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Stand characteristics of gap formation phase through the development of oriental beech (*Fagus orientalis* Lipsky) stands in the Hyrcanian Forests, northern Iran

Bestandescharakteristik in der Lückenbildungsphase von Orient-Buchenbeständen (*Fagus orientalis* Lipsky) in den Hyrkanischen Wäldern, Nord-Iran

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Keywords: *Gap formation phase, pristine forest stands development, canopy gap dynamic, mingling, Fagus orientalis*

Schlüsselbegriffe: *Lückenbildungsphase, Entwicklung von Urwälder, Lücken-dynamik, Vermischungsindex, Orient-Buche*

Abstract

The quantification of forest stand dynamics and structural characteristics within the development phases can be useful in facing with new challenges in the close to nature forestry. The formation of gaps is known as a critical part of the natural dynamics of oriental beech stands. This research was carried out to describe the structural features of naturally regenerated oriental beech stands in the gap formation phase using a set of stand structure quantification indices. Our results revealed that gaps have an average size of 178 m^2 and are closed mostly by oriental beech and velvet maple, while

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gap formation is done exclusively by beech. Also stands have slightly heterogeneous diameter distributions and uniform tree height. The average number of trees per hectare and the average of stocking volume were 379 stem ha^{-1} and 514.8 m^3 ha^{-1}, respectively. Furthermore, the mean value of dead tree volume was 36.3 m^3 ha^{-1}. The average mingling was 0.23 and tree-to-tree interval calculated and 4.87 m. Meanwhile, the mean value of diameter and height differentiation were 0.45 and 0.87 m, respectively. Knowledge on formation of natural gaps is useful for planning management interventions that are in accordance with natural process of development of the stands and exhibit minimum deviation from natural processes. We can conclude that harvesting in the gap formation phase led to shifting stand to the next phase and accelerate the natural gap phase scale disturbance. Removing trees in other phases does not emulate natural stand development pathways.

Zusammenfassung

Das Verständnis der Dynamik und der Bestandesstruktur in den einzelnen Entwicklungsphasen von Waldbeständen kann helfen, um neue Herausforderungen in der naturnahen Forstwirtschaft zu bewältigen. Die Lückenbildung gilt als kritischer Teil in der natürlichen Dynamik der Orient-Buchenbeständen (Fagus orientalis Lipsky). Diese Studie beschreibt die Strukturmerkmale von natürlich verjüngten Orient-Buchenbeständen in der Lückenbildungsphase mittels mehrerer Strukturindizes. Unsere Ergebnisse zeigen, dass die Lücken eine durchschnittliche Größe von 178 m^2 haben und überwiegend von Orient-Buche und Samt-Ahorn (Acer velutinum Boiss.) geschlossen werden. Die Lückenbildung erfolgt allerdings ausschließlich durch die Buche. Die untersuchten Bestände haben leicht heterogene Durchmesserverteilungen und eine einheitliche Baumhöhe. Die durchschnittliche Anzahl der Bäume pro Hektar betrugen 379 ha^{-1} und das durchschnittliche Baumvolumen ist 514.8 m^3 ha^{-1}. Der durchschnittliche Totholzvorrat (stehend und liegend) beträgt beachtliche 36.3 m^3 ha^{-1}. Der durchschnittliche Vermischungsindex beträgt 0.23 und der mittlere Baum-zu-Baum-Abstand 4.87 m. Die Mittelwerte der Durchmesser- Differenzierung und der Höhe-Differenzierung betragen 0.45 bzw. 0.87. Dieses Wissen über die Bildung und Struktur natürlicher Lücken ist nun für die Planung von Managementeingriffen hilfreich, um natürliche Prozesse in der Bestandesentwicklung nachzubilden. Wir vermuten, dass die Entnahme von Bäumen in der Lückenbildungsphase zu einem Wechsel in die nächste Phase führt und der Eingriff somit die natürliche Entwicklung beschleunigt. Das Entfernen von Bäumen in anderen Entwicklungsphasen hingegen entspricht nicht der natürlichen Waldentwicklung.

