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Research paper

Structural Characteristics of Coppice Stands of Oriental Beech (*Fagus orientalis* Lipsky) in the Hyrcanian Forests: A Comparative Analysis

Mohsen Javanmiri Pour[1*], Vahid Etemad[2], Mehran Esmaeili[2]

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ABSTRACT Forests exhibit unique characteristics shaped by various environmental factors, with stand structure playing a crucial role in forest regeneration and microclimate regulation. This study investigates the structure of forest stands, focusing on coppice oriental Beech (*Fagus orientalis* Lipsky) within the Hyrcanian forests of Iran. Three 25-hectare coppice beech stands were selected for analysis in the Chetan, Douhezar, and Garasmassar regions. To evaluate spatial structure—the distribution patterns of tree species within a stand-five rectangular sample plots, each measuring 50 × 100 meters (0.5 hectares), were established within each stand, reflecting the high density characteristic of coppice stands. The volume of deadwood was estimated by measuring the height and diameter of all standing dead trees, as well as the length and diameter of fallen dead trees. In Chetan, the species density was 219.35 trees per hectare, primarily comprising beech (184 trees per hectare), with a total volume of 205.8 m^3ha^{-1}. Douhezar and Garasmassar exhibited densities of 294 and 365.5 trees per hectare, with volumes of 204.5 m^3ha^{-1} and 350.7 m^3ha^{-1}, respectively. Across all stands, beech accounted for the highest volume and demonstrated a significant presence of deadwood. Chetan showed a notable prevalence of groups with four sprouts, whereas Douhezar and Garasmassar exhibited more groups with five sprouts. The deadwood analysis indicated varying degrees of decay, with the highest frequency observed for first-degree deadwood across all stands. Structural indices, including the Pielou separation index, Clark and Evans index, and diameter differentiation index, were applied to assess species diversity and stand uniformity. Statistical analysis using ANOVA and Kruskal-Wallis tests revealed significant differences in these indices among the studied regions. The structural analysis of beech coppice stands in the Hyrcanian forests—specifically in the Chetan, Douhezar, and Garasmassar regions—highlighted notable variations in species density, volume, and deadwood distribution. The findings underscore the necessity for sustainable forest management practices that address both ecological integrity and socio-economic needs of local communities.

KEYWORDS: Dead tree, beech, spatial structure, volumetric inventory.

Introduction

Forests, shaped by environmental factors, exhibit unique characteristics, with stand structure playing a crucial role in forest regeneration and microclimate regulation (Tinya et al. 2021, Shabani et al. 2022). In forest management, analyzing the structure of forest stands (SFS) is essential for evaluating the current status and developing future guidelines, such as cutting operations and regeneration strategies (Kint et al. 2000, Latterini et al. 2023). Understanding and describing forest ecosystems rely heavily on examining stand structure, which serves as a fundamental component of forest ecology (Javanmiri Pour et al. 2016, Seidl et al. 2022).

A forest stand, whether originating from seed or coppice, typically undergoes various structural transformations throughout its life cycle, akin to the evolution of a building's design (Alder et al. 2023, Trentanovi et al. 2023). To effectively understand, study, and manage forest stands, it is essential to first examine their defining characteristics (Eriksson et al. 2021, Achim et al. 2022). Analyzing the profile of a forest stand is particularly significant, as it provides a comprehensive understanding of its structural attributes (Javanmiri Pour et al. 2017, Ali 2019, Hämäläinen et al. 2024, Javanmiri Pour et al. 2024).

The structure of a forest stand generally encompasses multiple elements, including species diversity, density, volume, the distribution of tree sizes, the vertical distribution of crowns, the spatial distribution of trees and shrubs, the abundance of standing deadwood (i.e., snags), fallen deadwood (i.e., logs), and regeneration dynamics (Javanmiri Pour et al. 2019, Ali 2019, Bowditch et al. 2020, Kaushal and Baishya 2021, Hébert 2023).

In the field of structural analysis, European researchers have extensively studied natural seed-origin and coppice stands in recent decades. Prominent contributions include works by Leibundgut (1983), Korpel (1995), Emborg et al. (2000), Coppini and Hermanin (2007), Nocentini (2008), Šrámek et al. (2015), Sjölund and Jump (2015), Mariotti et al. (2017), Alder et al. (2023), and Latterini et al. (2023).

In Iran, research on the structure of natural seed-origin stands (i.e., standard stands) in the Hyrcanian forests has also gained attention in recent years, though it remains relatively scattered. Notable studies include those by Mehdiani et al. (2012), Delfan Abazari et al. (2004), Namiranian (2010), and Mataji and Namiranian (2021).

The Hyrcanian forests are home to approximately eighty tree species and fifty shrub species (Mahmoudi et al. 2016, Mohammadnezhad Kiasari et al. 2023). Historically, these forests were subject to traditional exploita-

1 - Agriculture and Natural Resources Research and Education Center - Iran
2 - Natural resources faculty, University of Tehran - Iran
*Corresponding author: mjavanmiri@ut.ac.ir

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tion. However, since 1959, they have been managed under formal forestry plans employing various silvicultural methods (Marvi Mohadjer 2013). The forest stands resulting from these exploitations are predominantly of seed-origin, with a limited presence of coppice stands (Marvi Mohadjer 2013, Karami et al. 2017).

Coppice forests generally lack significant value for industrial wood production. However, due to their critical role in regulating water cycles, preventing soil erosion, and maintaining the ecological balance of habitats, they require careful attention and evaluation, particularly in less degraded areas (Sagheb Talebi et al. 2014, Nocentini et al. 2022). Further degradation and alterations to natural conditions may render their future restoration infeasible (Pourhashemi 2019, Nocentini et al. 2022).

These forests serve several important functions, including livestock grazing, fuelwood harvesting, seed collection, and the gathering of non-timber forest products (Sagheb Talebi et al. 2014, Derebe and Alemu 2023).

The oriental beech (*Fagus orientalis* Lipsky) is one of the commercially significant species in the northern forests of Iran. It predominantly occurs in irregular to regular seedling forms and is often observed in two- to three-stemmed clusters (Moradi 2022, Fazlollahi Mohammadi et al. 2022). Historical exploitation by local villagers in some upland areas has led to the formation of coppice stands in certain beech forests.

Oriental beech is a dominant species in the northern forests of Iran, which are primarily seed-origin forests (Javanmiri Pour et al. 2019). Although oriental beech generally exhibits poor sprouting capability, it can produce shoots and establish coppice stands under specific circumstances (Marvi Mohadjer 2013). These conditions may arise naturally due to harsh climatic or habitat factors, or unnaturally as a result of human-induced disturbances (Khoshnevis et al. 2019, Mora et al. 2022).

Research on coppice stands has been limited to studies in Fandoghlo (Aghabarati et al. 2018) and the Zagros forests (Amirghasemi et al. 2001, Pilehvar et al, 2015, Pourhashemi et al. 2014, Pirozi et al. 2018, Pourhashemi and Alimahmoodi Sarab 2021, Esmaeili et al. 2023). In contrast, extensive research has been conducted on seed-origin stands (SOS) of beech forests in the Hyrcanian region over recent decades. However, no comparable studies exist on the coppice stands of this species.

Coppice forests have often transitioned in density and growth form from seed-origin to coppice due to factors such as degradation and uncontrolled grazing (Unrau et al. 2018). However, the extent of degradation varies across regions, with some areas still maintaining dense and well-preserved seed-origin forest cover. Given the variability in stand density and diversity, a detailed examination of the structural characteristics of these stands as ecosystems—often influenced over time by threatening factors, particularly human activities—is essential.

This study aims to investigate and compare the structure of coppice beech stands in different regions of the Hyrcanian forests, providing valuable insights into their ecological dynamics and contributing to informed management and conservation strategies.

Material and Methods

Study area

The Caspian Hyrcanian mixed forests, also known as the Caspian Hyrcanian forest, form a biogeographical region within the broadleaf mixed forests along the southern shores of the Caspian Sea and the northern slopes of the Alborz Mountains, covering an area of 55,000 square kilometers (21,000 square miles), or approximately 7% of Iran's total land area. These forests extend along the southern and southwestern shores of the Caspian Sea, across five Northern provinces of Iran, and into the Republic of Azerbaijan. With a history spanning 25 to 50 million years (Paleogene period), this forest is regarded as one of the most valuable in the world and is often referred to as a "natural museum." During the Paleogene period, such forests once covered much of the northern temperate regions of Earth. Although they shrank during the Ice Age (Quaternary period), they began to expand again following its conclusion.

