Iranian Journal of Forest
Vol. 13, No. 5, Winter 2022
pp. 43-55

DOI: 10.22034/ijf.2022.317191.1822
DOR: 20.1001.1.20086113.1400.13.5.4.1

Research Article

Spatial distribution pattern of beech (*Fagus orientalis* Lipsky) coarse woody debris in managed and unmanaged stands of Caspian forests, Iran

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(Received: 28 November 2021, Accepted: 11 March 2022)

Abstract
The ecological significance of deadwoods has led to an ever-increasing collection of related information to be taken into account in management plans. The Coarse woody debris (CWDs) is a significant component of forest ecosystems. Here, managed and one unmanaged forest stands were selected in Gorazbon district of Kheyrudkenar Experimental Forest, Noshahr, Mazandaran Province, Iran. Based on the full-calipering inventory method, CWD attributes were collected in both stands. The distribution pattern of CWD was evaluated using univariate O-ring statistics. Results showed that the highest and lowest decay classes in two forest stands were 3-6 and 1-2, respectively. Results from distribution pattern analysis showed a random distribution pattern of CWD in the managed forest stand. Overall, the unmanaged forest stand with 3-6 decay classes showed a random distribution pattern of CWD. Conclusively, disturbances in the managed and the unmanaged forest stands occur in small scales.

Keywords: CWDs; Decay classes; Distribution pattern; O-rings statistic.

1. Introduction
Distribution pattern of plants is one of the most important aspects of plant ecology. The spatial distributions of tree species in forests and their influencing mechanisms have always been a crucial research topic, as such information can help us to understand the potential ecological processes that control species coexistence and community structure. Furthermore, spatial distribution can also be affected by differences in functional traits (e.g., growth form, shade tolerance, and seed dispersal limitation) and ecological strategies (Du et al., 2017). Distribution pattern of plants is influenced by natural and human disturbances (Sánchez et al., 2009), internal competition, including intra-specific and inter-specific competition (Stoll & Bergius, 2005), regeneration (Fajardo et al., 2006) and mortality (Barot et al., 1999). Deadwoods are divided into two main types: standing deadwood (SDW) and downed deadwood (DDW). Deadwood contributes to ecosystem stability, enhances forest products (Dudley et al., 2004; Kajar et al., 2015) and plays an important role in the habitat quality for the sustainability of organisms. The best-preserved deadwood for biodiversity is Coarse Woody Debris (CWDs) (Hopkins et al., 1984) which are an important component of forest ecosystems (Helfenstein & Kienast, 2014; Thomas & Druscilla, 2012; Stella

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et al., 2016; Stella et al., 2015; Forrester et al., 2012). Several reports have been provided on CWDs. A study in Canada indicated that CWDs play a very important role in biodiversity conservation (Thomas & Druscilla, 2012). In another study, CWDs in managed ecosystems are found to increase biodiversity, the size of gaps and regeneration (Nicholas et al., 2011). According to reports from the United States, CWDs are very important in determining the structure and composition of forest ecosystems (Woodall et al., 2008; Matthew et al., 2015). Also, the evolutionary stages of young forests, natural disturbances, and human-induced turmoil play an important role in the characteristics of CWDs in these forests (Yuan et al., 2014). According to Mataji et al. (2014), The frequency and volume of deadwood depend on the natural disturbance pattern, developmental stages and stand structure. Further, Khalili et al. 2019 showed higher frequency of deadwood in managed forest stand compared with the unmanaged forest stand, whereas higher volume of deadwoods was observed in unmanaged forest stand. Several studies have been carried out to estimate the rates of deadwood and their decay rates. In Gorazbon Khayrud series near Noshahr, about one-fifth of the total volume of deadwood consist of snags, while half of them were in the early stages of decay (grade 1 and 2) (Rahanjam et al., 2018) and 72% of the deadwood was in decay classes 3 and 4 (Sefidi, 2012; Sefidi & Marvi-Mohajer, 2010). According to Hang chang et al. (2001), harvesting and gathering of fallen trees and snags from the forest floor would have a negative effect on the density of seedlings in the forests in the northern part of Taiwan. The distribution patterns of points belonging to one of the random states are Coupé (cluster) and regular (uniform) (Jayarman, 2000). On the one hand, the random patterns of a population refer to environmental homogeneity or non-selective behavioral patterns. On the other hand, non-random patterns (cluster and uniform) implicitly imply some limitations in the population (Quinn & Dunham, 1983). A uniform distribution of negative countermeasures such as competition for food or space has been achieved. Obviously, defining a pattern and explaining possible causes are two separate issues (Quinn & Dunham, 1983). In unmanaged forests, clustered and individual distributions of snags and CWDs have been reported, whereas it was cluster-dominated in managed forests as a result of storms (Bottorff, 2009). Moreover, forest processes and patterns are very important for forest researchers and managers in surveys (Matthew et al., 2015). Considering the importance of CWDs in forest ecosystems, the aims of this study was to compare the status of CWDs in managed and unmanaged forests and to investigate the effect of management on distribution pattern of CWDs and decay classes.

2. Materials and Methods

2.1. Study area

The research area, covering 950 ha, was located in the experimental forest of Kheirudkenar-Nowshahr as a part of Hycanian forests in north of Iran (Figure 1).

In the managed forest stand, management activities (thinning/harvesting) were implemented since 2010, while no management activities have been taken place so far in the unmanaged forest stand (protected stand).

The altitude ranges between 1150 and 1350 m and the mean slope is 30% on the southwest-facing. The average annual temperature and rainfall are 15.9°C and 1300 mm, respectively. In both northern and southern aspects with a slope of 0 to 50%, the structure of the stands includes high forest, uneven-aged, irregular, with a dominant type of beech-Hornbeam (*Fagus orientalis* - *Carpinus betulus*) and ca. 90% canopy cover with a relatively intermediate regeneration. The geological structure of the study stand consists of limestone of the second period of the Jurassic era. Major of the soil is Alfisol and Inceptisol. According to the information of the nearest weather station to the region (Noshahr Climatology Station), the mean annual precipitation is 1,300 mm, with minimum and maximum rates in July and October, respectively. The warmest month is August with a mean temperature of 29.2 °C and the coldest month is January with a mean temperature of 15.9°C (Anonymous, 2010).

