of only portions of CDW_{logs} located within the sample plot (Fridman and Walheim, 2000; Webster and Jenkins, 2005; von Oheimb et al., 2005), DBH ($d_{1,30}$: diameter at breast height; it measured with tree calliper) ≥ 10 cm. CDW was assigned to one of four decay classes (CDW_{log1}, CDW_{log2}, CDW_{snag1}, and CDW_{snag2}) by species whenever possible (adapted from Pyle and Brown, 1998; Coomes et al., 2002; Webster and Jenkins, 2005; Vanderwel et al., 2006). For each sample plot for volume estimation of LW (living wood) tree height and DBH ≥10 cm were measured.

The volume of CDW_{snag1} (the dead trees with crown), CDW_{log1} (completely fallen and uprooted) and LW (living wood) were estimated using tree volume tables (DBH and the tree height were inputs to the volume tables) from Miraboglu (1955) for *Abies bornmülleriana*; by Sun et al., (1978) for *Pinus sylvestris*; by Gülen (1959) for *Pinus nigra*; by Kalipsiz (1962) for *Fagus orientalis*; by Eraslan (1954), Eraslan and Evcimen (1967), Atici (1998) for *Quercus* sp., and by Birler et al. (1984) for *Populus* sp.

The volume of CDW_{snag2} (the top-cut / without crown dead trees) was estimated as the sum of lower and upper part of the snag. Therefore the Smalian equation and the one applied by Husch et al. (1993) were combined (Eq. 1). According to this equation, the volume of the lower part was accepted as the volume of 1,3 m high top-cut

CDW_{snags} (standing dead wood) for hardwood trees

CDW_{snags} (standing dead wood) for softwood trees

Stage 1: $\mathbf{CDW_{snag1}}$

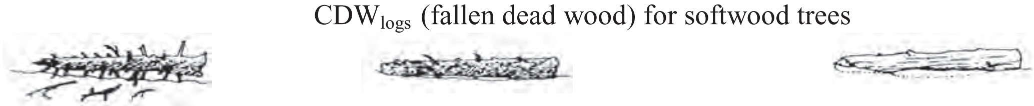
- Tree is recently dead. Top is intact. Most fine branching still present. Bark is intact.
- Top is intact. Most of the fine branches have dropped. Bark may begin to loosen.
- Top is intact. Bark may or may not have sloughed off.

Stage 2: $\mathbf{CDW_{snag2}}$

- Top is broken. No coarse branches remain. Bark may or may not have sloughed off.
- Top repeatedly broken. No coarse branches remain. Bark may or may not have sloughed off.

CDW_{logs} (fallen dead wood) for hardwood trees

CDW_{logs} (fallen dead wood) for softwood trees



Stage 3: $\mathbf{CDW_{log1}}$

- Wood is hard. All bark is still intact.
- Slightly decayed or hard wood. Bark has begun to fall off.

Stage 4: $\mathbf{CDW_{log2}}$

- Wood is soft and has some give when kicked. Usually no bark remaining.
- Wood is substantially decayed and pieces easily slough off. Inner heartwood may be soft but is intact. Moss usually present on the outer surface (Decayed or well-decayed wood).

Figure 2. Decay stages (modified after McComb and Lindenmayer, 1999; Atici et al., 2008) and class descriptions of CDW_{snags} and CDW_{logs} (modified after Fridman and Walheim, 2000; Coomes et al., 2002; Mark et al., 2006; Vanderwel et al. 2006; Tobin et al., 2007 and Atici et al., 2008).

neiloid (frustrum of a neiloid) and the volume of the upper part of the snag (above 1,3 m; frustrum of a paraboloid) was estimated by the Smalian equation. The diameter at 1,3 m (DBH) was measured by tree calliper, while the diameter on the top of the snag was estimated by the relascope (Debeljak, 2006).