The first forest stand under investigation is located southwest of Chetan village, in the Panjek-e Rostaq district of Kojur County, Nowshahr, and approximately 67 kilometers from the city. The geographical coordinates of this area are approximately 54°19'36" latitude and 08°28'51" longitude, with an average elevation of 1,950 meters above sea level.

Another stand under investigation is located in the Two Thousand area of Tonekabon County. The nearest city, Tonekabon, is approximately 35 kilometers from the study area. Situated at an elevation of 2,100 meters above sea level, the stand is surrounded by four prominent mountains. It is bounded by the Sialan Strait, the peaks of Khoshchal and Kandigan to the west, and Taleghan to the east. The geographical coordinates are approximately 40°45'665" latitude and 47°45'90" longitude.

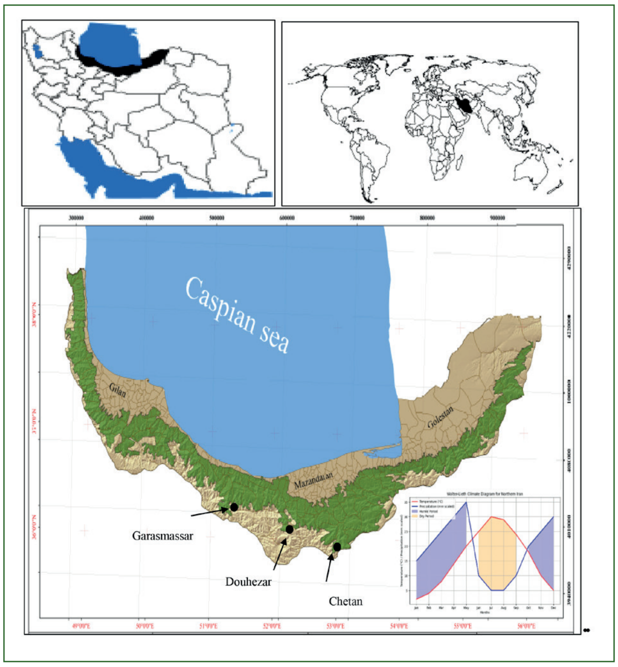
A third forest stand is located in Ramsar County, near Garasmassar village, at an elevation of 2,000 meters above sea level, approximately 60 kilometers southwest of Ramsar city.

The approach to forest management varies across these stands. Traditional management methods are employed in Chetan, while Garasmassar follows a formal forest management plan. In contrast, the Douhezar stand remains unmanaged, with no special interventions (i.e., habitat control).

The climate of these forests is humid and directly influenced by the Caspian Sea. Annual rainfall varies across the region, ranging from 530 mm in the east to 1,350 mm in the west, with occasional peaks reaching up to 2,000 mm in the western areas. Based on data from meteorological stations, the maximum rainfall typically occurs in spring, late fall, and winter. The average annual temperature in the Hyrcanian region ranges from 15°C in the west to 17.5°C in the east. Overall, the climate in the eastern Hyrcanian region is classified as warm Mediterranean, while the central and western parts are characterized by temperate and semi-temperate Mediterranean climates, with occasional temperate xeric conditions.

According to the De Martonne method, the climate of oriental beech habitats in Iran-one of the region's most important forest ecosystems-is very humid and cold in the lowlands and midlands (up to 1,700 m), and very humid and ultra-cold in the highlands (up to 2,200 m) (Sagheb Talebi et al. 2014).

Figure 1 - General location of the study areas across the Hyrcanian forests, Northern Iran with the Walter-Lieth climate diagram for northern Iran.



The species diversity in the forests under investigation is exceptionally high. Some of the major tree species include Oriental beech (*Fagus orientalis* Lipsky), Chestnut-leaved oak (*Quercus castaneifolia* C.A. Mey), European hornbeam (*Carpinus betulus* L.), Velvet maple (*Acer velutinum* Boiss), Cappadocian maple (*Acer cappadocicum* Gled.), Field maple (*Acer campestre* L.), Wild pear (*Pyrus glabra* Boiss), Wild service tree (*Sorbus torminalis* (L.) Crantz), Medlar (*Mespilus germanica* L.), Cornelian cherry (*Cornus* sp.), Oriental hornbeam (*Carpinus orientalis* Mill.), Persian oak (*Quercus macranthera* Fisch et Mey), Rowan (*Sorbus aucuparia* L.), Fly honeysuckle (*Lonicera nummularifoli*a Jaub. & Spach), and Wild roses (*Rosa* sp.).

It appears that the mountainous coppice forests of Chetan and Douhezar are currently being exploited without a formal forest management plan. In contrast, the Garasmassar forest operates under a management plan, which likely facilitates more effective forest resource management. The residents of Chetan village are still utilizing forest resources for household purposes. However, charcoal extraction, which was once prevalent in the region, has significantly declined in recent years. The presence of charcoal-enriched black soils in the forest areas surrounding Chetan village is indicative of the intensity and scale of this activity in the past.

Data collection

For this research, three 25-hectare coppice beech stands were selected in the areas of Chetan, Douhezar, and Garasmassar. Each stand was fully inventoried. The species, diameter at breast height (DBH) of all trees exceeding the countable limit (7.5 cm), height, and the number of sprouts in each sprout group were measured. Tree volume was calculated using Equation 1 (Zobeiri 2003).

$$v = \frac{\pi}{4} \times d^2 \times h \qquad \text{(eq.1)}$$

Where V is the volume in cubic meters, d is the diameter at breast height (DBH) in centimeters, and h is the height of the tree in meters.

To examine the spatial structure, which investigates the distribution patterns of different tree species within the stand, five rectangular sample plots were established in each stand, each measuring 50x100 meters and covering 0.5 hectares. These plots were oriented along the dominant slope, with their length aligned to the elevation gradient. Due to the high density of coppice stands, this sampling approach was chosen. The coordinates of the southwestern corner of each sample plot were recorded using a Global Positioning System (GPS) device in the UTM coordinate system.

In the Hyrcanian forests, particularly in coppice stands, the distance between trees is typically short, and the accuracy of GPS devices is limited to approximately five meters. To address this, the distance-azimuth method was employed to record the trees within the sample plots. Additional data, including species, height, crown base height from the ground, crown diameter along the contour lines, general slope of the site, and maximum crown diameter, were also measured and recorded (Javanmiri Pour et al. 2017).

In the sample plot located in the Chetan coppice stand, 340 structural groups were measured; in the Douhezar coppice stand, 315 groups; and in the Garasmassar forest, 325 groups. The relationships, sources, range of values, and interpretations of each spatial structure index are presented e 1.

Pielou's Evenness Index (CE = 1) measures the interspecific mingling of two tree species. Its value ranges from +1 to -1. A value less than zero indicates cohesion, while a value greater than zero indicates spatial separation of species. If tree distribution in the forest follows a random pattern, the value of CE = 1 becomes 0. If CE < 1, a clumped distribution exists, and if CE > 1, it indicates regular positioning of trees (Bravo-Oviedo et al. 2018). A low value (Wi) suggests regularity among trees, while in clumped distributions, this value tends toward 1. When neighboring trees exhibit minimal differences, the DBH differentiation index tends toward zero; however, if there is significant heterogeneity among neighboring trees, this index tends toward 1. If the dimensions of the reference tree are greater than or equal to

Table 1 - Relationships, references, range of values and interpretation of each structure index.

Index	Formula	Range of values	Reference
Pielou index	$P=\pi\lambda\left(\frac{\sum_{i=1}^{n} r_{pi}}{n}\right)^2$	-1<p<1	Pielou, 1977
Clark & Evans	$R=\frac{\hat{r}_{Observed}}{E\,(r)}$	$0 \leq R \leq 2.14$	Bravo-Oviedo et al. 2018
Uniform angle	$W_i = \frac{1}{n}\sum_{j=1}^{n} Vj$	$Vj = \begin{cases} 1, \propto j \leq \propto 0 \\ 0, otherwise \end{cases}$	Pommerening 2002
Mixture	$M_i = \frac{1}{n}\sum_{i=1}^{n} Vj$	$Vj = \begin{cases} 1, species\ j \neq species\ i \\ 0, otherwise \end{cases}$	Füldner 1995, Aguirre et al. 2003
DBH differentiation	$TD_i = \frac{1}{n}\sum_{j=1}^{n} (1 - rij)$	$rij = \frac{smaller\ DBH}{higher\ DBH}$	Füldner 1995, Pommerening 1997, 2002
DBH dominance	$U_i = \frac{1}{3}\sum_{j=1}^{3} v_{ij}$	$v_{ij} = \begin{bmatrix} 1 \rightarrow DBH_i \geq DBH_j \\ 0 \rightarrow DBH_i < DBH_j \end{bmatrix}$	Hui et al. 1998

those of its four neighbors, the dominant DBH index value is 1; if the reference tree is smaller than its neighbors, this index tends toward zero. In the mixture index, when using three neighbors in a structural group, one of the following values is obtained: 0 (all neighbors are similar to the reference species), 0.33 (one neighbor is different from the reference species), 0.66 (two neighbors are different from the reference species), or 1 (none of the neighbors are similar to the reference species).