1. Introduction

Forest stands change over time and this constant transitioning into a different state is known as forest stand dynamics. The study of dynamics and changes in the structure of forest stands has often considered as research. In natural forests, the development stages based on structural features of stands have been classified to different phases and stages according to the amount and volume of living trees, the amount and distribution of dead trees in the size classes as well as the presence of gaps in the canopy layers, regeneration and vertical structure of stands.

In "forest structure" considerations are given to the spatial arrangement of a series of characteristics of trees, including plant species, tree sizes, age distribution, tree canopy's layering (Graz, 2006) that change over time which known as forest stand dynamics (Chen & Popadiouk, 2002). The structure of stands affects the forest's wildlife, stands' dynamics, regeneration, and carbon synthesizing (Leibundgut, 1959). The conducted studies in the forests of beech and fir in Europe, especially in forests located in the Carpathian Mountains in Central Europe has a long history. The European beech forests have been more located in low and middle altitudes with minimal human intervening. Korpel (1982) and Leibundgut's (1959) researches in these areas are examples of this. In the 1950s and 1960s, extensive researches (Korpel, 1982; Leibundgut, 1959; Zukrigl et al., 1963) were conducted in the European beech forests in the countries like Germany, Switzerland, Czech, Slovenia, Serbia and Bosnia according to the results of these researches, phases and stages has been presented as a model. Three separate stages including initial, optimal, and decline stages were defined (Korpel, 1995). Also, these three stages were identified and studied in pure and mixed beech forests in the north of Iran (Sagheb-Talebi, 2013). Moreover, based on the Sefidi et al (2014a) investigations, three main stages including volume growing up, volume accumulation, and volume decline stages and their different phases were identified phases in the old growth beech stand in the northern Iran. The results of previous research showed the dynamics of oriental beech stands begin by formation small size gaps normally created by single gap maker in the canopy layer and followed by stand re-initiation and stem exclusion phases. The other reported phases including gap forming, understory initiation, regeneration, volume accumulations, lightning, stem exclusion, finally decline stage include old growth and volume degradation.

Quantification of stand structure in different development phases provide invaluable information for forest stand manager especially in the single selection method. In this method, timber marking must be done in the reasonable time and place. So, we tried to provide quantitative information for the best timber marking in the close to nature forestry in natural beech stands.

Forest canopy layer structure plays an important role in the dynamics of forest stands (Hardiman et al., 2011) and the forest structure changes often are driven by gap scale disturbance especially in the old-growth forests (Delong & Kessler, 2000). The quality of relative light within forest stands dramatically change after the formation of the canopy of trees (Canham et al., 1990; Nicotra et al. 1999) and these changes are definitely essential for the survival and growth of seedling and sapling (Zhu et al., 2003; Mountford et al., 2006). Abiotic factors such as humidity, air and soil temperature as well as biotic factors such as the frequency of insects, decay dynamics of dead wood (Sefidi et al., 2016) and root competition are associated with the distribution of irradiative components (Schütz, 2004). However, these factors may be different in terms of spatial structure inside the gap (Parhizkar et al., 2011). Direct and diffused radiation in the center of gap is different from its margin and also from north facing slopes to the east facing slopes (Canham et al., 1990). Previous studies have shown that the relative intensity of light in the center of gap is greater than its margin (Emborg, 1998). Structure of canopy gap has been studied as an important characteristic of gaps in virgin (*Fagus sylvatica* L.) forest (Zeibig et al., 2005; Sefidi et al., 2011). In the Northern part of Iran Sefidi et al (2011) reported that an average of 3 gaps/ha and gap sizes ranged from 19 to 1250 m² in size. The most frequent gaps size in this area were <200 m².