$V_{snag2} = V_{snag2}$ (upper) + V_{snag2} (lower) (Eq.1)

$$V_{snag2} = \pi \frac{L_{upper}}{6}(D^2 + d^2) + \frac{L_{lower}}{4}(Dg + \sqrt[3]{Dg^2 d} + \sqrt[3]{Dgd^2} + d) \text{ (Eq. 1)}$$

Where: d (DBH) = the diameter on the beginning of the part of lower-section (upper) and the diameter of the end of part of lower-section (cm); D = the diameter on the end of the section (cm); Dg = the diameter of the beginning of the section (diameter at the ground level) (cm); L_{upper} = the length of the section (cm); L_{lower} = the length of the section (cm).

Numerous equations are available to estimate CDW_{logs} without crown dead trees or the top-cut log volume. Some of the most common equations for CDW_{logs}: are Newton, Huber, Smalian, Patterson and Doruska, and the Centroid Method. The analyses indicated (Patterson et al., 2007) that the Patterson and Doruska Equation (Eq. 2: converted to m^3) performed best and does very well with normal length logs of all diameters. It appears to be insensitive to changes in species and site:

$$V_{log} = [P(\pi Dg^2) + (1 - P)(\pi D^2)]xLx0{,}02832$$

(Eq. 2; Patterson and Doruska Eq.)

$$P = 0{,}15 + \frac{136}{Dg^3} + 0{,}002xL$$

Where: V_{log} = log volume (m^3); D = the diameter on the small end (inch); Dg = the butt end diameter (inch); L = log length (ft)

For each sample plot was calculated living wood (LW) volume (m^3/ha), CDW_{logs} volume (m^3/ha), CDW_{snags} volume (m^3/ha), total CWD volume (m^3/ha) (Christensen et al., 2005), and these measurements converted to per-hectare. CDW/LW ratio (%) was compiled (Beets et al., 2008).

Data analysis

The following equation (Eq. 3) was used to calculate 95% confidence interval of population of CDW_{snags}, CDW_{logs}, total CDW and LW as m^3/ha (Atici *et al.*, 2008; Kalipsiz, 1994; Sachs, 1972):

$$\mu = \bar{x} \pm t\, s_{\bar{x}} \qquad \text{(Eq. 3)}$$

Where: $\bar{x}$: Arithmetic mean; $s_{\bar{x}}$: Std. Error; *t*: Student's t coefficient (P:0,05)

The audit of the data was done by using Kolmogorov-Smirnov Z test (to test the normality of the distribution). The data were normally distributed in the Managed Forest (P:0,114), but not so in the Forest Reserve (P:0,034). The Levene Test was applied for analysis of variance (ANOVA) in the Managed Forest to provide homogeneity of variances. However, with the Levene Test, 5,002 (P:0,005) homogeneity could not be determined and so the Mann-Whitney U-test was applied as a nonparametric test in order to assess the data in both Managed Forest and Forest Reserve. Mann-Whitney U test and Chi-Square-test were carried out to test these differences in the Managed Forest and the Forest Reserve between CDW classes. This established a significant difference between the Managed Forest (χ^2:11,596; P:0,009) and the Forest Reserve (χ^2:21,078; P:0,000).

Statistical evaluation including t-test, Chi-Square-test, Mann-Whitney U-test, Kolmogorov-Smirnov Z-test and Levene test for homogeneity of variances (Levene) were applied to the data collected using SPSS 5.01 software for Windows.

Results

Abundance of CWD

Table 1 shows that all CDW decay classes, as CDW_{log1}, CDW_{log2}, CDW_{snag1} and, CDW_{snag2} were found in the Managed Forest and the Forest Reserve and presented different ratios. The cross-tab comparisons of the results for the Forest Reserve (Table 1) show that the CDW_{log1} and CDW_{snag1} are the most abundant CDW classes. CDW_{log2} and CDW_{snag2} had the lowest abundance. Mann-Whitney U test and Chi-Square-test were carried out to test these differences in the Managed Forest and Forest Reserve between CDW classes (Table 1) and established a significant difference between the Managed Forest (χ^2:11,596; P:0,009) and the Forest Reserve (χ^2:21,078; P:0,000). Mann-Whitney U test was applied to the difference in the Forest Reserve and two typical separate groups (1- CDW_{log1} and CDW_{snag1}; 2- CDW_{log2} and CDW_{snag2}) were determined as a result. Mann-Whitney U test was applied to the difference in the Managed Forest and two typical separate groups (1- CDW_{log2}; 2- $CDW_{log1,}$ CDW_{snag1} and CDW_{snag2}) were found. CDW_{log1} and CDW_{snag2} are in-between these two groups in the Managed Forest.