To estimate the volume of deadwood, the height and diameter of all standing dead trees (i.e., snags) and the length and diameter of fallen dead trees (i.e., logs) were measured. For the fallen trunk sections and branches, the length and diameters at the thin end, middle, and thick end were also recorded. Additionally, considering the importance of decomposition and decay in deadwood and their role in the forest environment, the degree of decay of standing and fallen deadwood was classified into four categories (Tab. 2).

Table 2 - Description of decay classes of deadwood.

Row	Class	Description	References
1	First-degree decay	Freshly fallen tree, with the upper part and crown of the tree intact. Often, thin branches remain, the bark is intact, and the wood is hard.	Harmon et al. 2010
2	Second-degree decay	The upper part and crown of the deadwood remain intact, but most thin branches are dry and fallen. The bark begins to detach from the trunk and becomes less present, although the wood remains hard.	Harmon et al. 2010
3	Third-degree decay	The crown of the tree is broken, and there is no bark or branches. The wood remains hard.	Harmon et al. 2010
4	Fourth-degree decay	The top portion of the deadwood is broken, with no bark or large branches. The wood is transitioning from hard to soft, with more than 70% of it converted into softwood.	Harmon et al. 2010

To calculate the volume of fallen deadwood, since the longitudinal shape of the trunk resembles an incomplete paraboloid, the Smalian (eq. 2) and Huber (eq. 3) formulas were used.

$$V = \frac{g_1 + g_2}{h} \times h \qquad \text{(eq. 2)}$$

$$V = \frac{g_1 + g_2}{h} \times h \qquad \text{(eq. 3)}$$

Where *g1*, *g2*, and gm represent the lower, upper, and middle cross-sectional areas, respectively, and *h* is the height of the incomplete paraboloid.

Visually, the longitudinal shape of the tree trunk at ground level initially resembles an incomplete hyperbolic Paraboloid (Zobeiri 2003). The formula for calculating the volume of an incomplete Paraboloid is presented in Equation 4.

$$v = \frac{h}{6}\left(g_1 + 4g_m + g_2\right) \qquad \text{(eq. 4)}$$

Where h is the height of the incomplete paraboloid, g1 is the lower cross-sectional area, g2 is the upper cross-sectional area, and gm is the middle cross-sectional area.

For standing dead trees that have broken due to structural failure, none of the previously mentioned equations are applicable. Instead, Equations 5 and 6, as proposed by Travaglini and Chirici (2006), were utilized. Equation 5 is used to calculate the diameter reduction coefficient (Namiranian 2010), and it is as follows:

$$d_{fg} = \frac{d_{1.3}}{h - 1.3} \qquad \text{(eq. 5)}$$

Where dfg represents the diameter reduction coefficient, d1.3 is the diameter at breast height (DBH), and h is the total height.

The Equation 6 is also used to calculate the mean diameter and is as follows:

$$d_m = d_{1.3} - \left(d_{fg} \times \frac{1}{2}\right) \qquad \text{(eq. 6)}$$

Where d_m represents the diameter at breast height of the tree.

Using the mean diameter obtained from Equation 5, the Huber formula (eq. 3) was used to calculate the volume.

The analytical method

For statistical analyses, SPSS version 24 was used to evaluate statistical differences between groups, while Integrate+ (Bravo-Oviedo et al. 2018) and R (R Core Team 2021) were employed to calculate indices related to spatial distribution patterns. Data normality was assessed using the Kolmogorov-Smirnov test. For normally distributed data, a parametric ANOVA test was conducted at a 95% confidence level to identify statistically significant differences between groups. For rank-based data, such as the degree of decay in dead trees, the non-parametric Kruskal-Wallis test was applied at the same confidence level.

Results

Main tree data attributes

In the beech coppice stand at Chetan, the species density was recorded at 219.35 trees per hectare, with beech contributing 184 trees per hectare to the total. Hornbeam and lime accounted for 10 and 5 trees per hectare, respectively, while other species included hawthorn, plum, wild apple, wild pear, and ash (Tab. 3).

The total volume of all species in the stand was 198.5 m³ha⁻¹, with beech having the highest volume at approximately 146.2 m³ha⁻¹. Wild pear exhibited the lowest volume at 0.75 m³ha⁻¹. The volume of deadwood across all species was 7.3 m³ha⁻¹, with beech contributing the largest share at 3.6 m³ha⁻¹ and hawthorn the smallest at 0.12 m³ha⁻¹ (Tab. 3).

In the Douhezar coppice stand, the total tree density was 273 trees per hectare, with a combined volume of 190.8 m³ha⁻¹. Beech, Hornbeam, and Maple were the most prevalent species, with densities of 175.5, 16, and 9 trees per hectare, respectively (Tab. 4).

The total volume of standing deadwood in this stand was estimated at 13.25 m³ha⁻¹, with beech contributing the largest share at 7.3 m³ha⁻¹.

In the Garasmassar coppice stand, the total tree density was 338 trees per hectare, with a combined volume of 215.6 m³ha⁻¹. Beech, Hornbeam, and Maple were the most abundant species, with densities of 312, 15, and 5 trees per hectare, respectively (Tab. 3).

The total volume of standing deadwood in this stand was estimated at 9.7 m³ha⁻¹, with beech accounting for the largest share at 8.3 m³ha⁻¹.

The primary structural characteristics of the studied habitats, including density, mean height, cross-sectional area, volume, and age, are summarized in Table 6. The highest tree density was recorded in the Garasmassar habitat, with 365.5 individuals per hectare. The Douhezar habitat exhibited the tallest trees, with a mean height of 21.5 meters. The Douhezar habitat also contained the oldest beech trees among the studied sites.

In the Chetan coppice stand, the highest frequency of sprouts within beech sprout groups was observed in groups

Table 3 - The total volume, the mean volume of one stem and the volume per hectare of all types of species and plants present in the Chetan stand.

Species	Type	Mean diameter (cm)	Total volume (m³)	Total Frequency	Frequency (N ha⁻¹)	Volume per hectare (m³)	Volume Per one stem (ha)	The ratio of dead trees to living trees (%)
Beech	Live tree	18.4	3655	4350	174	146.2	0.84	2.46
	Dead tree	13.55	90	242.5	9.7	3.6	0.37	
Hornbeam	Live tree	20.4	613.75	250	10	24.55	2.45	7.98
	Dead tree	14.9	48.25	17.5	0.7	1.96	2.8	
Maple	Live tree	19.5	258.75	125	5	10.35	2.07	1.2
	Dead tree	11	3.125	5	0.2	0.125	0.625	
Wild pear	Live tree	12.7	18.75	15	0.6	0.75	1.25	44
	Dead tree	13	8.25	8.75	0.35	0.33	0.94	
Hawthorn	Live tree	9.4	49.5	82.5	3.3	1.98	0.6	6.06
	Dead tree	10.5	3	20	0.8	0.12	0.15	
Common Medlar	Live tree	9.6	162.5	205	8.2	6.5	0.79	17.5
	Dead tree	9.25	28.5	100	4	1.14	0.285	
Ash	Live tree	36.85	175	8.75	0.35	7	20	0
	Dead tree	-	-	-	-	-	-	
Plum	Live tree	-	-	-	-	-	-	0
	Dead tree	10.7	28.75	53.75	2.15	1.15	0.53	
Sum	Live tree	-	4914.5	5036.25	203.6	198.5	0.97	3.7
	Dead tree	-	209.875	447.5	15.75	7.3	0.46	

Table 4 - The total volume, the mean volume of one stem and the volume per hectare of all types of species and plants present in the studied Douhezar stand.