2.2. Methodology

Historical studies within the test site illustrated that some of areas including 4 unmanaged and managed parcels with approximately 50 ha (after decreasing side effects of neighbor area) represent the least human influence and have been categorized as virgin forests. These areas were considered as study area and all CWD (SDWs and

DDWs) with an average middle diameter more than 7.5 cm (Vasile et al., 2017) was recorded. In this study, only CWDs of *Fagus orientalis* were sampled. The distance-azimuth method (Meour, 1993) was used to determine the position of the all CWDs in the study area. Each CWD was mapped using slope-corrected distance and azimuth from a reference point (i.e., precise coordinates of distinct points on the forest road). Then, these distances and azimuths were transformed into Cartesian coordinates. Diameter at breast height and height for SDWs and the average diameter (cm) and their length (m) for DDWs were measured and recorded. For non-circular cross-sections of CWD, especially in the higher decay stages, diameter was measured by tape. Based on diameter size, the measured CWDs were classified in small (7.5-32.5cm), medium (32.5-52.5cm), and large (> 52.5 cm) (Sagheb-Talebi & Schutz, 2002). The degree of CWDs decay (SDWs and DDWs) was determined using the modified proposed method of Christensen & Vesterdal (2003) (Table 1).

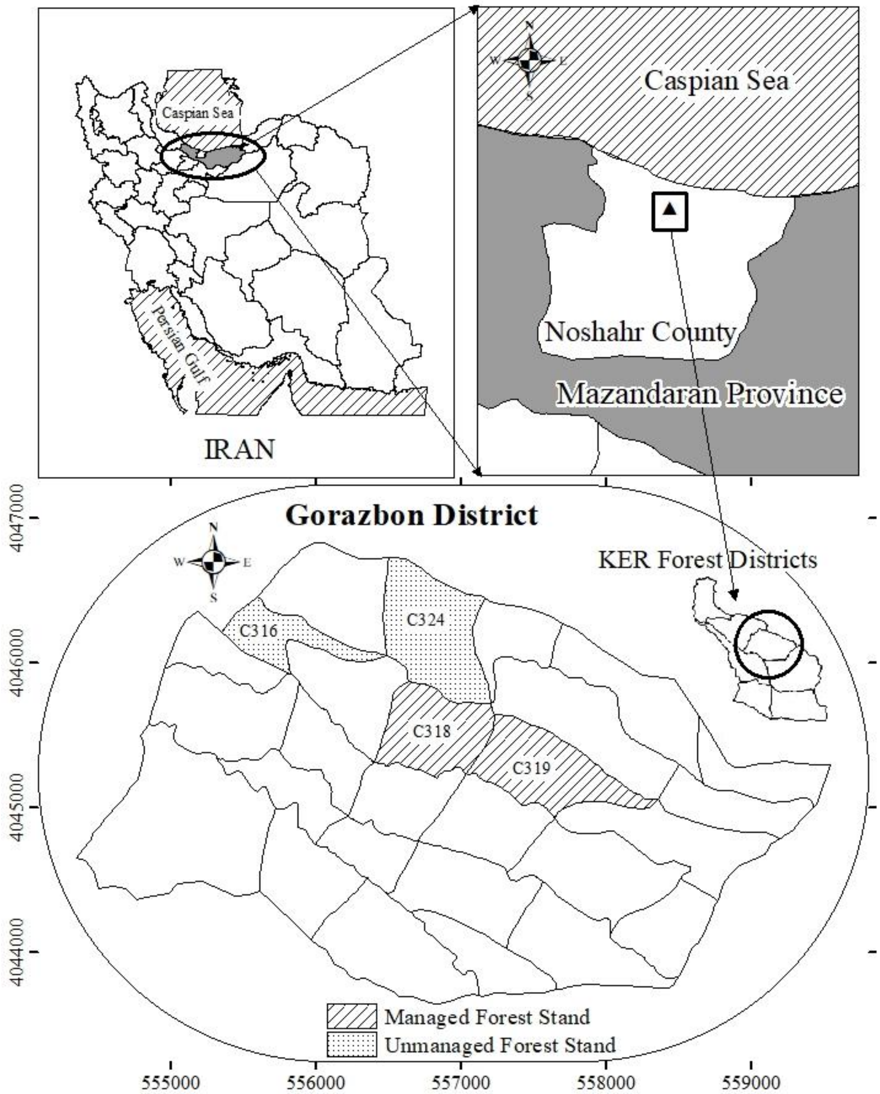

Figure 1. Geographic location of the study area in Kheyroud Educational–Research Forest.

Table 1. Decay classification for CWDs (Modified from Christensen & Vesterdal (2003).

Decay phases	Bark	Twigs branches	Softness	Surface	Shape
D1	intact or missing only in small patches, more than 50%	present	hard or knife penetrate 1-2 mm	covered by bark, outline intact	circle
D2	missing or less than 50%	only branches (>3 cm) present	hard or knife penetrate less than 1 c	smooth, outline intact	circle
D3	missing	missing	begin to be soft, knife penetrate 1-5 cm	smooth or crevices present, outline intact	circle
D4	missing	missing	soft, knife penetrate more than 5 cm	large crevices, small pieces missing, outline intact	circle or eliptic
D5	missing	missing	soft, knife penetrate more than 5 cm	large pieces missing, outline partly deformed	flat eliptic
D6	missing	missing	soft, partly reduced to mould, only core of wood	outline hard to define	flat eliptic covered by soil

To determine the distribution pattern of CWDs, the univariate O-ring statistic as a probability density function was applied in Programita software (Wiegand & Moloney, 2004).