Table 1. Quantitative description of CDW classes and LW. The data on CDW_{snag}, CDW_{logs} and LW from 20 sample plots selected in the managed forest and forest reserve

Forest	Statistical analysis		CDW volume (m^3/ha)						Total CDW volume (m^3/ha)	LW volume (m^3/ha)	Total CDW/LW volume (m^3/ha)
			CDW_{logs}			CDW_{snags}					
			CDW_{log1}	CDW_{log2}	Total CDW_{log}	CDW_{snag1}	CDW_{snag2}	Total CDW_{snag}			
Managed Forest	**Arithmetic mean**	$\overline{x}$	2,94	0,91	3,85	3,58	1,89	5,48	9,31	510,97	1,96
	Arithmetic mean of total population (Eq. 3)	μ	2,94 ± 1,52	0,91 ± 0,51	3,85 ± 2,01	3,58 ± 2,32	1,89 ± 0,68	5,48 ± 2,42	9,31 ± 2,84	510,97 ± 72,46	1,96 ± 0,84
	Chi-Square (Between CDW decay classes)	χ^2			11,596 (P:,009)						
Forest Reserve	**Arithmetic mean**	$\overline{x}$	12,03	1,12	13,36	13,19	3,72	16,68	30,05	536.10	6,33
	Arithmetic mean of total population (Eq. 3)	μ	12,03 ± 5,95	1,12 ± 0,66	13,36 ± 6,17	13,19 ± 9,33	3,72 ± 3,69	16,68 ± 10,01	30,05 ± 11,06	536,10 ± 113,22	6,33 ± 2,98
	Chi-Square (Between CDW decay classes)	χ^2			21,078 (P:,000)						

Comparisons of ratios between the Managed Forest and the Forest Reserve

Comparisons of ratios between the Managed Forest and the Forest Reserve with abundant decay classes CDW_{log1} (P:0,001) and CDW_{snag1} (P:0,016) identified large differences between them. The results showed that in the Forest Reserve the CDW_{log1} volume was 4,09 times greater than that in the Managed Forest. The CDW_{snag1} volume was 3,68 times higher.

Average sizes of CWD

The mean volumes for particular CWD classes were calculated and statistically significant differences between the Managed Forest and Forest Reserve CWD were assessed by t-test. Among the particular CDW classes, the CDW_{snag1} was the highest (3,58±2,32 m^3/ha Managed Forest; 13,19±9,33 m^3/ha Forest Reserve) and the CDW_{log2} was the lowest (0,91±0,51 m^3/ha managed forest; 1,12±0,66 m^3/ha forest reserve) (Table 1).

The volume of total CDW in the Managed Forest ranged from 1,25 to 15,78 m^3/ha (mean of 9,31±2,84 m^3/ha). This accounted for 1,96±0,84% of the total LW. The total CWD in the Managed Forest had a mean 5,48±2,42 m^3/ha (58%) as CDW_{snag} and 3,85±2,01 m^3/ha (52%) as total CDW_{log} (Table1).

The volume of total CDW in the Forest Reserve ranged from 10,64 to 55,40 m^3/ha with a mean of 30,05±11,06 m^3/ha. This accounted for 6,33±2,98% of the total LW. Within the total CWD in the Forest Reserve there were 16,68±10,01 m^3/ha (55%) as total CDW_{snag} and 13,36±6,17 m^3/ha (45%) as total CDW_{log} (Table 1).

