Characteristics of coarse woody debris in successional stages of natural beech (*Fagus orientalis*) forests of Northern Iran

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ABSTRACT: Coarse woody debris (CWD) is an important structural and functional component in forests in Northern Iran. In this study we determine the temporal patterns of CWD in Kheyroud Forests by examining the CWD volume in different decay classes and size classes along a chronosequence of secondary forest succession. The volume of CWD followed the general "U-shaped" temporal trend: the highest in the late successional forest (51.25 $m^3.ha^{-1}$), lowest in the middle successional forest (25.95 $m^3.ha^{-1}$) and intermediate in the early successional forest (37.05 $m^3.ha^{-1}$). The late successional forest had a larger amount of logs, snags and stumps than the other two forests. In contrast, the snag volume did not differ between the late and middle successional forest. CWD in decay classes III and V was greater in the late successional forest than that in the other two forests, while CWD in decay classes II and I did not differ among the three successional forests. CWD in class II and I was significantly higher in the early successional forest than that in the middle successional forest. In the early and middle successional forests, CWD in early decay class was dominated by *Carpinus betulus* L. followed by *Fagus orientalis* Lipsky. In the late successional forest, CWD in early decay class was dominated by *Fagus orientalis* while CWD in the late decay class was dominated by *Carpinus betulus*. While forest succession had a large influence on the amount of CWD in different decay classes, it had no effect on CWD distribution among the different size classes. Our results suggest that both anthropogenic and natural disturbances have had a long-term effect on the distribution of CWD among three forests.

Keywords: coarse woody debris; *Fagus orientalis* Lipsky; forest succession; natural beech forest; Northern Iran

Coarse woody debris (CWD) is dead woody material in various stages of decomposition, including fresh and rotting logs, snags, stumps and large branches (Harmon, Sexton 1996). An important feature of natural forests is that they possess high amounts of dead wood in all stages of decay and also high proportions of old, living trees with dead components (Harmon et al. 1986). Dead wood has been denoted as the most important manageable habitat for biodiversity in forests (e.g. Huston 1996), supporting a wide diversity of organisms, including birds, mammals, insects, mites, collembolans, nematodes, bryophytes, lichens, fungi, slime moulds and bacteria. Of these, fungi and insects are clearly the richest among the species groups (Siitonen 2001).

It is an important functional and structural component of forested ecosystems and plays a substantial role in nutrient cycling, long-term carbon storage, tree regeneration and the maintenance of environmental heterogeneity and biological diversity (Harmon et al. 1986; Harmon, Sexton 1996; Stevens 1997; Sturtevant et al. 1997; Currie, Nadelhoffer 2002). During the past decades, numerous studies attempted to relate CWD characteristics with forest succession (Idol et al. 2001; Carmona et al. 2002; Woodall, Nagel 2006), community composition (Sturtevant et al. 1997; Santiago 2000; Pedlar et al. 2002; Motta et al. 2006; Sefidi et al. 2007), nutrient cycling (Raija, Prescott 1999; Chambers et al. 2001; Currie, Nadelhoffer 2002;

Fisk et al. 2002) and forest management (Lee et al. 1997; Siitonen et al. 2000; Grove 2001; Tinker, Knight 2001; Shawn et al. 2002; Webster, Jenkins 2005; Montes, Cañellas 2006). A general understanding of the CWD quantity and quality is crucial for the assessment of multiple functions of CWD in forest ecosystems. Some CWD characteristics, such as amount and type (i.e. logs, snag, and stumps), size classes, decay state and nutrients stocks, are often used to reflect stand structure, ecosystem function and forest management history (Lee et al. 1997; Siitonen et al. 2000; Pedlar et al. 2002; Ekbom et al. 2006). Currie and Nadelhoffer (2002) compared CWD in natural deciduous forests with that in coniferous plantations and showed that almost all classes of CWD existed in deciduous forests. In contrast, the majority of biomass in coniferous plantations was accumulated in the lowest size classes. In temperate forests of southern South America, recently disturbed and old-growth forests had the largest CWD biomass (Carmona et al. 2002). Early- and mid-successional stands had the lowest value. In addition, carbon stored in logs and snags was nearly 10 times higher in old-growth and primary forests than in young-successional forests (Carmona et al. 2002). Despite the ecological relevance of CWD characteristics in a forest ecosystem, there is no such quantitative information about Caspian forests in the North of Iran.