Wiegand & Moloney (2004) suggested the use of O-ring statistics that is generally used as a useful complement to the K- Ripley function. The K function may only apply to a given distance, while the O-ring statistic enable detecting density and dispersion at a hypothetical distance. The use of the O-rings statistic has been emphasized to be more useful in studying the distribution pattern than the K- Ripley function and its linear form, the L-function. Considering the advantage of the O-ring statistic, this is a probability distribution function by describing neighbor density and adjacent points, the power of pattern discovery, analysis and interaction increase with respect to the cumulative K function (Stoyan & Penttinen, 2000). Replacing rings in O(r) instead of circles in the K function enables the statistics to detect different spacing patterns (Illian et al., 2008; Wiegand & Moloney, 2004). Thus, One-variable O-rings statistic issued to indicate the distribution of species (random, clustered, and regular) according to Eq. 1.

$$O(r) = \lambda\, g(r) \qquad (1)$$

Where, O(r) is a single-variable statistic for O-ring; λ is density (number per stand unit), and g(r) is derived from the K-Ripley function.

In a complete randomized pattern, O(r) = l and O(r) > l indicate the clustering of the pattern at r, and O(r) < l indicates the regular pattern.

The simplest zero assumption that is widely used in the analysis of a single-variable spatial pattern is a complete randomized pattern that can be considered as a homogeneous Poisson process. (Wiegand & Moloney, 2004) To test the zero assumption and find a significant difference, the results obtained from O(r) are compared at a probability level with Monte Carlo simulation. If the values of O(r) are placed within the Monte Carlo range, then the zero assumption is confirmed, while the zero assumption is rejected if the values are outside the Monte Carlo range. In the present study, 99 Monte Carlo simulations were performed and the spacing of 100 meters was used to calculate the univariate O(r) statistic. This distance is typically equal to half of the length of the small side of the piece (Woodall & Graham, 2004). In this research, the distance of more than 100 meters was also investigated, but the results were presented only up to 100 meters, since the spatial pattern for the univariate functions did not change. All calculations related to the determination of O-ring statistics were performed using Programita software (Wiegand & Moloney, 2004).

3. Results

3.1. Descriptive analysis

The abundance and density (per ha) of CWDs in three diameter classes are presented in Table 2. Results revealed that both highest abundance and density of CWDs belong to the small diameter class (n=188; 3.76 ha^{-1}) in both managed and unmanaged forest stands. The second frequent and denser CWD diameter class was the large and very large class. (n=69; 1.38 ha^{-1}).

Table 2. Number of CWDs pieces by diameter classes.

Diameter class	Range (cm)	Forest stands: Managed (25 ha) SDW	Forest stands: Managed (25 ha) DDW	Forest stands: Unmanaged (25 ha) SDW	Forest stands: Unmanaged (25 ha) DDW	Total
Small	7.5 - 32.5	91 [3.64]	41 [1.64)]	28 [1.12)]	28 [1.12]	188 [3.76]
Medium	32.5 - 52.5	11 [0.44]	29 [14.5]	2 [0.08]	15 [0.6]	57 [1.14]
Large and very large	> 52.5	21 [10.5]	12 [0.48]	15 [0.6]	21 [0.84]	69 [1.38]
Total diameter class		123 [4.92]	82 [3.28]	45 [1.8]	64 [2.56]	314 [6.28]
Total CWDs		205 [8.2]		109 [4.36]		

Number inside the brackets: CWDs per hectare, SDW: standing dead wood, DDW: downed dead wood

The abundance and density of CWDs based on decay classes are shown in Table 3. In Figure 2, different stages of CWDs decay are presented. The results show that the decay classes of D4 (109) and D1 (4) represent the highest and lowest CWDs in two forest stands respectively. On the other hand, the managed forest stand (205; 8.2 ha^{-1}) was associated with both more frequent and denser CWDs in comparison to unmanaged forest stand (109; 4.36 ha^{-1}).

Table 3. Number of CWDs by decay grade.

Decay classes	Forest stands: Managed (25 ha) SDW	Forest stands: Managed (25 ha) DDW	Forest stands: Unmanaged (25 ha) SDW	Forest stands: Unmanaged (25 ha) DDW	Total
D1	3 [0.12]	1 [0.04]	-	-	4 [0.08]
D2	4 [0.16]	-	3 [0.12]	3 [0.12]	10 [0.2]
D3	51 [2.04]	6 [0.24]	14 [0.56]	20 [0.8]	91 [1.82]
D4	52 [2.08]	25 [1]	19 [0.76]	13 [0.52]	109[2.18]
D5-D6	13 [0.52]	50 [2]	9 [0.36]	28 [1.12]	100 [2]
D1-D6	123 [4.92]	82 [3.28]	45 [1.8]	64 [2.56]	314 [6.28]
Total CWDs	205 [8.2]		109 [4.36]		

Number inside the brackets: CWDs per hectare, SDW: standing dead wood, DDW: downed dead wood

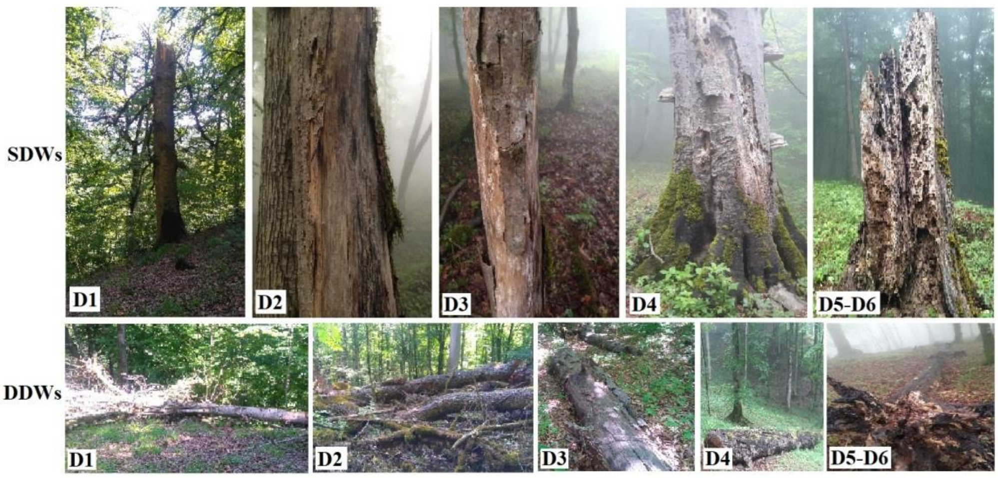

Figure 2. Different stages of CWDs ecay.