Total CDW to LW ratio

The results of Kolmogorov-Smirnov Z-test showed no statistically significant difference (P:0,759) in the volume of LW between the Managed Forest (510,97±72,46 m^3/ha) and the Forest Reserve (536,10±113,22 m^3/ha). The mass of CDW in the Managed Forest (9,31±2,84 m^3/ha) and the Forest Reserve (30,05±11,06 m^3/ha) were statistically significantly different (P:0,001). Ratios were 3,22 times higher in the Forest Reserve (6,33±2,98%) than in the Managed Forest (1,96±0,84%) (Table 1).

Relative structure of CWD

The total CDW volume was 3,22 times more in the Forest Reserve than in the Managed Forest, and decreased from 30,05±11,06 to 9,31±2,84 m^3/ha over the forty-year period in the Managed Forest (Table 1). Statistical analysis showed that the total CDW volume depended significantly on the management system (Forest Reserve or Managed Forest) (P:0,001).

The ratio of CWD classes in the Managed Forest to CWD classes in the Forest Reserve confirmed the pattern already identified. The highest difference found was in the CDW_{log1} 4,09 (P:0,001), followed by CDW_{snag1} 3,68 (P:0,016), then total CDW_{log} 3,47 (P:0,016), Total CDW 3,22 (P:0,001) and finally total CDW_{snag} (P:0,034). These differences were statistically significant. There were no significant variations between Managed Forest and Forests Reserve in the ratio of CDW_{log2} (P:0,520) and CDW_{snag2} (P:0,650).

The balance between CDW_{logs} and CDW_{snags}

The results demonstrated a balance between total CDW_{logs} and total CDW_{snags}, and between CDW_{snag} classes (CDW_{snag1} and CDW_{snag2}), in both Managed Forest and Forest Reserve. The differences between total CDW_{logs} and total CDW_{snags} and between CDW_{snag} classes (CDW_{snag1} and CDW_{snag2}) were not statistically significant (Managed Forest: P:0,226 and P:0,364; Forest Reserve: P:0,705 and P: 0,089. But there was no balance between CDW_{log} classes (CDW_{log1} and CDW_{log2}) in either Managed Forest (P:0,005) or Forest Reserve (P:0,000).

Discussion and Conclusions

The amount of CDW in forests is presently attracting attention from forest managers. This is as part of their interest in increasing biodiversity within forests managed for timber (Kirby et al., 1998) and CDW has been identified as a crucial component for forest biodiversity. The volume of CDW per hectare is one characteristic for which data are required for assessments and for baseline studies. Without such data an evaluation of whether the environmental objectives are being achieved or not, or if progress is positive or negative, is impossible (Fridman and Walheim, 2000). As presented here the total CDW volume has increased in the reserved portion. It is suggested that this is a direct consequence of forest management in the Managed Forest. It is indicated therefore that there is a need for more CDW to be retained, with a compromise between the demands of timber production and conservation in commercially managed forest. The results presented here will help inform the future debate and provide guidance to work on CDW in Turkish forests.

Since there are no accepted standards for definitions and the inventory design for CDW assessment (Fridman and Waldheim, 2000), comparisons of results from CDW inventories, should be done with caution. It seems that there are large differences between the Forest Reserve and the Managed Forest. This confirms other studies (Harmon et al., 1986; Kirby et al., 1998; Kruys et al., 1999; Fridman and Walheim, 1999; Vallauri et al., 2003). The results suggested that areas of Forest Reserve contained significantly more (3,22x) total CDW volume than the Managed Forest.

