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 m³/ha in the Forest Reserve (6.33±2.98% of the LW volume), and 9.31±2.84 m³/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 m³ / ha en la Reserva Forestal (6.33 ± 2.98% del volumen de madera en pie), y 9.31 ± 2.84 m³ / 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 entre 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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Coarse dead wood in forest reserves and managed forests

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 (Ranías 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 formerly uneven-aged old-growth forests in Turkish silviculture since 1963. A result is that uneven-aged old-growth forests have been 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 light 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 41°19’15”-41°15’03”, longitude between 32°30’54”-32°34’41”; 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 bornmülleri ana Mattf., Pinus sylvestris L., Pinus nigra Arnold., Fagus orientalis Lipsky and Quercus petraea subsp. iberica (Steven ex M.Bieb.) Krassiln are the dominant tree species. Acer platanoides 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-
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 like-
ness 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 (20mx 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 com-
ponent 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 (Ranis et al., 2003; and Norden et al., 2004; Webster and Jenk-
ins, 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 diam-
eter 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 (d1,30: 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 (liv-
ing wood) were estimated using tree volume tables (DBH and the tree height were inputs to the volume tables) from Miraboglu (1955) for Abies bornmulleriana; by Sun et al., (1978) for Pinus sylvestris; by Gülen (1959) for Pinus nigra; by Kalipisz (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
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).

Figure 2. Decay stages (modified after McComb and Lindenmayer, 1999; Atici et al., 2008) and class descriptions of CDWsnag and CDWlog (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).
\[ V_{\text{snag}_2} = V_{\text{snag}_2}^{\text{upper}} + V_{\text{snag}_2}^{\text{lower}} \] (Eq.1)

\[ V_{\text{snag}_2} = \pi \frac{L_{\text{upper}}}{6} (D^2 + d^2) + \frac{L_{\text{lower}}}{4} (Dg + \sqrt{Dg}d^2 + \sqrt{Dgd^2} + d) \] (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); \( L_{\text{upper}} \) = the length of the section (cm); \( L_{\text{lower}} \) = 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 m³) performed best and does very well with normal length logs of all diameters. It appears to be insensitive to changes in species and site:

\[ V_{\text{log}} = [P(\pi Dg^2) + (1 - P)(\pi D^2)]Lx0.02832 \] (Eq. 2; Patterson and Doruska Eq.)

\[ P = 0.15 + \frac{136}{Dg^2} + 0.002xL \]

Where: \( V_{\text{log}} \) = log volume (m³); \( D \) = 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 (m³/ha), CDW logs volume (m³/ha), CDW snags volume (m³/ha), total CWD volume (m³/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 m³/ha (Atici et al., 2008; Kalipsiz, 1994; Sachs, 1972):

\[ \mu = \bar{x} \pm t \cdot s_x \] (Eq. 3)

Where: \( \bar{x} \): Arithmetic mean; \( s_x \): Std. Error; \( t \): Student’s t coefficient (P:0.05)

**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. This established a significant difference between the Managed Forest (\( \chi^2:11,596; P:0,009 \)) and the Forest Reserve (\( \chi^2:21,078; P:0,000 \)).

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.
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 m³/ha Managed Forest; 13.19±9.33 m³/ha Forest Reserve) and the CDW_{log2} was the lowest (0.91±0.51 m³/ha managed forest; 1.12±0.66 m³/ha forest reserve) (Table 1).

The volume of total CDW in the Managed Forest ranged from 1.25 to 15.78 m³/ha (mean of 9.31±2.84 m³/ha). This accounted for 1.96±0.84% of the total LW. The total CWD in the Managed Forest had a mean 5.48±2.24 m³/ha (58%) as CDW_{snag} and 3.85±2.01 m³/ha (52%) as total CDW_{log} (Table 1).

The volume of total CDW in the Forest Reserve ranged from 10.64 to 55.40 m³/ha with a mean of 30.05±11.06 m³/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 m³/ha (55%) as total CDW_{snag} and 13.36±6.17 m³/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 m³/ha) and the Forest Reserve (536.10±113.22 m³/ha). The mass of CDW in the Managed Forest (9.31±2.84 m³/ha) and the Forest Reserve (30.05±11.06 m³/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 m³/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 CDW classes in the Managed Forest to CDW classes in the Forest Reserve confirmed the pattern already identified. The highest difference found was in the CDW log 4.09 (P:0.001), followed by CDW snag 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 CDW 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 CDW 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 m³ per hectare total CDW in a recently managed forest, with at least 50% as CDW snag, was of benefit to both birds and
insects (Ammer, 1991). The present study established that the Forest Reserve zones had 30.05±11.06 m³ per hectare total CDW and the Managed Forest had 9.31±2.84 m³ 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\textsubscript{logs} and total CDW\textsubscript{snags} and between CDW\textsubscript{snag\textsubscript{1}} and CDW\textsubscript{snag\textsubscript{2}} classes (CDW\textsubscript{snag\textsubscript{1}} and CDW\textsubscript{snag\textsubscript{2}}) in the Managed Forest and the Forest Reserve. The differences between total CDW\textsubscript{logs} and total CDW\textsubscript{snags} were not statistically significant. But there is no balance between CDW\textsubscript{log\textsubscript{1}} classes (CDW\textsubscript{log\textsubscript{1}} and CDW\textsubscript{log\textsubscript{2}}) 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 m³/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 m³/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\textsubscript{logs} and CDW\textsubscript{snags} (Christensen et al., 2005). This study found a balance between CDW\textsubscript{log\textsubscript{1}} and CDW\textsubscript{snag\textsubscript{1}} classes (CDW\textsubscript{log\textsubscript{1}} and CDW\textsubscript{snag\textsubscript{1}}) 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 silvicultural 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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