3.2. Distribution pattern analysis

3.2.1. Unmanaged forest stand

The results of the CWDs distribution pattern of beech using O-ring statistic is summarized in Figure 3. It shows its distribution within Monte Carlo limits and indicates a random distribution of CWDs pattern in unmanaged forest stand. In addition, the O-r value of DDW and SDW were also shown to fall within Monte Carlo limits.

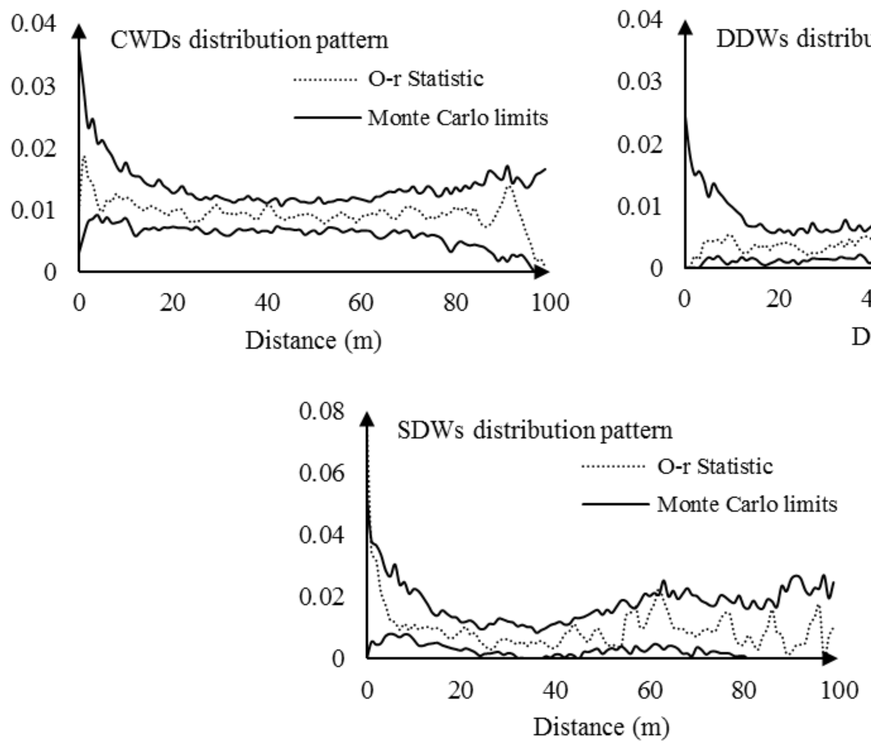

Figure 3. Distribution pattern of beech CWDs in the unmanaged forest stand.

Figure 4 shows the distribution pattern of CWDs in the unmanaged forest stand based on diameter class size of beech. Results shows that for unmanaged forest stand the O-r values in the statistical distances occurred within Monte Carlo limits in the case of small and large-very large diameter class sizes. This revealed a random distribution of CWDs in this forest stand. In other diameter class sizes, no distinct distribution pattern was observed because of the low numbers of CWDs.

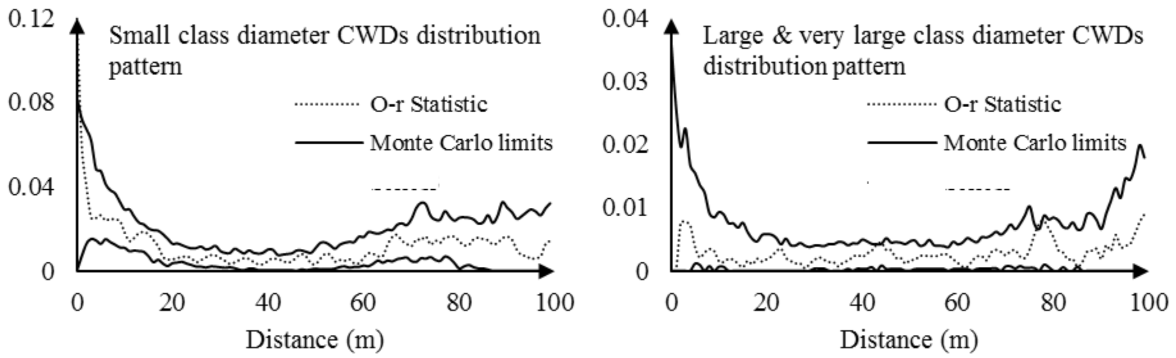

Figure 4. Distribution pattern of beech CWDs based on diameter classes in the unmanaged forest stand.

Furthermore, results of the CWDs distribution pattern of beech in the unmanaged forest stand are shown in Figure 5, which revealed that CWDs of beech in decay classes of 3,4 and 5 follows a random distribution as the O-r values fall within Monte Carlo limits. The CWDs in other decay classes do not follow a specific distribution pattern.

3.2.2. Managed forest stand

The distribution pattern of CWDs for beech in the managed forest stand based on O-r statistic is presented in Figure 6. Results showed a random distribution for the CWDs. The O-r values relative to the Monte Carlo limits also suggested random distribution of DDWs in the managed forest stand. Similar trend was observed for SDWs distribution as well.