The study of the structure of forest stands is one of the most important components of forest management and nowadays is regarded as a basis of forestry close to nature (Marvi-Mohajer, 2009). The spatial structures of trees present valuable information about dynamics of forest ecosystems and both within and between species competitions. Sefidi et al (2014a) studied the oriental beech stand dynamics and recognized specific development phases in the old growth beech stand in the northern Iran. The results of giving research showed the dynamics of oriental beech stands begin by formation small size gaps normally created by single gap maker and followed by stand re-initiation and stem exclusion phases. In another research, Akhavan et al. (2010) studied spatial patterns of three development stages of an intact old-growth beech forest in the Caspian region (i.e., initial, optimal, and decay) defined by Korpel (1982) showed that trees in the small size class exhibited an aggregated distribution in every development stage, which matched the overall spatial pattern of all trees in each stage. Moridi et al. (2015) quantified structural characteristics of stands in the stem exclusion phase using common structural indices. The average distance between trees was 3.3 m. Stocking volume of the stands had an average of 540 m³ ha^{-1} and 412 stems ha^{-1}. The mean value of mingling and tree-to-tree interval indices revealed that beech was mixed intensively with hornbeam and appears to be a more successful competitor for space and light compared with hornbeam; moreover, we found relatively high evidence of inter-species competition in this phase. Ruprecht et al. (2010) reported structural diversity of English yew populations. They showed that the vitality of each individual yew was influenced by the interspecific competition of the neighboring tree species. As a conclusion, they suggested that a combination of different structural indicators is needed for an integrative assessment of conservation status in the gene conservation forests. Sefidi et al. (2014b) were quantified Persian Ironwood structure within natural forests in the northern part of Iran using indices. Persian ironwood trees are more likely to be surrounded by other Persian ironwood trees rather than by other tree species. Persian ironwood grew in fairly pure stands and had a slightly heterogeneous diameter distribution and fairly uniform tree height.

Quantification of forest structure is essential to understand and predict the performance of forest stands as well as for the conservation and management of their different services and functions (Puettmann et al., 2012). So, we focused on structural variability of stands in this phase for proper interpretation of stand characteristics. The other motivation for doing this research is that structural characteristics of development phases remain poorly understood for the beech forests of the northern Iran. The main aim of this research was to quantify the key structural characteristics of beech stands in the gap formation phase in the undisturbed beech stands, which can provide a unique opportunity to study the diameter and height distribution and structural properties of beech stands in the natural and undisturbed areas. The quantification of stand structure in this phase will broad our knowledge on stand structure and help manger to make a good decision in tree marking process. Accordingly, specific objective was the investigating quantitative and qualitative characteristics of dead and alive trees in stands in the gap formation phase of oriental beech, and developing management options that utilize and emulate gap formation processes.

2. Methods

2.1 Study area

The study was conducted within the Asalem Forest in northern Iran. This forest located in the Shafaroud catchment in the western part of Guilan province that covers a total area of 37,467 hectares and ranges in latitude from 37°23′N to 37°40′N and in longitude from 48°42′E to 49°00′E (Fig .1). The selected study area was in the reference district of forest management plan in the compartment number 914 in the Talesh region. At altitude between (800) 1,200 and 2,000 m. The soil properties change from brown washed with clay to silty-clay and are very deep with a granular structure. It has moles of deep acid humus, good root, and the permeability is good to moderate. The undisturbed mature beech stands were classified as a late successional stage forest and represent example of old-growth beech forests with no historical cutting or harvesting of trees (Sefidi et al. 2013). Oriental beech is a dominant tree species and other tree species in this area include European hornbeam (*Carpinus betulus*), Persian maple (*Acer velutinum*), Cappadocian maple (*Acer cappadocicum*), largeleaf linden (*Tilia platyphyllos*), smooth leaved elm (*Ulmus minor*), Wych elm (*Ulmus glabra*) and sweet cherry (*Cerasus avium*) (Sagheb-Talebi et al. 2013). The climate is sub-Mediterranean with a mean annual temperature of 15.7°C and total annual precipitation of 1300 mm (Amanzadeh et al., 2011).