Caspian forests with an area around 2,000,000 ha are located on the northern slopes of Alborz Mountain between 20 and 2,200 m a.s.l. in the north of Iran (south of the Caspian Sea). Pure and mixed beech stands belong to the most important, rich and beautiful stands appearing at the middle and upper elevation on the northern slopes. The natural dense stands are found at 1,000–2,100 m and the high stocking volume stands at 900–1,500 m a.s.l. (Marvie Mohadjer 1976). Beech (*Fagus orientalis* Lipsky) is the most valuable wood-producing species in the Caspian forests covering 17.6% of the area and representing 30% of the standing volume; it can grow taller than 40 m and exceeds diameter at breast height larger than 1.5 m (Resaneh et al. 2001). Late frost, early heavy snow and direct sunlight damage its seedlings. As a sapling, *F. orientalis* is much more resistant to frost, sun scald and drought stress than the European beech (*Fagus sylvatica* Lipsky) (Svoboda 1953). This forest was managed by a close-to-nature silvicultural method such as tree selection method.

The knowledge of CWD attributes and dynamics will help forest managers understand the impact of current management practices on the CWD cycle and facilitate the incorporation of this important resource into future plans for more productive, diverse, and healthy forest ecosystems (Sturtevant et al. 1997). This study aimed to understand CWD characteristics and the associated relationships with forest management and forest succession in Gorazbon forest in the north of Iran. Our specific objectives were to:

(1) compare CWD characteristics (volume, size and decay state) in a successional chronosequence;
(2) examine whether the CWD volume along a chronosequence in Gorazbon forest displayed the general "U-shaped" temporal trend observed in other forest systems;
(3) determine factors affecting the distribution pattern of CWD in this forest.

MATERIALS AND METHODS

Study site

This study was carried out in Kheiroud Forest (36°40'N, 51°43'E), Mazandaran Province, Iran. The climate of this region is sub-Mediterranean with mean annual temperature and precipitation of 8.6°C and 1,380.5 mm. Selected forest communities occupy plateaus or moderately inclined slopes with good soil conditions above the limestone bedrock and with the surface largely free of rocks. All stands are dominated by oriental beech but in some sites additional important tree species were observed that are presented in Table 1 (Ramezani et al. 2008).

These forests are characterized by the natural uneven-aged structure. They show the latest human interventions such as logging and their structure and gap dynamics are similar to those reported from old growth forests (Marvie Mohadjer et al. 2005). Fig. 1 shows the Caspian forest in the north of Iran.

The mature forests in the centre of Gorazbon are considered as climax forests. At altitudes between (700) 1,000 and 2,000 m, beech forests (*Fagetum*, *Fageto-Carpinetum* or *Carpineto-Fagetum*) prevail. Here *Fagus orientalis* and *Carpinus betulus* are the dominant species, while *Acer velutinum, A. cappadocicum, Tilia platyphyllos, Ulmus minor, U. glabra, Cerasus avium, Taxus baccata, Fraxinus excelsior* subsp. *coriariifolia* and *Sorbus torminalis* are less common (Marvie Mohadjer 2006). This forest is a natural forest that developed without human disturbance such as logging.

Experimental design and field sampling methods

Beech dominated forest (mature climax forest) and mixed beech forests were chosen to represent late,

Fig. 1. The distribution of Caspian forests in Iran (modified according to MARVIE MOAHDJER et al. 2005)

middle and early successional stages, respectively (MARVIE MOHADJER 2006). We randomly chose five study plots in each of the three forest types (plot details in Table 1). Each plot was located at least 50 m from the forest edge and was separated from other plots by at least 20 m buffer strip surrounding it. Within each plot, CWD was measured using a fixed-area plot sampling method (HARMON, SEXTON 1996; YAN et al. 2007). In the spring of 2008, three types of CWD were examined according to the protocol of HARMON and SEXTON (1996):

(1) logs (downed or leaning deadwood with minimum diameter 10 cm at the widest point and length 1 m),
(2) stumps (vertical deadwood 1 m in height and 10 cm in diameter at the widest point),
(3) snags.