As proposed for this study, the reason for the currently low CDW in the Managed Forest is related to forest management history in Turkey. In particular it is suggested that this reflects a period of intensive forest management. The main reason for difference is thinning of the forest stands due to the silviculture over a period of about forty years. Thinning reduces the CWD in the Managed Forest because the suppressed and weakened trees are cut and removed. The competition for growing space amongst the remaining trees is reduced and consequently the natural mortality of the remaining trees is decreased. Therefore, forest management measures in general and forest thinning in particular is considered the main reasons for differences in CWD between the managed and unmanaged forest (Debeljak, 2006). As has been put forward in this study the CDW_{log1} and CDW_{snag1} are the most abundant CDW classes and the CDW_{log2} and CDW_{snag2} are the least common in both Forest Reserve and the Managed Forest. This is because CDW_{log2} and CDW_{snag2} provide an essential source of fuel energy and timber for the households of local people in forest villages. This is a similar situation to that experienced over many centuries elsewhere in Europe for example in France (Bartoli and Geny, 2005). During thinning operations and extraction for household utilization it is suggested that especially large CDW_{logs} and CDW_{snags} should be protected (Chambers, 2002).

In considering the benefits for nature conservation Butler and Schlaeper (2004) found over 15-30 m^3 per hectare total CDW in a recently managed forest, with at least 50% as CDW_{snags}, was of benefit to both birds and insects (Ammer, 1991). The present study established that the Forest Reserve zones had 30,05±11,06 m^3 per hectare total CDW and the Managed Forest had 9,31±2,84 m^3 per hectare CDW. In demonstrating total CDW volumes at this level the research indicates that the total CDW volume in the Forest Reserve samples was above the minimum desired level. However, in the Managed Forest and as expected, it is below the minimum desired level for nature conservation. As proposed in this study, that there is balance between total CDW_{logs} and total CDW_{snags} and between CDW_{snag} classes (CDW_{snag1} and CDW_{snag2}) in the Managed Forest and the Forest Reserve. The differences between total CDW_{logs} and total CDW_{snags} were not statistically significant. But there is no balance between CDW_{log} classes (CDW_{log1} and CDW_{log2}) in the two zones.

Surveys in Finland, Sweden, Germany, France, Belgium, and Switzerland show the average total CDW volume in present-day production forests is less than 10 m^3/ha (Christensen et al., 2005). From the results of this study it seems that total CDW volume is in Turkish managed forests (9,31±2,84 m^3/ha; Table 1) similar as those in Europe.

Butler and Schlaeper (2004) and Jedicke (1995) proposed an optimal value of 10% CDW per compartment in the managed forests. This research found total CDW volume of the Managed Forest samples was 1,96±0,84% of the total LW volume and total CDW volume of the Forest Reserve was 6,33±2,98% of the total tree volume (Table 1). Consequently the research indicates that the total CDW component of the total LW volume in the Managed Forest is below the optimal value.

In order to effectively conserve the biodiversity associated with CDW in forests it is important to achieve a balance CDW_{logs} and CDW_{snags} (Christensen et al., 2005). This study found a balance between CDW_{logs} and CDW_{snags} in the Managed Forest and the Forest Reserve. However, it indicated and imbalance in the cases of log decay classes (CDW_{log1} and CDW_{log2}) and snag decay classes (CDW_{snag1} and CDW_{snag2}) in both situations. Therefore it is recommended that balance between these decay classes should be taken into consideration during future silvicultural treatments in the managed forests.

It seems that with increased awareness of conservation issues following publications of papers and guidance, some of the silvitcultural management systems in Turkish forests have already been reduced. In the interests of sustainable forestry and biodiversity conservation, efforts are being made to increase CDW levels in managed forests (e.g. Kirby et al., 1998; Christensen et al., 2005; Marage and Lemperiere, 2005). Along with the nationally based studies this wider information may help the formulation of the necessary management prescriptions for Turkey.

Dead wood enhancement and management to both maintain and restore dead wood, presents a major opportunity in forests such as those of Turkey, such as the Black Sea Mountains. The opportunities and silvicultural treatments differ in plantations and in old woodlands, and the problems differ between stand types –hardwoods, mixed stands, and softwoods.

The results presented here are important in helping to inform the future debate and to guide silvicultural management affecting CDW in northwest Turkey. Further work is needed on the assessment of the CDW resource in the Forest Reserves as well as in the Managed Forests outside this study region.

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