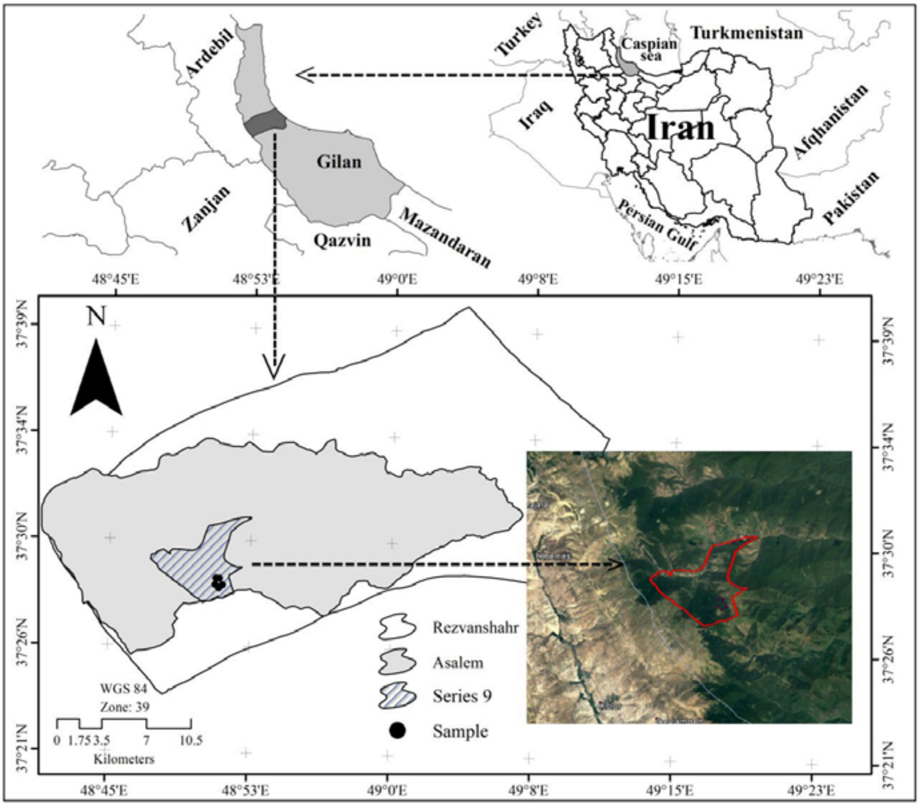

Figure 1: The location of Study area within in the Shafaroud Forests in northern Iran

Abbildung 1: Die Lage des Untersuchungsgebietes in den Shafaroud Wäldern in Nord-Iran

2.2 Field work

Data collection and field inventories took place during the summer of 2016. To characterize the structure of stands in the gap formation phase (Sefidi et al., 2014a), three mature F. orientalis dominated stands (identified as SA1, SA2, and SA3) in the Asalem Forest within the Guilan Province of Iran (37°23'N, 49°00'E) were selected. In each stand, we established a grid of 36 sampling points. In each study area, all dead and live trees of at least 7.5 cm diameter at breast height (DBH, 1.3 m above the root collar) were identified, and their diameter at breast height and height was recorded within one-hectare study area.

In order to quantify the structure of stands in this phase, according to the Ruprecht et al. (2010), at each sampling point, the nearest beech tree to the intersection point were selected as a reference tree, then DBH and height of trees were measured and classified the trees into a four vitality classes (Mueller-Dombois & Ellenberg 1974). Vitality Class 1 included individuals with full crowns that appeared to be exceptionally healthy. Class 2 was normal individuals. Class 3 trees had feeble vitality and Class 4 included trees with very sparse crowns and no evidence of fruiting. The three nearest neighboring trees to each reference tree were identified and the distance between the reference tree and the neighboring trees was measured. The diameter at breast height (DBH), height, and vitality class of the neighboring trees was also recorded. The caliper and Vertex were used to measurements of trees diameters and height, respectively.

All canopy gaps and related parameters were measured in each of the three stands on a one ha area. Gaps were analyzed by classifying area including: small, medium and large gaps. In this examination minimum area for gaps was 20 m². If saplings in a gap reached half of the surrounding canopy, the gap was considered to be closed and was not measured (Kucbel et al., 2010; Sefidi et al., 2011). The numbers of canopy gap maker within gaps were identified as well.

For dead trees, we recorded species, total length, form (log, snag, or stump), diameter at both ends, diameter at the midpoint (for stumps, only the diameter at the midpoint was recorded), and decay class. For species, that could not be identified in the field, a small section was collected and identified in the lab using macro and microscopic characteristics (Parsapajoh and Schwein Gruber 1980). The diameters of logs, snags and stumps were measured using calipers; however, for taller snags, top diameters were estimated visually as suggested by Harmon and Sexton (1996). Decay classes were defined according to Albrecht (1990) as Class 1 (recently dead), Class 2 (bark loose with some decay in the sapwood), Class 3 (decay obvious throughout the secondary xylem) and Class 4 (woody debris mixing with soil, little structural integrity). Thus, according to these definitions a snag could never be identified as Class 4.