Species	Type	Mean diameter (cm)	Total volume (m^3)	Total Frequency (N)	Frequency (N ha^{-1})	Volume (m^3 ha^{-1})	The ratio of dead trees to living trees (%)
Beech	Live tree	34.2	3983.75	4387.5	175.5	159.35	4.58
	Dead tree	21.5	182.5	537.5	21.5	7.3	
Hornbeam	Live tree	38	452.5	400	16	18.1	25.4
	Dead tree	31	115	100	4	4.6	
Maple	Live tree	25.5	112.5	225	9	4.5	18.7
	Dead tree	43	21	100	4	0.84	
Other Sp.	Live tree	21	221.25	200	8	8.85	5.65
	Dead tree	15	12.5	25	1	0.5	
Sum	Live tree	-	4770	5212.5	273	190.8	6.95
	Dead tree	-	331	762.5	21	13.25	

Table 5 - The total volume, the mean volume of one stem and the volume per hectare of all types of species and plants present in the Garasmassar stand.

Species	Type	Mean diameter (cm)	Total volume (m^3)	Total Frequency (N)	Frequency (N ha^{-1})	Volume (m^3 ha^{-1})	The ratio of dead trees to living trees (%)
Beech	Live tree	28.4	5150	7800	312	197.5	4.2
	Dead tree	21	207.5	537.5	21.5	8.3	
Hornbeam	Live tree	33	320	375	15	12.8	5.5
	Dead tree	15	17.7	100	4	0.7	
Maple	Live tree	28.5	79.7	125	5	3.2	11.25
	Dead tree	34	9.07	100	4	0.36	
Other Sp.	Live tree	21	52	150	6	2.08	14.4
	Dead tree	14	7.5	50	2	0.3	
Sum	Live tree	-	5601.7	8450	338	215.6	4.5
	Dead tree	-	241.8	787.5	31.5	9.66	

Table 6 - Summary of forest stand structure variables for each surveyed forest.

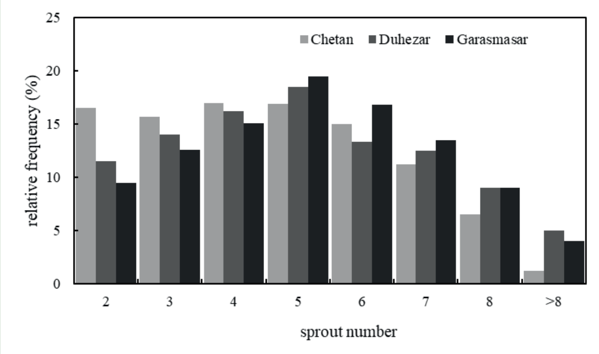
Study Area	Stem Density (stems/ha)	Average Height (m)	Basal Area (m^2ha^{-1})	Volume (m^3ha^{-1})	Age (years)
Chetan	219.35	14.40	30.70	205.80	70
Douhezar	294	21.50	34.65	204.50	120
Garasmassar	365.5	16.50	36.50	350.70	90

with four sprouts, accounting for 17% of the total. This was followed by groups with five sprouts (16.9%) and two sprouts (16.5%) (Fig. 2).

In the Douhezar coppice stand, the highest frequency (18.5%) occurred in groups with five sprouts. Groups with four sprouts and three sprouts followed with frequencies of 16.2% and 14%, respectively (Fig. 2).

In the Garasmassar coppice stand, the most frequent sprout groups were those with five sprouts, making up 16.5% of the total. Groups with six sprouts (15.4%) and four sprouts (14.1%) followed in frequency (Fig. 2).

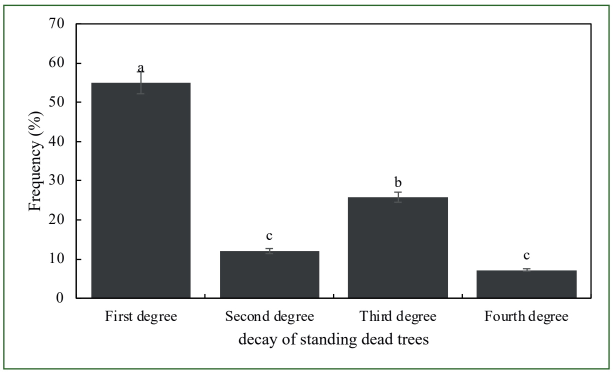
Figure 2 - The frequency of the number of shoots in a Beech coppice group in Chetan, Duhezar and Garasmssar.



In the Chetan coppice stand, all dead beech trees were classified as standing deadwood. Among these, first-degree standing dead trees had the highest frequency, accounting for 55% of the total. This was followed by third-degree (25.7%), fourth-degree (12.1%), and second-degree (7.2%) standing dead trees (Fig. 3).

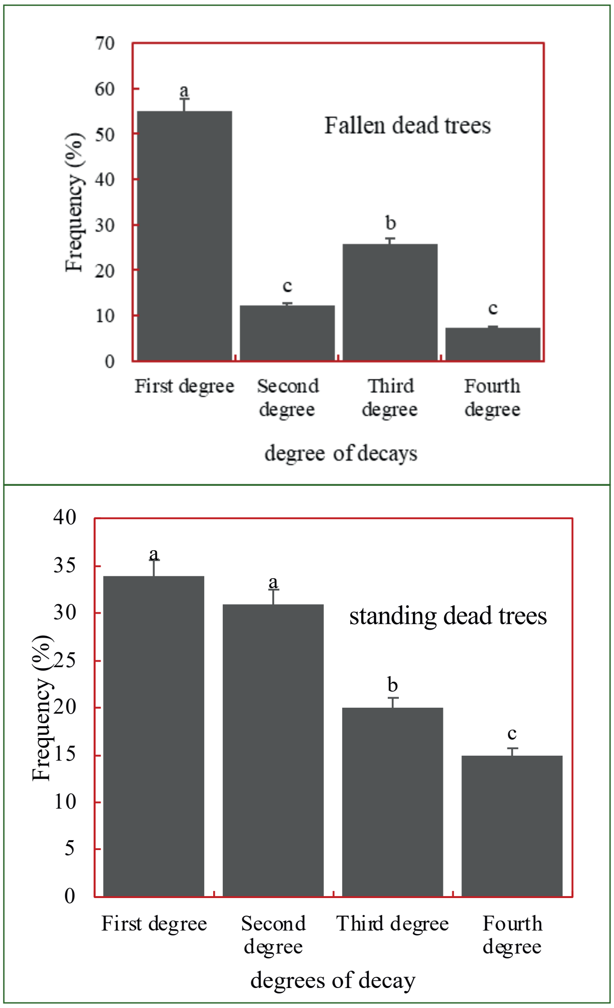
The deadwood in the Douhezar coppice stand comprised

Figure 3 - The frequency of beech standing dead trees decay in the studied coppice stand.



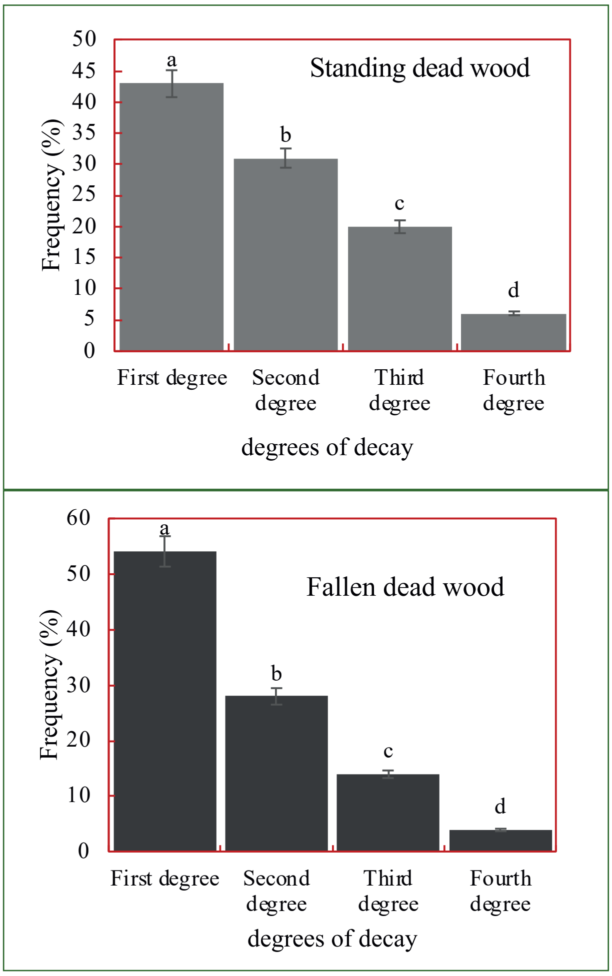
both standing and fallen types, with volumes of 10.35 and 2.9 m³ha⁻¹, respectively. Among standing deadwood, first-degree deadwood exhibited the highest frequency at 35%, followed by second-degree (31%), third-degree (20%), and fourth-degree (15%) categories. For fallen deadwood, first-degree deadwood also had the highest frequency at 42%, with second-degree, third-degree, and fourth-degree categories following at 32%, 18%, and 8%, respectively (Fig. 4).