The dead trees with the gradient (departure from the vertical direction) less than 45° and diameter larger than 10 cm at the widest point were classified as snags while those with the gradient larger than 45° were classified as logs. We recorded the following variables for each log, snag and stump inventoried in the field: species, length, types, diameter at both ends and at the midpoint (for stumps only the diameter at midpoint was recorded), decay class (details in Table 2) (YAN et al. 2007).When applicable, lengths and diameters were taken at the point where the log extended outside the plot boundaries. Diameters of logs, snags and stumps were measured using 100 cm callipers; however, in some tall snags the diameter of the top end was visually estimated and calibrated with a snag top that was within manual reach (HARMON, SEXTON 1996). The length of logs was measured and the height of snags was measured with a meter stick. For snags taller than 4 m, a clinometer was used to estimate the height. Decay class of coarse woody debris (Table 2) was determined by the system proposed by MASER et al. (1979), SOLLINS (1982), CARMONA et al. (2002), ROUVINEN et al. (2002) and YAN et al. (2007).

Calculation of volume

The volume of each piece of logs and snags was calculated using Newton's formula (HARMON, SEXTON 1996). This formula uses the length and cross-sectional area at three points (i.e. top, end and middle) along the deadwood stem to generate a volume estimate. The volume was calculated as follows:

$$V = \frac{L(A_b + 4A_m + A_t)}{6}$$

where:

V – volume (m^3),
L – length,
A_b, A_m, A_t – areas of the base, middle and top, respectively.

For stumps, Huber's formula (HARMON, SEXTON 1996) was used to estimate the volume:

$$V = A_m \times L$$

Table 1. Description of study site, indicating position in the successional chronosequence and other characteristics in Kheyroud Forest, North of Iran (Forest management history – Protected from human disturbance and logging)

Position in chronosequence	Canopy height (m)	Dominant tree species	Forest type	Plot size (m)	Site code
Early-succession	14	*Fagus orientalis* *Carpinus betulus* *Acer velutinum*	DBLF	25 × 30	ES1
	15	*Fagus orientalis* *Carpinus betulus*	DBLF	25 × 30	ES2
	18	*Fagus orientalis* *Carpinus betulus*	DBLF	40 × 40	ES3
	18	*Fagus orientalis* *Carpinus betulus*	DBLF	40 × 40	ES4
	19	*Fagus orientalis* *Carpinus betulus*	DBLF	40 × 40	ES5
Intermediate	17	*Fagus orientalis* *Carpinus betulus*	DBLF	40 × 30	MS1
	18	*Fagus orientalis* *Carpinus betulus*	DBLF	25 × 25	MS2
	20	*Fagus orientalis* *Carpinus betulus*	DBLF	40 × 30	MS3
	22	*Fagus orientalis* *Carpinus betulus*	DBLF	40 × 30	MS4
	20	*Fagus orientalis* *Carpinus betulus*	DBLF	40 × 30	MS5
Late-succession	25	*Fagus orientalis* *Carpinus betulus*	DBLF	40 × 40	LS1
	27	*Fagus orientalis* *Carpinus betulus*	DBLF	25 × 30	LS2
	28	*Fagus orientalis* *Carpinus betulus*	DBLF	25 × 30	LS
	24	*Fagus orientalis* *Carpinus betulus*	DBLF	25 × 30	LS
	28	*Fagus orientalis* *Carpinus betulus*	DBLF	25 × 30	LS5

DBLF – deciduous broad-leaved forest

where:
V – volume (m^3),
A_m – area at the midpoint,
L – length.