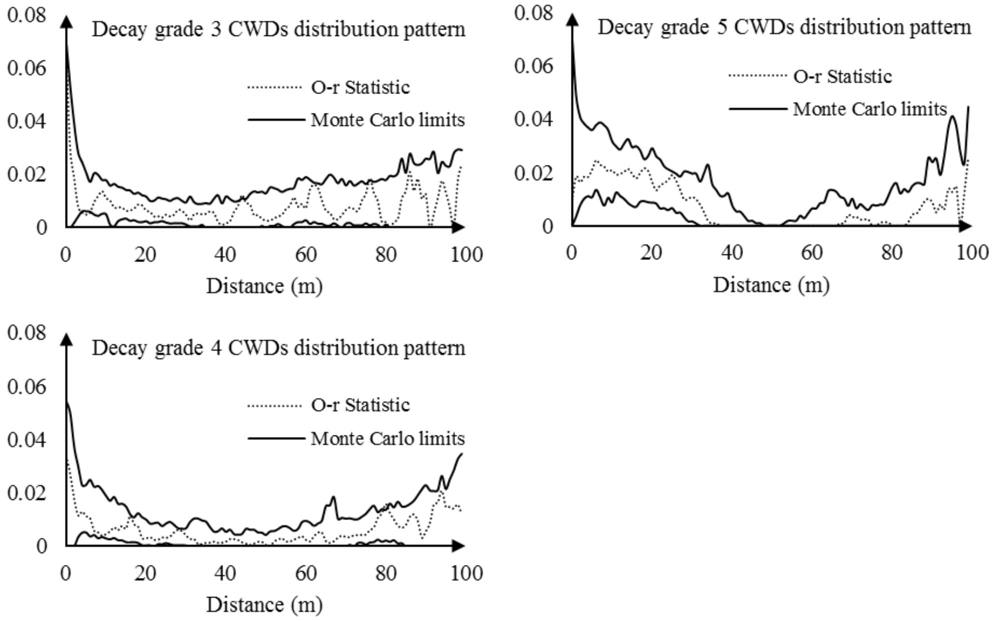

Figure 5. Distribution pattern of beech CWDs based on decay classes in the unmanaged forest stand.

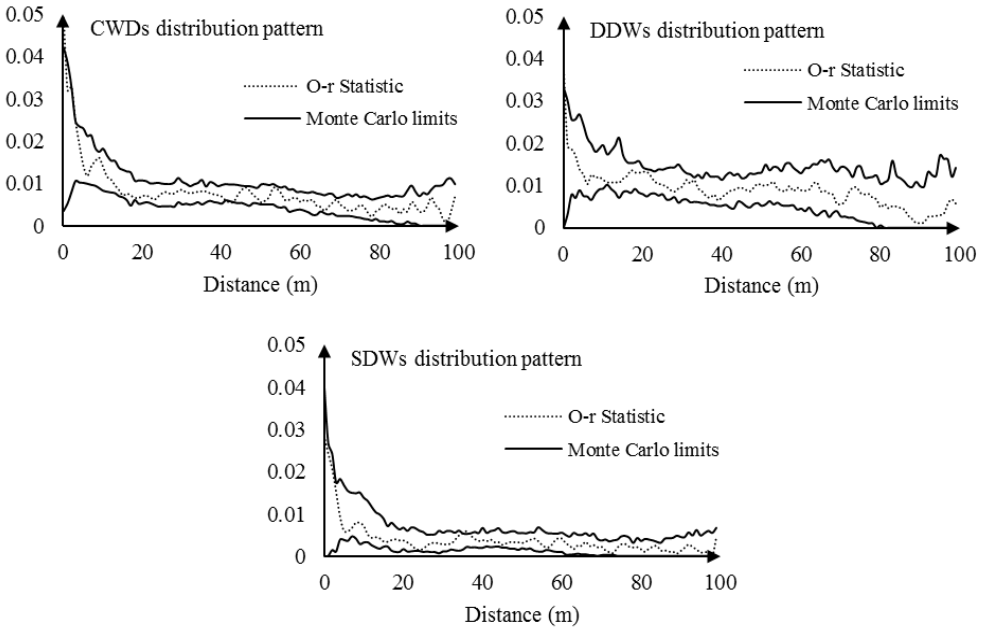

Figure 6. Distribution pattern of beech CWDs in the managed forest stand.

Distribution pattern of beech CWDs within diameter size classes (Figure 7) revealed the random distribution of CWDs in small, medium and large-very large diameter classes of managed forest stand, since all statistical distances of O-r were within the Monte Carlo limits.

The distribution pattern of beech CWDs in the managed forest stand was also evaluated based on decay classes (Figure 8), which indicated a random distribution pattern in the managed forest stand within decay classes of 3, 4 and 5, respectively. However, CWDs in other decay classes did not follow a specific distribution pattern.

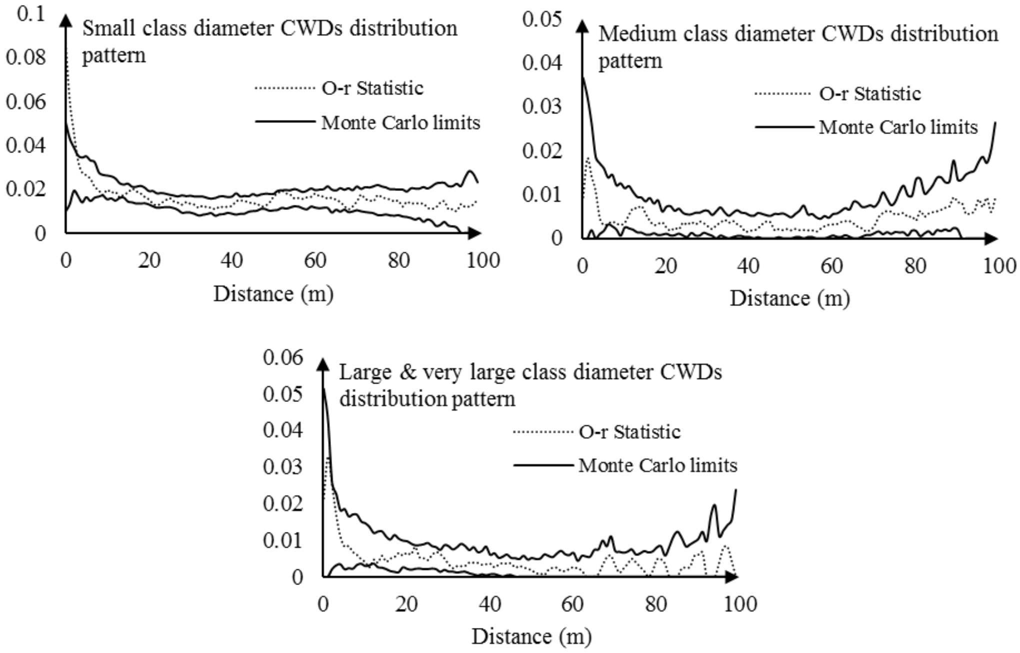

Figure 7. Distribution pattern of beech CWDs based on diameter classes in the managed forest stand.