Figure 4 - The frequency of beech standing and fallen dead trees decay in the studied standard stand in Duhezar.



In the Garasmassar stand, the volumes of standing and fallen deadwood were 7.5 and 3.6 m³ha⁻¹, respectively. Among standing deadwood, first-degree deadwood had the highest frequency at 43%, followed by second-degree (31%), third-degree (20%), and fourth-degree (6%) categories. For fallen deadwood, first-degree deadwood exhibited the highest frequency at 54%, with second-degree, third-degree, and fourth-degree categories following at 28%, 14%, and 4%, respectively (Fig. 5).

Figure 5 - The frequency of beech standing and fallen dead trees decay in the studied stand in Garasmassar.



The average Pielou separation index for the Chetan, Douhezar, and Garasmassar coppice stands were -0.004, -0.59, and -0.40, respectively. Additionally, the average Clark and Evans values for the beech coppice stands in Chetan, Douhezar, and Garasmassar were 0.37, 0.45, and 0.39, respectively (Tab. 7).

The highest frequency of the tree species diversity index in the beech coppice stands of Chetan, Douhezar, and Garasmassar occurred in the zero class (low difference), with frequencies of 74%, 70%, and 68%, respectively (Fig. 6).

The highest uniform angle values in the Chetan, Douhezar, and Garasmassar coppice stands were 71%, 73%, and 84%, respectively, all occurring in class 1 (Fig. 6).

Table 7 - Values of Pielou segregation and Clarke-Evans indices in coppice beech stands.

Index	Chetan	Douhezar	Garasmassar
Pieluo segregation index	-0.004	-0.59	-0.4
Clarke-Evans index	0.37	1	0.39

The highest value of the diameter differentiation index in the Chetan beech coppice stand was observed in the 0.2-0.4 class (low diameter difference) with a value of 63%. In the Douhezar coppice stand, the highest value occurred in the 0.4-0.6 class with a value of 63%. In the Garasmassar stand, the highest diameter differentiation index was observed in the 0.4-0.6 class with a value of 65% (Fig. 6).

In the Chetan beech coppice stand, the highest level of differentiation in the diameter variation index was observed in class 1 (low diameter difference) with a value of 52%. The highest values of this index in the Douhezar and Garasmassar coppice stands occurred in class 1, with values of 68% and 65%, respectively (Fig. 6).

The ANOVA test revealed a significant difference in the UA index among the studied groups (i.e. Chetan, Duohezar and Garasmassar) at a 95% probability level (p=0.05); (table 8).

Table 8 - Results of analysis of UA index using ANOVA test among the studied stands.

UAI	Sum of Squares	df	Mean Square	F	p-value
Between Groups	0.089	2	0.044	0.418	0.046*
Within Groups	6.046	57	0.106		
Total	6.135	59			

*** Significance at the 0.01 level, * significance at the 0.05 level, ^{ns} no significance*

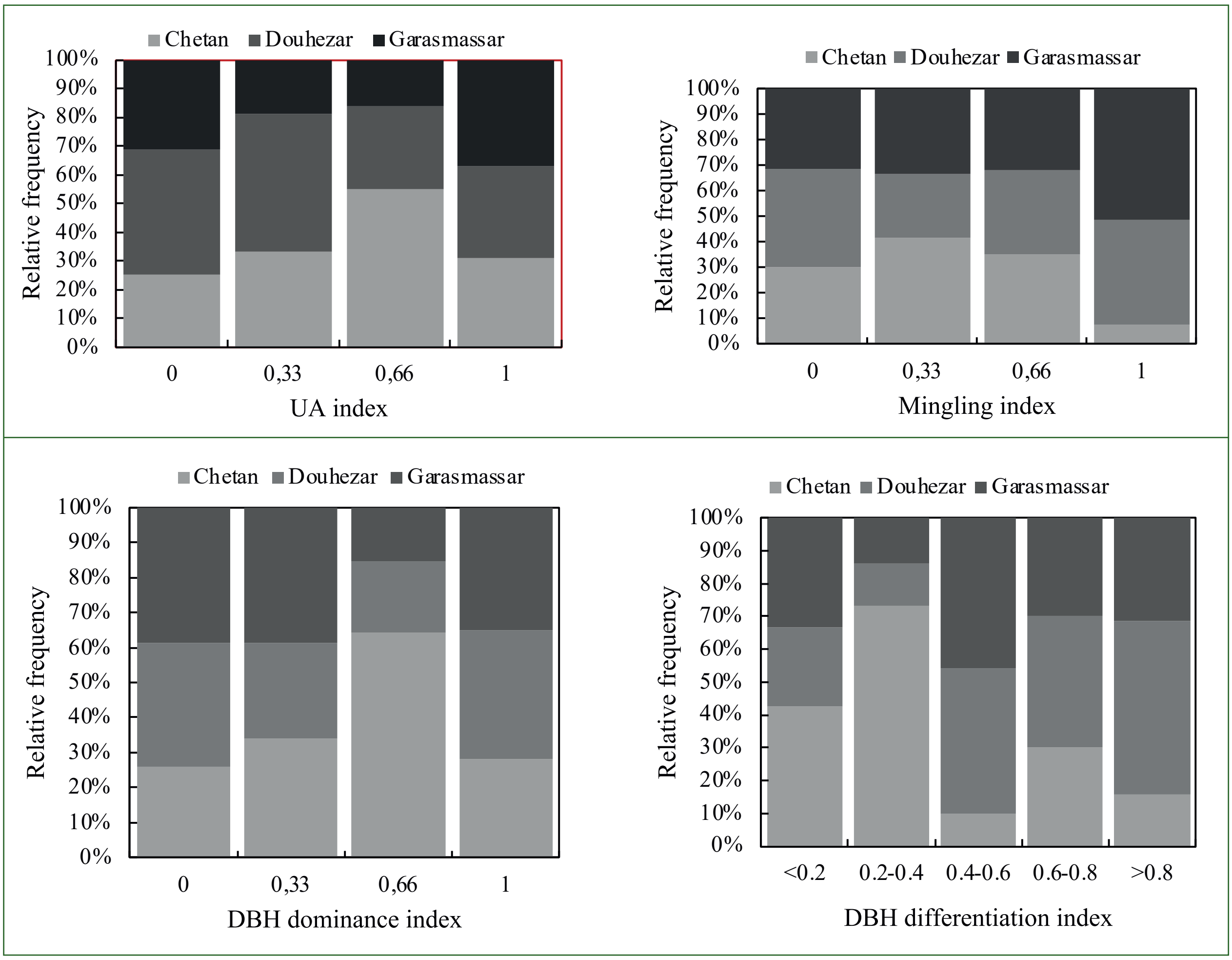
The ANOVA test revealed a significant difference in the Mingling index among the studied groups (i.e. Chetan, Duohezar and Garasmassar) at a 95% probability level (p=0.05); (Tab.) 9).

Table 9 - Results of analysis of mingling index using ANOVA test among the studied stands.

Mingling	Sum of Squares	df	Mean Square	F	p-value
Between Groups	0.000	2	0.000	0.001	0.049*
Within Groups	4.250	57	0.075		
Total	4.250	59			

*** Significance at the 0.01 level, * significance at the 0.05 level, ^{ns} no significance*

Figure 6 - Graph showing mixed, uniform angle, DBH difference, and DBH dominance indices for beech trees across the Chetan, Duohezar, and Garasmassar forest stands.



The ANOVA test revealed a significant difference in the DBH dominance index among the studied groups (i.e. Chetan, Duohezar and Garasmassar) at a 95% probability level (p=0.05); (Tab. 10).

Table 10 - Results of analysis of DBH dominance index using ANOVA test among the studied stands.

DBH dominance	Sum of Squares	df	Mean Square	F	p-value
Between Groups	0.000	2	0.000	0.001	0.04**
Within Groups	2.907	57	.051		
Total	2.907	59			

*** Significance at the 0.01 level, * significance at the 0.05 level, ^{ns} no significance*

The ANOVA test revealed a significant difference in the DBH differentiation index among the studied groups (i.e. Chetan, Duohezar and Garasmassar) at a 95% probability level (p=0.05); (Tab. 11).