2.3 Data analysis

The commonly used indices were employed to discovering the structural properties of natural beech stands and characterize the distribution of stems and species within an oriental beech stands in the Gap formation phase. The Mingling Index (Pommerening, 2002) describes the tendency of species to be mixed with other tree species and also the interspecific competition of the site and is calculated by:

$$M_i = \frac{1}{n}\sum_{j=1}^{n} v_{ij}\,; \quad M_i \in [0,1]$$

where v_{ij} is equal to 1 when the reference tree (i) and the neighboring tree (j) are different species and v_{ij} is equal to 0 when the reference tree (i) and the neighboring tree (j) are both *F. orientalis*. A plot-level mingling index is calculated by averaging the indices for all sample points. Although the mingling index is frequently used as a measure of species diversity (Aguirre et al. 2003, Sefidi et al., 2014b); in this research, we try to measure of how beech interspread with other tree species in this phase. A low mingling index (closer to 0) indicates a purer stand of beech with fewer other species present and a high mingling index (closer to 1) indicates other species are intermingled with the reference trees.

The tree-to-tree Interval Index (D_i) used to quantify the density of trees in this phase (Ruprecht et al. 2010):

$$D_i = \frac{1}{n} \sum_{j=1}^{n} s_{ij}$$

Where s_{ij} the distance from the ith is reference tree to the j^{th} neighboring tree and n is the number of sampled trees. Thus, D_i represents the density of the stand with larger indices representing trees that are further apart and lower indices trees that are closer together.

We also calculated the diameter differentiation index to characterize the tree size (measured by DBH and height) and distribution of structure of the beech stands in the gap formation phase (Pommerening, 2006; Ruprecht et al., 2010):

$$TD_i = \frac{1}{n} \sum_{j=1}^{n} (1 - rd_{ij}); \ TD_i \in [0,1]$$

Where rd_{ij} is the ratio of the smaller tree's DBH to the larger tree's DBH and n is the number of neighboring trees. Similarly, height differentiation index is calculated by:

$$HD_i = \frac{1}{n} \sum_{j=1}^{n} (1 - rh_{ij}); \ HD_i \in [0,1]$$

Where rh_{ij} is the ratio of the taller tree's height to the shorter tree's height and n is the number of neighboring trees. A stand with small differentiation is characterized by trees that are uniform in size and will have an index value closer to 0.0, while a stand with a much wider range in the size of trees and will have an index value closer to 1.0.

Newton's formula was employed (Harmon & Sexton, 1996) for snag and log volume calculation:

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

Where, V = volume in m³, L = length, and A_b, A_m and A_t = the cross-sectional area at the base, middle, and top, respectively.

The volume for stumps was calculated by:

$$V = Am \times L$$

Where, V = volume in m³, Am = cross-sectional area at the middle of the stump, and L = length.

An index of mortality rate in the DBH classes was calculated by dividing the number or volume of dead trees by the number or volume of live trees per class.

Calculation of gap area was based on elliptically shaped gaps, following the ellipse formula (Runkle, 1982). The individual gap size (*A*), was calculated by maximum lengths (*L*), and maximum perpendicular widths, (*W*) within an ellipse gap. Usually most of the gaps assumed as an ellipse (Runkle, 1981).

$$A = \frac{\pi\,LW}{4}$$

This formula is the most applicable method in the similar forests (Runkle, 1982; Zeibig et al., 2005; Kenderes et al., 2009; Nagel et al., 2010; Sefidi et al., 2011). Gaps were classified into three groups: small (<200 m²), medium (200–500 m²), and large (>500 m²) gaps (Zeibig et al., 2005; Nagel et al., 2010; Sefidi et al., 2011).

3. Results

3.1 Stand structure and composition

For three stands in the gap formation phase the DBH and height of all woody stems (> 7.5 cm) were recorded (total of 1138 stems on three sample area). Table 1 shows some structure related parameters. The average stocking volume was 514 m^3 ha^{-1}, the mean DBH was 30.2 cm and the highest DBH we measured was 138 cm. In all three sites, *F. orientalis* was more frequent than any other species (average stem number of beech 355.3 ha^{-1}, 93.5% of total stem number). *C. betulus* was the second most frequent tree species, followed by *Acer velutinum*, *Alnus subcordata* and *Ulmus glabra*.