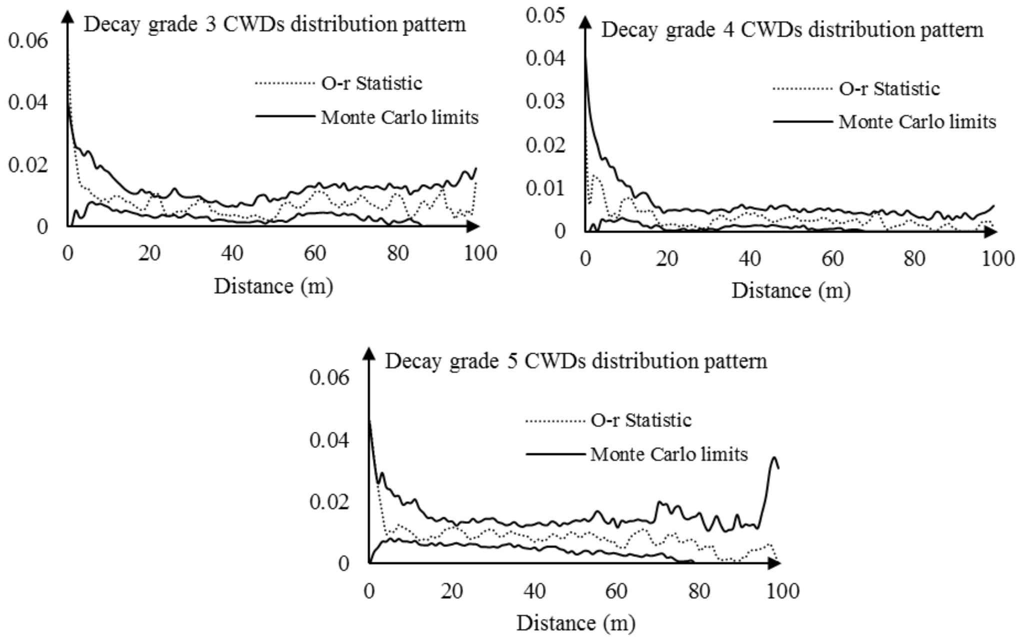

Figure 8. Distribution pattern of beech CWDs based on decay classes in the managed.

4. Discussion

This study evaluated the distribution pattern of beech CWDs based on diameter and decay classes using the O-ring statistic in a part of Hyrcanian Forests of Iran. Results showed that small diameter classes had the highest amount of CWDs in both managed and unmanaged forest stands (Figure 2). The intraspecific competition in early stages growth of beech (in particular for light) and consequently the removal of trees are known as the main causes of frequent CWDs in small diameter class compared with other diameter classes. This is consistent with the results reported by Amiri et al. (2013). Furthermore, the higher frequency of CWDs in the managed forest stand and especially in small and medium classes diameter class as compared with unmanaged forest stand is due to unsustainable forest exploitation and logging practices. The share of CWDs in large and very large diameter classes was almost equivalent in both forest stands. This suggests that the decay stage 4 had the highest percent of CWDs within decay classes, which indicates that the study forest stand is an old forest type (Sefidi, 2012; Sefidi & Marvi –Mohajer, 2010).

However, the quantity of total CWDs in the managed forest stand from small to large and very large classes followed a decreasing trend. Moreover, the quantity of total CWDs in the unmanaged forest stand followed a decreasing trend from small to medium class, whereas it increased from medium to large and very large classes. Therefore, the unmanaged forest or natural state of a forest has a random pattern distribution of CWDs. This implies that proper distribution of CWDs in different class sizes should be considered in management of similar stands in the future in order to reach more stable and closer to the natural forest. In this study, the decay classes of CWDs were evaluated as qualitative attribute in both managed and unmanaged forest stands. According to the Nat-Man classification (Christensen & Vesterdal, 2003), results of the present study showed that the total number of CWDs by decay classes (grades) in the unmanaged forest stand, the total number of CWDs has been decreasing from grade 3 to grade 4 and increasing from grades 4 to 6, and in the managed forest stand, the total number of CWDs has been increasing from grade 3 to grade 4 and decreasing from grades 4 to 6. This can be due to the fact that the managerial interventions and non-standard logging operations hinder the natural process of CWDs to a random pattern. In the Nat-Man classification, with an increase of CWDs, they are placed on a higher category. In contrast, the abundance of SDWs with decay grade 3 is two times greater in the managed forest stand than in the unmanaged forest stand. This implies that the fallen trees, which could be exploited, have been withdrawn from the managed forest stand due to managerial interventions and anthropogenic activities. The remarkable point is that the managed forest stand has not been exploited by human harvesting from the past time until the last two years. On the other hand, competition between trees has led to the random tree mortality and creation of a randomized pattern of CWDs in the study stand, which is consistent with the results obtained by Bottroff (2009), Nouri et al. (2013) and Vasile et al. (2017). Based on diameter classes (small, medium and large and very large), the distribution pattern of CWDs in both managed and unmanaged forest stands was random , with the removal of trees in these classes due to the light and nutrient competition being the main influential factors. This is consistent with the results reported by Bottroff (2009), Nouri et al. (2013), Amanzadeh et al. (2013) and Vasile et al. (2017).