Table 11 - Results of analysis of DBH differentiation index using ANOVA test among the studied stands.

DBH differentiation	Sum of Squares	df	Mean Square	F	p-value
Between Groups	0.000	2	0.000	0.000	0.045*
Within Groups	3.643	72	0.051		
Total	3.643	74			

*** Significance at the 0.01 level, * significance at the 0.05 level, ^{ns} no significance*

The results of the Kruskal-Wallis non-parametric test indicated an non-significant difference (p = 0.001) in the frequency of decay degrees of dead trees among the Chetan, Garasmassar, and Douhezar coppice stands at a 5% probability level (Tab. 12).

Table 12 - Results of analysis of dead trees abundance using Kruskal-Wallis test among the studied stands.

Kruskal-Wallis H	df	p-value
.464	2	0.397^{ns}

*** Significance at the 0.01 level, * significance at the 0.05 level, ^{ns} no significance*

Discussion

Density, Volume and Species Composition

The highest density in the Garasmassar coppice stand was attributed to the beech species, accounting for approximately 365.5 stems per hectare (46.4%) and a volume of 350.7 m^3ha^{-1} (46.15%). In contrast, the Chetan coppice stand contained 219 beech stems per hectare (28.1%) and a while total volume of 205.5 m^3ha^{-1} (26.85.9%). Similarly, in the other two stands, beech species dominated in both abundance and volume density, as it remains the sole coppice species.

Marvi Mohadjer (2013) estimated the volume of forest stands in northern Iran to be approximately 300 m^3ha^{-1}. A study by Sefidi et al. (2014) on managed Oriental beech stands using the selection method in the Kheyroud Forest of Nowshahr reported an average volume of 386 m^3ha^{-1}, with an average of 189 trees per hectare. Similarly, Javanmiri Pour et al. (2017) recorded an average volume of 389.14 m^3ha^{-1}, with 282 trees per hectare, in managed stands subjected to the selection method in the same forest.

These findings pertain to seed-origin beech stands, where the calculated volumes are approximately twice those observed in the coppice stands of the present study. This discrepancy persists despite a similar number of trees per hectare, as noted by Javanmiri Pour et al. (2017). The observed difference suggests a higher prevalence of low-quality trees in the coppice stands, including those with broken crowns, fractured trunks, hollow interiors, uprooting, or fungal infections.

Comparison of Beech Abundance and Diameter Variations

The distribution and structural characteristics of beech (*Fagus* spp.) vary across different coppice stands, reflecting the influence of local environmental conditions and stand dynamics. In the present study, the abundance of beech in the Garasmassar coppice stand was found to be higher than in the Douhezar and Chetan coppice stands. Similarly, the total volume of beech in Garasmassar exceeded that recorded in both the Chetan and Douhezar stands, indicating more favorable growth conditions or differences in stand history and management practices.

A closer examination of volume differences between the Chetan and Douhezar coppice stands suggests that tree size distribution plays a significant role. Although the total volume of beech trees in Chetan surpasses that of Douhezar, this difference can be attributed to variations in tree density and diameter distribution. Specifically, the smaller average diameter of beech trees in Chetan (18.4 cm) compared to Douhezar (34.2 cm) suggests that the higher tree density in Chetan compensates for the reduced individual tree size, thereby contributing to a greater overall volume.

These findings align with previous studies on coppice beech forests. Aghabarati et al. (2018) investigated coppice beech stands in Fandoghlou, Ardabil, and reported substantial variability in tree diameters across different sites. At the Suha and Abibiglou locations, the maximum recorded diameters were 55 cm and 60 cm, respectively, with mean diameters at breast height (DBH) of 19.6 cm and 14.15 cm. In contrast, the Niaraq site exhibited a weaker stand structure, characterized by a maximum diameter of 35 cm and a mean DBH of 9.25 cm.

In comparison, the results of the present study reveal that the Chetan coppice stand exhibits considerable diameter diversity. The mean DBH recorded in this study (18.4 cm) falls within the range reported by Aghabarati et al. (2018), while the maximum observed diameter of 140 cm significantly exceeds the values documented in their study. This suggests that the Chetan coppice stand not only supports a high density of smaller-diameter trees but also contains a subset of large-diameter individuals, contributing to a more structurally diverse forest stand. Such diameter diversity may indicate a mix of age classes or varying growth rates within the stand, possibly influenced by site-specific factors such as soil conditions, microclimate, and past management interventions.

Ecological and Climatic Influences on Coppice Development

The results of this study are compared with those of the Fandoghlou region due to the lack of similar research on coppice beach in the Hyrcanian forests. Although the comparative study was conducted outside the northern forests of Iran, the Fandoghlou area shares ecological characteristics conducive to the growth and survival of coppice beech. Its proximity to the northern forests and its similar humidity and environmental conditions make it a relevant point of comparison.

Certain broadleaf species possess a natural ability to produce shoots or suckers, making them valuable for firewood and charcoal production (Marvi Mohadjer 2013). The beech species in the study areas exhibit this characteristic. The presence of coppice beech stands in the temperate forests of northern Iran underscores the adaptability of this species. Beech trees typically thrive in mid-elevation forests (700–1,800 m), where they achieve optimal growth. However, under specific natural or anthropogenic conditions, coppice beech trees can also develop.

It is widely believed that drier and harsher climates enhance the ability of trees to produce shoots (König et al. 2022). According to Marvi Mohadjer (2013), the beech forests of northern Iran are predominantly seed-originated, as beech inherently exhibits a weak capacity for shoot production. However, under conditions such as severe human interventions, beech can produce shoots and form coppice stands, as observed in the Chetan stand. Findings by Mariotti et al. (2017) on the successful conversion of coppice beech to seed-origin stands in the Alps further support this observation.

Deadwood Distribution and Forest Utilization

The total volume of deadwood per hectare in the Chetan coppice stand was 7.3 m^3, with beech contributing the highest volume (3.6 m^3ha^{-1}) and hawthorn the lowest (0.12 m^3ha^{-1}). In comparison, the Douhezar coppice stand recorded a total deadwood volume of 13.25 m^3ha^{-1}, including 7.3 m^3ha^{-1} from beech, while the Garasmassar coppice stand reported a total of 14.25 m^3ha^{-1}, with 8.3 m^3ha^{-1} attributed to beech. These volumes are significantly lower than those reported in other areas of the northern forests.

In the Chetan coppice stand, deadwood is predominantly standing, whereas both standing and fallen deadwood are observed in the Douhezar and Garasmassar stands. The absence of fallen deadwood in the Chetan stand is primarily attributed to local exploitation; villagers promptly remove fallen deadwood for household and fuel use. Additionally, standing deadwood in decay class four is often harvested by locals, driven by the lack of a forest management plan and the absence of alternative energy sources, such as a gas and oil supply system. This heavy reliance on forest resources places substantial pressure on the Chetan stand.

Implications for Forest Management and Conservation

The analysis of spatial distribution indices in coppice stands provides valuable insights, although the results suggest that these indices deviate significantly from the optimal state found in natural forests unaffected by human intervention. Despite the dominance of beech due to regeneration through coppicing, most indices reflect a clustered or clumped spatial pattern. This outcome is primarily attributed to extensive human activities, particularly logging, to fulfill the needs of local rural communities.

The distribution pattern of many species in forest communities is typically either clumped or regular. Other research indicates that random distribution is rare in forests, as trees often exhibit mutual relationships that influence spatial structure. Furthermore, forest utilization plays a role in shaping tree distribution (Kint et al. 2000). In the present study, human intervention has significantly altered the tree distribution in both the Douhezar and Chetan coppice stands.

Historically, coppice stands were harvested for charcoal production, with surplus charcoal transported to cities for sale. Over time, this practice disrupted the natural state of these stands, making it difficult to determine whether the current structural condition of the trees reflects their original state. However, comparing different stands provides valuable insights into spatial patterns.

Residents of the Chetan and Garasmassar villages continue to rely on tree exploitation for household needs due to the absence of a gas supply network. Consequently, spatial structure indicators may not accurately reflect natural conditions. In this context, Sefidi and Sadeghi (2021) attributed long-term human disturbances such as tree cutting, grazing, and wildfires to changes in the spatial pattern of Oriental beech trees in the Arasbaran stands.

Conclusion

The study reveals substantial variations in density, volume, and species composition across the three stands, primarily attributed to anthropogenic interventions and local environmental factors. Beech emerges as the dominant species in all three stands, albeit with notable discrepancies in tree quality and volume compared to seed-origin stands, indicative of the impact of coppicing practices.