Statistical analysis

To determine whether the volume of CWD of different types, decay classes and size classes differed among these three successional forests, successional stage was considered as a fixed factor and volume of CWD was analyzed as a response variable using one-way analysis of variance (ANOVA). If there was a significant effect of successional stage, the least-squares mean separation with Tukey's correction was used to test for differences among successional stages. Normality and homogeneity of variance of the residuals were tested and data were log-transformed if the homogeneity of variance was not met. All statistical tests were considered significant at the $P < 0.05$ level (Zar 1999).

Table 2. Qualitative classification system of different types of CWD in five decay classes

Type	Character	Decay class				
		I	II	III	IV	V
Snags	leaves	present	absent	absent	absent	
	bark	tight	loose	present partly	absent	
	crown, branches and twigs	all present	only branches present	only large branch slub present	absent	
	trunk	recently dead	standing, firm	standing, decayed	heavily decayed, soft and block structure	
	indirect measure	cambium still fresh, died less than 1 year	cambium decayed, knife blade penetrates a few milimeters	knife blade penetrates less than 2 cm	knife blade penetrates 2–5 cm	
Logs	structure integrity	round	sapwood slightly rotting, heartwood sound	sapwood missing, headwood mostly sound	heartwood decayed soft	
	leaves absent	present	absent	absent	absent	
	branches	11 twigs present larger	larger twig present	branches present	branch stubs present	
	bark	present	present	often present	often absent	
	trunk shape	round	round	round	round	round to oval oval
	wood consistency	solid	solid	semi solid	partly soft	fragmented, powdery
	color of wood	original color	original color	original color to faded	original color to faded	heavily faded
	portion of log cm ground	elevated on support point	elevated on support point	near or on ground	all of log on ground	all of log on ground
	indirect measure	cambium still fresh, died less than 1 year	cambium decayed, knife blade penetrates a few milimeters	knife blade penetrates less than 2 cm	knife blade penetrates 2–5 cm	knife blade penetrates all the way
Stumps	indirect measure	cambium still fresh, died less than 1 year	cambium decayed, knife blade penetrates a few milimeters	knife blade penetrates less than 2 cm	knife blade penerates 2–5 cm	knife blade penetrates all the way

Note: Adapted from Sollins (1982), Maser et al. (1979), Carmona et al. (2002), Rouvinen et al. (2002), Yan et al. (2007).

RESULTS

Amount of CWD

There was a significant effect of successional stage on total CWD volume (*F* = 3.49, *P* < 0.049, Table 3). Late-successional forest (LS) had the highest CWD volume (51.25 $m^3.ha^{-1}$) while mid-successional forest (MS) had the lowest (25.98 $m^3.ha^{-1}$) and early-successional forest (ES) had the intermediate value (37.05 $m^3.ha^{-1}$).

Type of CWD

The CWD composition varied considerably among different successional forests (Fig. 1). Logs were the major component of CWD in LS, MS and ES forests, while stumps were the dominant form of CWD in MS forests. The volume of snags exhibited significant differences among the different successional forests while logs and stumps did not differ (Table 3). The amount of snags was significantly greater in MS forest than that in LS (volume: *P* = 0.075) and ES forest (volume: *P* = 0.075), while LS and ES forests did not differ (volume: *P* = 0.63). Similarly, LS forest had a significantly larger amount of log volume and mass than did ES and MS forests (Fig. 1). In contrast, the stump volume did not differ among these three forests (Fig. 1). *F. orientalis* dominated the logs and stumps in ES forest and the logs in MS forest (Table 4). In contrast, a low percentage of *F. orientalis* was observed for logs and snags in MS forest.

Decay state of CWD

The distribution of CWD in different decay classes changed across forests in the successional chronosequence (Fig. 2). Decay classes IV and V were more abundant in LS forest relative to that in ES and MS forests. Decay classes III were the most abundant decay classes in ES and LS forests.

CWD in decay classes III and V was greater in LS forest than that in the other two forests (Fig. 2). In contrast, CWD in decay classes II and I did not differ among the three successional forests. CWD in class III was significantly higher in ES than that in MS forest (Table 3).