In fact, the accumulation of CWDs indicated that the competition-induced change in the distribution pattern of CWDs is more important than random or age-related deaths in the study stand (Nouri et al., 2014). The CWDs distribution pattern based on decay classes was random in both stands with decay classes3-6. Thus, it can be stated that disturbances in managed and unmanaged forest stands occurred in the small scales.

5. Conclusions

At present, the ecological value of CWDs is not prominent in managed forests, while monitoring this important component of natural forests should be one of the main goals of managers in sustainable forest management. Therefore, it is recommended to keep CWDs in the forest according to normal qualitative/quantitative ranges. Also, quantifying the fine woody debris (FWD) (smaller than 7.5cm) and the mass/ weight of CWD are important issues that can be studied in future researches to understand the role of CWD for habitat suitability, carbon storage, fire risk, and nutrient supply.

6. Acknowledgments

The authors thank all those who helped in this research.

References

Amanzadeh, B., Sagheb-Talebi, K., Foumani, B.S., Fadaie, F., Camarero, J.J., & Linares, J.C. (2013). Spatial distribution and volume of dead wood in unmanaged Caspian Beech (Fagus orientalis) forests from Northern Iran. *Forests Journal*, *4*(4), 751-765.

Amiri, M., Rahmani, R., Sagheb-Talebi, Kh., & Habashi, H. (2013). Dynamics and Structural Characteristics of a Natural Unlogged Oriental Beech (*Fagus orientalis* Lipsky) Stand during a 5-year Period in ShastKalate Forest, Northern Iran. *The international Journal of Environmental Resources Research, 1*(2), 107-129.

Anonymous (2010). Forest Management Plan Gorazbon District of Khyrud Forest. Department of Forestry and Forest Economics, Faculty of Natural Resources. *University of Tehran, Karaj,* 191-273.

Barot, S., Gignoux, J., & Menaut, J.C. (1999). Demography of a Savanna Palm tree: predictions from comprehensive spatial pattern analyses. *Ecology, 80,* 1987-2005.

Bottorff, J. (2009). Snags, coarse woody debris and wildlife. *Washington state department of natural resources,* 1-5.

Christensen, M., & Vesterdal, L. (2003). Nat-Man WP7 report: prepared by members of Work-package7 in the Nat-Man project (Nature-based Management of beech in Europe) funded by the European Community 5th framework programme. *Nat-Man Working Report,* 25P.

Dudley, N., & Equilibrium Vallauri, D. (2004). Deadwood living forests. *WWF Report,* 1-19.

Fajardo, A., Goodburn, J.M., & Graham, J. (2006). Spatial patterns of regeneration in managed uneven-aged Ponderosa pine/Douglass fir forests of Western Montana, USA. *Forest Ecology and Management, 223*, 255-266.

Du, H., Hu, F., Zeng, F., Wang, K., Peng, W., Zhang, H., Zeng, Z., Zhang, F., & Song, T. (2017). Spatial distribution of tree species in evergreen-deciduous broadleaf karst forests in southwest China. *SCIentIfIC RePorTS, 7,* 15664.

Forrester, J.A., Mladenoff, D.J., Gower Stith, T., & Stoffel Jennifer, L. (2012). Interactions of temperature and moisture with respiration from coarse woody debris in experimental forest canopy gaps. *Forest Ecology and Management, 265*(2012),124-132.

Hang Chang, N., Husui Ray, Y., & Wen Hormg, F. (2001). Natural seedling and seedling occurrence in the Chamacyparis forest at Chilan Mt. Area Taiwan. *Journal of Forest Research*, *16*(4), 321 – 326.

Helfenstein, J., & Kienast, F. (2014). Ecosystem service state and trends at the regional to national level: a rapid assessment. *Ecological Indicators, 36*, 11–18.

Hopkins, A., Harrison, C., Yee-Stamm, L., Wardlaw, T., & Mohammed, C. (1984). Coarse woody debris, old Trees and Biodiversity conservation in production forests. *Forestry Tasmania,* 1-36.

Illian, J., Penttinen, A., Stoyan, H., & Stoyan, D. (2008). Statistical Analysis and Modeling of Spatial Point Patterns. *John Wiley & Sons,* 556p.

Jayarman, K. (2000). A Statistical Manual for Forestry Research. *FORSPA-FAO Publication,* 240p.

Yuan, J.A., Cheng, F.A., Zhao, P.A., Qiu, R.A., Wang, L.A., & Zhang, S.h. (2014). Characteristics in coarse woody debris mediated by forest developmental stage and latest disturbances in a natural secondary forest of Pinus tablaeformis. *Acta Ecologica Sinica,* 232–238.

Kajar, K., Metslaid, M., Engelhart, J., & Koster, E. (2015). Deadwood basic density, and the concentration of carbon and nitrogen for main tree species in managed hemiboreal forests. *Forest Ecology and Management,* 35–42.

Khalili, A., Mataji, A., Sagheb Talebi, KH., & Hodjati., S.M. (2019). Spatial pattern and amount of deadwoods in managed and unmanaged natural forests in Kheiroudkenar region, Noshahr. *Journal of Renewable Natural Resources Research, 2*(1), 1-16.

Mataji, A., Sagheb-Talebi, KH., & Eshghi-Rad, J. (2014). Deadwood assessment in different developmental stages of beech (Fagus orientalis Lipsky) stands in Caspian forest ecosystems. *International journal of Environmental Science and Technology, 11*(5), 1-8.

Matthew, R., Shawn, F., Tuomas, A., Jeffrey, H., Gove Christopher, W., Woodall Anthony, W., D'Amato, F., & Mark, J.D. (2015). Quantifying carbon stores and decomposition in dead wood: A review. *Forest Ecology and Management, 350*(2015), 107–128.

Meour, M. (1993). Characterizing spatial patterns of trees using stem-mapped data. *Forest science,* 756-775.

Nicholas, W., Bolton, A., & D'Amato, W. (2011). Regeneration responses to gap size and coarse woody debris within natural disturbance-based silvicultural systems in northeastern Minnesota, USA. *Forest Ecology and Management*, 1215–1222.