Garasmassar exhibits the highest beech abundance and volume, suggesting more favorable growth conditions or less intensive historical management. Conversely, Chetan, despite its higher tree density, demonstrates a lower average tree diameter, indicative of substantial diameter diversity. This stand also presents the lowest deadwood volume, predominantly in standing form, a consequence of intensive local utilization for fuel due to the absence of alternative energy sources.

The spatial distribution patterns observed in all three stands deviate significantly from those typical of natural forests, exhibiting a clustered arrangement. This pattern is largely attributed to prolonged anthropogenic activities, particularly logging to meet local community needs. These historical and ongoing practices have markedly altered tree distribution, obfuscating the original stand conditions.

The findings underscore the necessity for sustainable forest management practices that address both ecological integrity and socio-economic needs of local communities. Provision of alternative energy sources and implementation of appropriate forest management plans are crucial for mitigating pressure on these valuable coppice ecosystems and promoting their long-term resilience.

References

Achim A., Moreau G., Coops N. C., Axelson J. N., Barrette J., Bédard S., Byrne K., E. Caspersen, J. Dick, A. R. D'Orangeville, L., Drolet G., Eskelson B. N. I., Filipescu C. N., Flamand-Hubert M., Goodbody T. R. H., Griess V. C., Hagerman Sh. M., Keys K., Lafleur B., Girona M. M., Morris D. M., Nock Ch. A., Pinno B. D., Raymond P., Roy V., Schneider R., Soucy M., Stewart B., Sylvain J-D., Taylor A. R., Thiffault,E., Thiffault N., Vepakomma U., White J. C. 2022 - *The changing culture of silviculture. Forestry: An International Journal of Forest Research* 95 (2): 143–152.

Aghabarati A., Marvie Mohajer M.R., Etemad,V., Sefidi K. 2018 - *Structural characteristics of coppice forest stand in Fandoghloo Forest, Ardebil Province Province*. Journal Forest Research & Development 4 (2): 223-239.

Aguirre O., Hui G., Gadow K.V., Jimenez J. 2003 - *An analysis of forest structure using neighborhoodbased variables*. Forest Ecology and Management 183: 137-145.

Alder D.C., Edwards, B., Poore, A., Norrey, J., Marsden, S.J. 2023 - *Irregular silviculture and stand structural effects on the plant community in an ancient semi-natural woodland.* Forest Ecology and Management 522: 120622.

Ali A. 2019 - *Forest stand structure and functioning: Current knowledge and future challenges*.

Amirghasemi F., Sagheb Talebi Kh., Dargahi D. 2001- *Investigating the natural regeneration structure of Arsbaran forests in the study basin of Sten Chai*. Iranian Forest and Poplar Research 6: 1-61.

Bravo-Oviedo A., Pretzsc, H., del Río M. 2108 - *Dynamics, Silviculture and Management of Mixed Forests. Springer Cham*. 420 p.

Bowditch E., Santopuoli G., Binder F., del Río M., La Porta N., Kluvankova T., Lesinski J., Motta R., Pach M., Panzacchi P., Pretzsch H., Temperli Ch., Tonon G., Smith M., Velikova V., Weatherall A., Tognetti R. 2020 - *What is Climate-Smart Forestry? A definition from a multinational collaborative process focused on mountain regions of Europe.* Ecosystem Services 43: 101113.

Coppini M., Hermanin L. 2007 - *Restoration of selective beech coppices: A case study in the Apennines (Italy)*. Forest Ecology and Management 249*:* 18–27.

Delfan Abazari B., Sagheb Talebi Kh., Namiranian M. 2004 - *Investigation of the evolutionary stages of natural beech in the control plot of Kelardasht region (Langa)*. Iranian Forest and Poplar Research 12 (3): 325-307.

Derebe B., Alemu A. 2023 - *Non-timber forest product types and its income contribution to rural households in the Horn of Africa: a systematic review*. Forest Science and Technology 19(3): 210–220.

Emborg J., Christensen M., Heilmann- Clausen J. 2000 - *The structure dynamics of Susurrup Skov, a near natural temperate deciduous forest in Denmark*. Forest Ecology and Management 126: 173-189.

Eriksson L., Fries C. 2021 - *Relations between structural characteristics, forest involvement, and forest knowledge among private forest owners in Sweden*. European Journal of Forest Research 140: 51–63.

Esmaeili M., Javanmiri Pour M., Etemad V., Namiranian M. 2023 - *Comparison of the structural characteristics of coppice and standard stands of oriental beech (*Fagus orientalis *Lipsky) in Hyrcanian forests (Case study: forests of Kojoor, Nowshahr)*. Iranian Journal of Forest 15(3): 259-276.

Fazlollahi Mohammadi M., Tobin B., Jalali S.G., Kooch Y., Riemann R. 2022 - *Fine-scale topographic influence on the spatial distribution of tree species diameter in old-growth beech (*Fagus orientalis *Lipsky.) forests, northern Iran*. Scientific Report 10 -12 (1): 7633.

Füldner K. 1995 - *Strukturbeschreibung von Buchen-Edellaubholz-Mischwäldern. [Describing forest structures in mixed beech-ash-maple-sycamore stands.]* PhD dissertation, University of Göttingen, Cuvillier Verlag, Göttingen, 163 p.

Harmon Mark E., Woodall, Christopher W., Fasth Becky, Sexton Ja; Yatkov M. 2010 - *Differences between standing and downed dead tree wood density reduction factors: A comparison across decay classes and tree species.* Res. Pap. NRS-15. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 40 p.

Hämäläin A., Runnel, K., Ranius T. et al. 2024 - *Diversity of forest structures important for biodiversity is determined by the combined effects of productivity, stand age, and management*. Ambio 53: 718–729.

Hébert C. 2023 - *Forest Arthropod Diversity*. In: D. Allison, J. Paine, T.D., Slippers B., Wingfield M.J. (eds) Forest Entomology and Pathology. Springer, Cham.

Hosseinzadeh, J., Namiranian M., Marvi Mohajer M.R., Zahedi Amiri Gh. 2004 - *Investigation of the structure of less destroyed forests in Ilam province*. Iranian Journal of Natural Resources 75 (1): 75-90.

Hui G. Y., Albert M., Gadow K. v. 1998 - *Das Umgebungsmaß als Parameter zur Nachbildung von Bestandesstrukturen. [The diameter dominance as a parameter for simulating forest structure.]* Forstwiss Centralbl. 117: 258-266.

Javanmiri Pour M., Marvi Mohadjer M.R., Etemad V., Jourgholami M. 2016 - *Quantitative changes of forest stand structure through full calipering method*. Iranian Journal of Forest 8 (4): 493-505.

Javanmiri Pour M., Marvi Mohadjer M.R, Etemad V., Jourgholam M. 2017 - *Effect of management intervention on structure of natural stands (Case Study: Gorazbon District of Kheyrud Forest)*. Iranian Journal of Forest and Poplar Research 2: 209-2019.

Javanmiri Pour M., Mohadjer M.R.M., Etema, V. et al. 2019 - *Determining structural variation in a managed mixed stand in an old-growth forest, northern Iran*. Journal of Forest Research 30: 1859–1871.

Javanmiri Pour M., Etemad V. 2022 - *Development of the dead trees structural legacy in the dynamics process of pure beech (*Fagus orientalis *Lipsky) stands (Case study: Gorazbon district of Kheyrud forest)*. Iranian Journal of Forest Ecology 10 (20): 73-87.

Javanmiri Pour M. J., Etemad V., Petritan I. C. 2024 - *Structural dynamics of deciduous mixed stands in the Hyrcanian forests, northern Iran*. Notulae Botanicae Horti Agrobotanici Cluj-Napoca 52(4): 13879.

Karami A., Karamshah A., Shahi E. 2017 - *Effects of forestry practices on the regeneration and biodiversity of woody plants in the northern forest ecosystems of Iran*. Geology, Ecology, and Landscapes 1 (4): 264-270.

Kaushal S., Baishya R. 2021 - *Stand structure and species diversity regulate biomass carbon stock under major Central Himalayan forest types of India*. Ecological Processes 10: 14.

Khoshnevis M., Teimouri M., Sadegzadeh Hallaj M., Matinizadeh, M., Shirvany, A. 2019 - *The effect of vegetative form and shading on planting success of Greek Juniper* (Juniperus excelsa *M. B.). Iranian Journal of Forest and Poplar Research* 27 (2): 125-134.