In ES and MS forests, CWD in early decay classes (e.g. class I) was dominated by *F. orientalis*, followed by *C. betulus*. In LS forest, however, CWD in early decay classes was dominated by beech and CWD in advanced decay class (e.g. class V) was dominated by *C. betulus* (Table 4).

Size classes of CWD

Different forest types had similar proportions of CWD between size classes (Fig. 3), with the exception of the volume of larger size class (> 50 cm)

Table 3. Results of one-way ANOVA's of different types, decay classes of CWD in three forest successional stages, deciduous broad-leaved forest of Northern Iran

Characteristics of CWD		df	*F*	*P*
Types	logs	2	0.401	0.632
	snags	2	2.905	0.097
	stumps	2	0.652	0.533
Decay class	I	2	13.341	0.000
	II	2	8.701	0.030
	III	2	6.982	0.070
	IV	2	1.006	0.380
	V	2	0.442	0.650
Size class	10–25	2	5.763	0.010
	25–50	2	0.726	0.495
	50 <	2	0.262	0.772
Total			3.220	0.049

The *F*-value and *P*-value are presented for the effect of successional stages

CWD, which was greater in LS forest than in MS forest (P = 0.010). Overall, the successional forest type had significant effects on the volume of CWD size classes (Table 3).

DISCUSSION

Amount of CWD along forest succession

To our knowledge, this study is the first report of CWD distribution along a successional chronosequence in forests in Northern Iran. This study showed that total CWD mass was the lowest in MS forest and the highest in LS forest. The early-successional forest is an approximately young forest that developed following the creation of large gaps in forest canopies. Snags composed the majority of the CWD input. The majority of the snag production was due to the mortality of trees which have been severely attacked by many pest infestations in the last decade. As succession progressed, amounts of CWD levelled off in MS forest. In China, Yan et al. (2007) reported the same results for evergreen broadleaved forests. It may be explained by three reasons. First, dead wood in MS forest is in the forest floor for a long time, so it has a sufficient opportunity for decaying. Second, *C. betulus*, the co-dominant species in MS forest, has a higher substrate quality (e.g. lower C/N compared to *F. orientalis*, unpublished data), which contributes to a faster decay rate for CWD. Third, local people harvested more logs from MS forest because it is easier to access than the ES and LS forests. Overall, CWD amounts followed the general "U-shaped" temporal trend observed in other forest systems (Sturtevant et al. 1997; Duvall, Grigal 1999; Carmona et al. 2002; Ranius et al. 2003; Ekbom et al. 2006; Yan et al. 2007). In forests of the Pacific northwest of North America, Harmon et al. (1986) and Spies et al. (1988) reported that recently disturbed stands had the highest biomass of woody residues. They reported that CWD biomass declined due to decomposition over time, and finally increased in old-growth forests. In contrast, our study showed that the late-successional forest, instead of the early-successional forest, had the highest CWD. One reason is that the pre-existing (or freshly created) CWD amounts in ES forest were small in our study area due to trees in early diameter growth. The amount of CWD in ES and LS is different but the difference is not significant. In other words, LS and ES forests have the same amount of CWD. The same results were reported by Yan et al. (2007) in China.

Table 4. Amount of CWD among spices by decay class, type and size classes at different succession stages in the deciduous broad-leaved forest, Kheyroud forest, north of Iran

Successional stage and species		Decay class					Type			Size class (cm)			Total
		1	2	3	4	5	log	snag	stump	10–25	25–50	50–75	
Early	*Carpinus betulus*	0	0	6.161282	0.169776	9.802256	0.169776	14.843930	1.119606	0.169776	1.119606	14.843930	16.133310
	Fagus orientalis	0	0.818677	9.776161	2.968765	0	14.49678	1.7122810	0.956130	0	4.681047	14.575470	19.256520
	Acer velutinum	0	0	3.752725	0	0	3.752725	0	0	0	0	3.752725	3.752725
Middle	*Carpinus betulus*	0.659910	0.906695	6.717533	1.420281	0	7.716088	0.473355	4.485098	0.338060	1.796568	7.569768	9.704395
	Fagus orientalis	0.740412	1.790291	0.550370	10.230050	0	13.311130	0	0	0.550370	2.530703	10.230050	13.311130
Late	*Carpinus betulus*	0	0	1.824432	10.478980	7.799374	7.799368	2.454139	2.049903	0.169776	4.000314	16.815980	20.986070
	Fagus orientalis	0	0	1.127456	27.557080	3.489390	24.940460	13.160980	1.101591	0.169776	7.421913	12.712450	20.304140