Table 1: Structural characteristics of old growth beech stands in the Gap formation phase

Tabelle 1: Zusammenfassung der Struktur der untersuchten Orient-Buchenbestände in der Lückenbildungsphase

Item	AS1	AS2	AS3
Density (N ha^{-1})	374	464	301
Tree DBH (cm)			
Mean	30.3±1.2	26.4±0.9	33.9±1.3
Median	19	18	27
Maximum	102	105	138
Minimum	8	7.8	8
Tree Height (m)			
Mean	23 ± 0.4	26 ± 0.3	24 ± 0.4
Median	25.5	25.2	24.3
Maximum	48.3	41.1	43.9
Minimum	5.9	5.5	6.1
Standing volume (m^3 ha^{-1})	480.9	475.2	588.4
Dead volume (m^3 ha^{-1})	36.98	37.8	38.1

The mingling value DMi showed different results for the three sites (Fig. 2). The relatively high proportion of the DMi was class 0.33 and 0.00 for study sites revealed high intra-specific competition in this phase. Across all three plots, in the 70.2 % of the sampling points, reference trees and all neighboring trees were oriental beech (Mi = 0.00) or the most neighboring trees (Mi = 0.33) were beech (Fig. 2). Surprisingly, for no sampling point we found Mi equal 0.66 or 1, which means that the reference beech trees were surrounded more intensively by other beech trees.

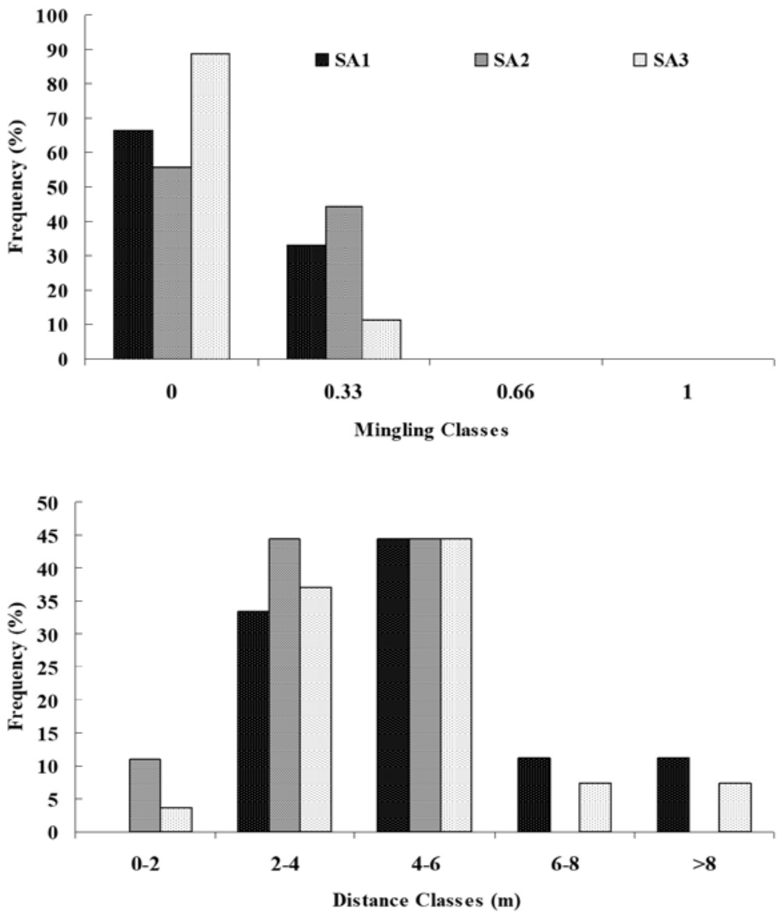

Figure 2: Comparison of mingling (top) and tree to tree interval (bottom) for F. orientalis at the three study sites in the gap formation phase. A total of 36 points were sampled in each stand.