Nouri, Z., Feghhi, J., & MarvieMohadjer, M.R. (2013). distribution pattern and volume of dead trees in Fagus orientalis stands of Iran (case study: Gorazbon district of Kheyrud forest). *Iranian Journal of forest and poplar Research,* 1-14.

Quinn, J.F., & Dunham, A.E. (1983). On hypothesis testing in ecology and evolution. *American Naturalist,* 602-617.

Rahanjam, S., Marvie Mohajer, M.R., Zobeiri, M., & Sefidi, K. (2018). Quantitative and qualitative assessment of deadwood in natural stands of Hyrcanian forests (Case study: Gorazbon district of Khayrud, Nowshahr. *Iranian Journal of forest and poplar Research,* 656-666.

Sagheb-Talebi, Kh., & Schütz, J.Ph. (2002). The structure of natural oriental beech (Fagus orientalis) in the Caspian region of Iran and potential for the application of the group selection system. *Forestry,* 465-472.

Sánchez, M., Moore, M.M., Bakker, J.D., & Parysow, P.F. (2009). 108 years of change in spatial pattern following selective harvest of a Pinus ponderosa stand in northern Arizona, USA. *Journal of Vegetation Science, 20*(2009), 1-12.

Sefidi, K. (2012). Late successional stage dynamics in natural Oriental Beech (Fagus orientalis Lipsky) stands, northern Iran. Unpublished, Ph.D. thesis of forestry. *University of Tehran,* 174p.

Sefidi, K., & Marvie-Mohadjer, M.R. (2010). Snag dynamic in a mixed Beech forest. *Iranian Journal of Forest and Poplar Research,18*(4), 517-526.

Sefidi, K., & Marvi-Mohajer, M.R. (2010). Characteristics of coarse woody debris in successional stages of natural beech (*Fagus orientalis* Lipsky) forests of northern Iran. *Journal of Forest Sciences*, *56*, 1.7–17.

Stella, T., Vehkaoja, M., & Nummi, P. (2016). Beaver-created deadwood dynamics in the boreal forest. *Forest Ecology and Management*, 1–8.

Stella, J.M., Cousins John, J., Battles John, E., & Sanders Robert, A.Y. (2015). Decay patterns and carbon density of standing dead trees in California mixed conifer forests. *Forest Ecology and Management,* 136–147.

Stoll, P., & Bergius, E. (2005). Pattern and process: competition causes regular spacing of individuals within plant populations. *Journal of Ecology, 39*(2), 395-403.

Stoyan, D., & Penttinen, A. (2000). Recent application of point process methods in forest statistics. *Statistical Science,* 61-78.

Thomas, P., & Sullivan Druscilla, S. (2012). Woody debris, voles, and trees: Influence of habitat structures (piles and windrows) on long-tailed vole populations and feeding damage, *Forest Ecology and Management, 263*(1), 189–198.

Vasile, D., Petritan, A.M., Tudose, N.C., Toiu, F.L., Scarlatescu, V., & Petritan, I.C. (2017). Structure and distribution pattern of Dead Wood in Two Temperate Old-Growth Mixed European Beech Forests. *Not Bot HortiAgrobo,* 639-645.

Wiegand, T., Moloney, K.A. (2004). Rings,circles, and null-models for point patternanalysis in ecology. *OIKOS,* 209-229.

Woodall, C.W., & Monleon, V.J. (2008). Sampling protocols, estimation procedures, and analytical guidelines for the down woody materials indicator of the Forest Inventory and Analysis Program. Gen. Tech. Rep. NRS-22. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station, 68 p.

Woodall, C.W., Westfall, J.A., Lutes, D.C., & Oswalt, S.N. (2008). End-point diameter and total length coarse woody debris models for the United States. *Forest Ecology and Management,* 3700–3706.

مجلهٔ جنگل ایران، انجمن جنگلبانی ایران
سال سیزدهم، شمارهٔ ۵، زمستان ۱۴۰۰
ص ۵۵-۴۳
مقاله پژوهشی

شناسه دیجیتال (DOI): 10.22034/ijf.2022.317191.1822
شناسه دیجیتال (DOR): 20.1001.1.20086113.1400.13.5.4.1

الگوی پراکنش مکانی خشک‌دارهای راش در جنگل‌های مدیریت شده و مدیریت نشده شمال ایران

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(تاریخ دریافت: ۱۴۰۰/۰۹/۰۷؛ تاریخ پذیرش: ۱۴۰۱/۱۲/۲۰)

چکیده

اهمیت اکولوژیک خشک‌دارها موجب شده تا جمع‌آوری اطلاعات مربوط به آنها به طور روزافزون گسترش یابد و در طرح‌های مدیریتی مورد توجه قرار گیرند. خشک‌دارها یکی از اجزای اصلی اکوسیستم‌های جنگلی محسوب می‌شوند. دو منطقه مدیریت‌شده و مدیریت نشده از سری گرازبن جنگل آموزشی-پژوهشی خیرودکنار نوشهر به عنوان منطقه مورد مطالعه انتخاب و آماربرداری صددرصد از خشک‌دارها انجام شد. برای بررسی الگوی مکانی خشک‌دارها، از تابع تک متغیره آماره اورینگ (*O-ring*) استفاده شد. نتایج مطالعه حاضر نشان داد که در هر دو منطقه بیشترین و کمترین درصد فراوانی خشک‌دارها به ترتیب مربوط به درجات پوسیدگی ۳ تا ۶ و درجات ۱ و ۲ می باشد. نتایج نشان داد که الگوی پراکنش خشک‌دارها در منطقه مدیریت شده تصادفی است. به طور کلی در منطقه مدیریت نشده الگوی پراکنش خشک‌دارها با درجات پوسیدگی ۳ تا ۶ تصادفی است. بر این اساس می توان بیان نمود که آشفتگی در منطقه مدیریت‌شده و نشده در مقیاس کوچکتری صورت گرفته است.

واژه‌های کلیدی: آماره اورینگ، الگوی مکانی، خشک‌دارها و درجات پوسیدگی.

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