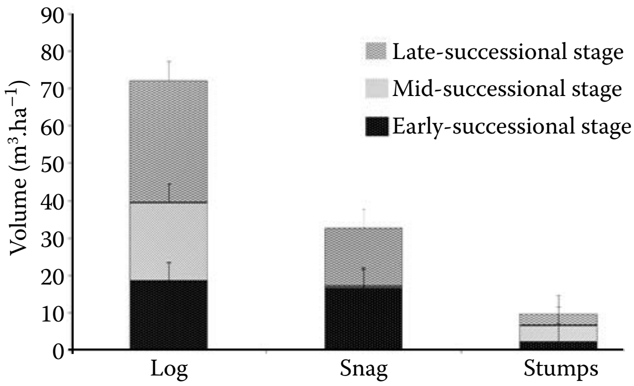

Fig. 2. The volume of CWD of different types along a successional chronosequence in Northern forests of Iran

CWD as an indicator reflecting forest management history

In forest ecosystems, different CWD types (i.e. logs, snags and stumps) can be an indicator of the origin and legacy of CWD. In addition, it can be used to reflect forest management and stand development history. For instance, a higher proportion of CWD due to stumps in a given site may suggest extensive anthropogenic disturbances, such as selective logging, in the past. Snags contributed the largest proportion of CWD in ES forest, which is dominated by *C. betulus*. This species was heavily attacked by diseases in the past decades and many trees died soon after the attack (filed observation). Current practice is not to remove dead trees from the forests as there are many snags due to the high tree mortality and limited labour in this region. The amount of CWD mass due to logs was the highest in LS forest. In contrast, MS and ES forests contained a lower amount of logs. The LS forest is natural old-growth forest and therefore it has been protected from cutting (Marvie Mohadjer 2006). Consequently, there was a large accumulation of logs in LS forest. In MS and ES forest, the highest percentage of CWD in LS forest is due to logs. The large amount of biomass due to logs is mainly due to high tree mortality caused by natural events such as wind and natural senescence.

In another study CWD in late forest amounted to 5 $m^3.ha^{-1}$, since the Patom forest is close to the village of Najardeh and considered as forest scenery, local forest practitioners often remove the dead trees from LS forest. As a result, snags are few in this mature forest. In our study area, *Acer velutinum* and *C. betulus* are pioneer species that occupy the early stages of succession. When secondary succession proceeds, these species are gradually replaced by *F. orientalis* and the late forest is mixed (Marvie Mohadjer 2006). Therefore, despite the disappearance of *A. velutinum* in mature forests due to species replacement, the stumps of *A. velutinum* have left a long-lasting legacy in the stand developmental history. For example, in LS forest. This is again confirmed by the high proportion of stumps of *C. betulus* in MS forest. After examining the distribution pattern of CWD in the forests of southern South America, Carmona et al. (2002) reported that a high proportion of woody residues was in advanced decomposition classes in the early stages of succession, while the majority was in the intermediate decomposition classes in older stands. In contrast, our study showed that CWD in decay classes VI and V was more abundant in LS forest, while CWD in class I was much greater in ES forest (Fig. 2). Yan et al. (2007) reported the same results in Chinese forests. The contradiction can partly be attributed to differences in the vegetation composition and disturbance type. In our study area, CWD in ES forest was mainly composed of *C. betulus* snags, which is caused by recent high tree mortal-