Kint V., Lust N., Ferris R., Olsthoorn A.F.M. 2000 - *Quantification of forest stand structure applied to Scots Pine* (Pinus Sylvestris *L.*) *Forests*. Investigación Agraria: Sistemas y Recursos Forestales 1: 147-163.

König L., Mohren F., Schelhaas M., Bugmannc H., Nabuursa G. 2022 - *Tree regeneration in models of forest dynamics – Suitability to assess climate change impacts on European forests*. Forest Ecology and Management 520: 120390.

Korpel S. 1995 - *Die Urwalder der westkarpaton*. Gustav Fisher, Stuttgart. 310p.

Latterini F., Mederski P.S., Jaeger D. et al. 2023 - *The Influence of Various Silvicultural Treatments and Forest Operations on Tree Species Biodiversity*. Current Forestry Report 9: 59–71.

Leibundgut H. 1983 - *Über Zweck und Methodik der Struktur- und Zuwachsanalyse von Urwäldern*. Schweizerische Zeitsschrift für Forstwesen 110: 111–124.

Mahmoudi S., Sheykhi Ilanloo S., Keyvanloo Shahrestanaki A., Valizadegan N., Yousefi M. 2016 - *Effect of human-induced forest edges on the understory bird community in Hyrcanian forests in Iran: Implication for conservation and management*. Forest Ecology and Management. 382: 120-128.

Mariotti B., Alberti G., Maltoni A., Tani A., Piussi P. 2017 - *Beech coppice conversion to high forest: results from a 31-year experiment in Eastern Pre-Alps*. Annals of Forest Science 74: 44.

Marvi Mohadjer M.R. 2013 - *Silviculture. University of Tehran Press*. 419 p.

Mataji A., Nemiranian M. 2007 - *Investigation of the structure and development of natural stands in northern Iran (Case study: Khairudkenar, Nowshahr)*. Iranian Journal of Natural Resources 55 (4): 251-260.

Mehdiani A.R., Heidari R., Rahmani R., Azadfar D. 2012 - *Investigation of oak structure (*Quercus macranthera*) in forest stands of Golestan province*. Journal of Wood and Forest Science and Technology 19 (2): 23-42.

Mohammadnezhad Kiasari S., Sagheb Talebi Kh., Rahmani R., Ghelichnia H. 2023 - *Comparison of plant diversity between managed and unmanaged forests in Haftkhal, Mazandaran Province, North of Iran*. Asian Journal of Forestry 7(2): 107-114.

Mora C., McKenzie T., Gaw I.M. et al. 2022 - *Over half of known human pathogenic diseases can be aggravated by climate change*. Nature Climate Change 12: 869–875.

Moradi Gh. 2022 - *A study of the richness of woody plants in the forests of northern Iran and temperate broadleaf forests of Central Europe*. Man and the Environment 19 (2): 75-90.

Moridi M., Fallah A., Pourmajidian M., Sefidi K. 2021 - *Quantitative Analysis of Forest Structure at Growing Up Volume Stage in the Evaluation of Natural Beech Stands (Case Study: Kheyroud Forest)*. Iranian Journal of Forest 13 (2): 115-128.

Namiranian N. 2010 - *Tree measurement and forest biometrics.* University of Tehran Press. Second edition. 594 p.

Nocentini S. 2008 - *Structure and management of beech (*Fagus sylvatica *L.) forests in Italy.* iForest Biogeosciences and Forestry 2: 105-113.

Nocentini S., Travaglini D. Muys B. 2022 - *Managing Mediterranean Forests for Multiple Ecosystem Services: Research Progress and Knowledge Gaps.* Current Forestry Report 8: 229–256.

Nouri Z., Zobeiri M., Feghhi J., Marvi Mohajer M.R. 2015 - *Application of nearest neighbor indices in studying the structure of intact beech stands in Khiroud forest of Nowshahr*. Applied ecology 4 (12): 11-20.

R Core Team 2021 - *R: A language and environment for statistical computing.* R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Pielou E.C. 1977 - *Mathematical ecology*. Wiley, New York.

B., Mirazadi Z., Alijani V., Jafari Sarabi H. 2015 - *Investigation of Hawthorn and Maple's Stands Structures of Zagros Forest Using Nearest Neighbors Indices*. Journal of Forest Ecosystems Research 1(2): 1-14.

Pirozi F., Soosan J., Adeli, K., Maleknia R., Naghavi H., Hosseinzadeh R. 2018 - *The comparison of forest structure in Oak stands with different density and mixture (Case study: Noyjian forests of Khorramabad).* Journal of Forest Research and Development 4 (1): 15-28.

Pommerening A. 2002 - *Evaluating structural indices by reversing forest structural analysis*. Forest Ecolgy and Management 224: 266-277.

Pourhashem M. 2019 - *Breeding operations, a way to improve the structure of small-diameter coppice oak stands in the Zagros forests.* Iran Nature 4 (4): 13-17.

Pourhashemi M., Alimahmoodi Sarab S. 2021 - *Effect of protection on structural characteristics of forest stands (Case study: Izeh forests, Khuzestan).* Iranian Journal of Forest and Poplar Research 29 (4): 339-348.

Pourhashemi M., Zandbasiri M.,Panahi P. 2014 - *Structural characteristics of oak coppice stands of Marivan Forests.* The Journal of Plant Research (Iranian Journal of Biology) 27 (5): 766-776.

Sagheb Talebi Kh., Sajedi T., Pourhashemi M. 2014 - *Forests of Iran: A Treasure from the Past, a Hope for the Future*. Springer, Dordrecht. 152 p.

Sefidi K., Sadeghi S. 2021- *Anthropogenic disturbance impacts on spatial pattern of Caucasian oak (*Quercus macranthera*) stands in the Hatam Mashe Si forests, Arasbaran. Iranian Journal of Forest* 13(2): 155-168.

Sefidi K., Marvi Mohajer M.R., Etemad V., Mozandel R. 2014 - *Dynamics of the final stage of sequencing in mixed beech forests in northern Iran (Case study: Gorazbon section of Khirud forest in Nowshahr).* Iranian Journal of Forest and Poplar Research 22 (2): 270-283.

Shabani S., Varamesh S., Sefidi K., Haghighi A. 2022 - *Studying the plants species diversity under microtopography in mixed beech forests, case study: Deldareh forests, Nowshahr*. Iranian Journal of Forest 14 (1): 1-13.

Sjölund M.J., Jump A. 2015 - *Coppice management of forests affects spatial genetic structure but not genetic diversity in European beech (*Fagus sylvatica *L.).* Forest Ecology and Management 336: 65-71.

Seidl R., Turner MG. 2022 - *Post-disturbance reorganization of forest ecosystems in a changing world.* Proc Natl Acad Sci U S A. 2022 Jul 12 119 (28): e2202190119.

Šrámek M., Volařík D., Ertas A., Matula R. 2015 - *The effect of coppice management on the structure, tree growth and soil nutrients in temperate Turkey.* Journal of forest science 61 (1): 27–34.

Tinya F., Kovács B., Bidló A., Dima B., Király I., Kutszegi G., Lakatos F., Mag Z., Márialigeti S., Nascimbene J., Samu F., Siller I., Szél G., Ódor P. 2021 - *Environmental drivers of forest biodiversity in temperate mixed forests* – A multi-taxon approach, Science of The Total Environment 795: 148720.

Travaglini D., Chirici, G. 2006 - *Deadwood assessment*. ForestBIOTA project Forest Biodiversity Test-phase Assessments. Accademia Italiana di Scienze Forestali. 20 pp.

Trentanovi G., Campagnaro Th., Sitzia T., Chianucci F., Vacchiano G., Ammer Ch., Ciach M. A., Nagel H., Miren del Río Th., Paillet Y., Munzi S., Vandekerkhove K., Bravo-Ovied A., Cutini, A., D'Andrea E.,De Smedt P., Doerfler, I., Fotakis D., Heilmann-Clausen J., Hofmeiste J., Burrascano S. 2023 - *Words apart: Standardizing forestry terms and definitions across European biodiversity studies.* Forest Ecosystems 10: 100128.

Unrau A., Becker G., Spinelli R., Lazdina D., Magagnotti N., Nicolescu V-N., Buckley P., Bartlett, D., Kofman P. D. 2018 - *Coppice Forests in Europe*. 392 p.

Zobeiri M. 2003 - *Forest inventory (measurement of trees and forests)*. University of Tehran Press, third edition 401 p.