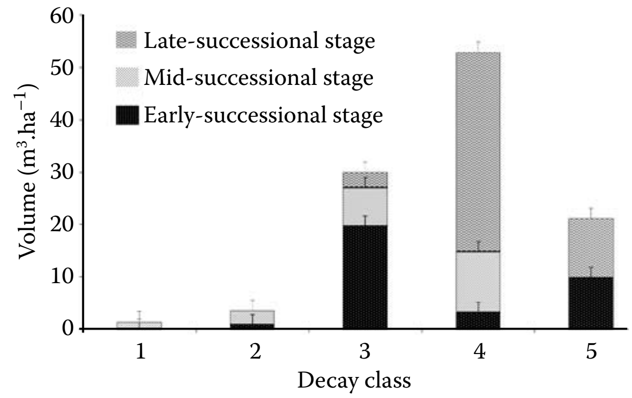

Fig. 3. The volume of CWD in each decay class along a successional chronosequence in Northern forests of Iran

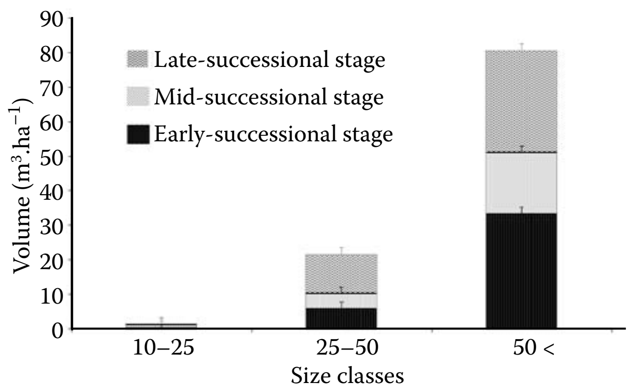

Fig. 4. Volume and biomass of CWD in each size class along a successional chronosequence in Northern forests of Iran

Table 5. CWD amount and quality in deciduous broad-leaved forests of Northern Iran

Location	Forest type	Successional stage	Snags	Stumps	Logs	Total	Reference
			(m³.ha⁻¹)				
Nour forests	mixed beech forest	late successional	7.50	–	25.15	32.67	Habashi (1998)
Chelir forests	beech and hornbeam	late successional	4.26	–	12.21	16.50	Zolfaghari (2005)
Patom* forests	beech and hornbeam	early successional	1.80	–	3.30	5.10	Sefidi (2006)
Namkhaneh forests*	beech and hornbeam	middle successional	1.01	–	2.50	3.30	Sefidi (2006)
Gorazbon forests	mixed beech forest	early successional	16.60	2.07	18.41	37.05	this study
Gorazbon forests	beech and hornbeam	middle successional	0.48	4.48	21.03	25.98	this study
Gorazbon forests	beech and hornbeam	late successional	15.62	3.16	32.74	51.25	this study

*These sites are managed and a logging operation was carried out

ity. Therefore a major part of CWD was in the early stage of decay class. Overall, our results suggested that both anthropogenic and natural disturbances left a significant impact on the distribution and abundance of coarse woody debris along a successional chronosequence in deciduous broad-leaved forests of Northern Iran.

Amount of CWD in the same deciduous broad-leaved forest of Northern Iran

CWD mass varies considerably among forest stands in deciduous broad-leaved forests of Northern Iran (Table 5). The large variations in CWD mass may be due to differences between the forest types and disturbance regimes, as well as to different classification methods. For example, some studies used 10 cm at the widest point to define CWD while others used 30 cm and some studies incorporated stumps as CWD while others did not.

CONCLUSIONS

Traditional management methods in Iran include harvesting CWD from the forests. Our results suggest that the removal of standing and fallen materials from early- and mid-successional forests leads to a sharp drop in total CWD biomass. Reductions in the volume of CWD in young- and intermediate successional forests may have negative consequences for populations of endemic, understory bird species that commonly nest in cavities located in or under logs on the forest floor (Yan et al. 2007). CWD creates within-stand heterogeneity and provides a favourable environment for many plant species; therefore, removing CWD may have long-term impacts on seedling recruitment and establishment (Sefidi 2006). Consequently, the removal of CWD would likely decrease the biodiversity in forest ecosystems. The removal of structural legacies is inconsistent with the scientific understanding of the natural process. Possible alternative management is to retain a combination of trees, snags and logs within forests.

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