Abbildung 2: Vergleich des Vermischungsindex (oben) und des Baum-zu-Baum-Abstandes (unten) für die drei untersuchten Orient-Buchenbestände in der Lückenbildungsphase. Insgesamt wurden 36 Probefläche pro Bestand erhoben.

The mean tree-tree interval (Di) allowed interpretation the stem density. The calculated Di values divided into 2 m Di classes (Fig. 3). The average tree-to-tree interval (Di) was 4.87 m and 14.82 % of the sample point had the longest average distance. The full calipering inventory across fixed area plots demonstrates the relative low density per hectare averaging 380 N ha^{-1} (Table 1).

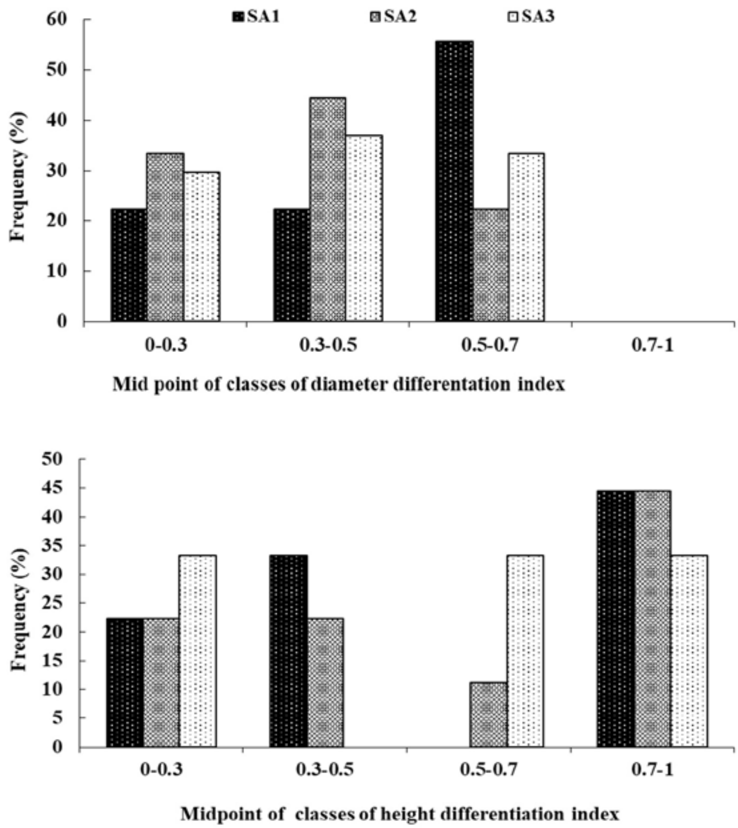

Figure 3: Distribution of diameter (top) and height (bottom) differentiation indices from three mature beech stands in the gap formation phase

Abbildung 3: Durchmesserverteilungsindex (oben) und Höhenverteilungsindex (unten) für die drei Orient-Buchenbestände in der Lückenbildungsphase

The mean of diameter at breast height within three sites calculate 30.2 ± 1.2 cm. The biggest recorded DBH was 138 cm (Table 1). The diameter differentiation TDi results for all three study sites indicated that beech generally has low differentiation in the gap formation phase. The highest percent of TDi index recorded in the 0.3-0.5 class (37.1%) indicated the average size of a neighbor is 30-50% larger or smaller than beech trees. The average height of tree species in the study sites was 24.33 ± 0.8 m (Table 1). the largest tree within study area was one *Acer velutinum* tree with 48.3 m. *C. betulus* represented on average 54.6 % of trees smaller than 15 m, while the share of this species in large height (> 30 m) classes was only 7.5%. The tree height differentiation HDi for the sampling point showed a similar pattern for all three study sites (Fig. 3). According to the results, 40.7 % of sampling point showed HDi more than 0.7 and 70% of neighbors were smaller than beech trees.

3.2 Canopy gap characteristics

A total of 12 canopy gaps were analyzed within the three-hectare sampling area. Thus approximately, there were on average four gaps per hectare within each beech stand. The mean sizes of canopy gap were 259.1 m². Gap areas ranged from the smallest of 70.8 m² to the largest of 751.5 m² (Table 2). The median of canopy gap size was 178 m², this indicated gaps the majority were small size (less than 200 m²) (Fig. 4). Among the three classification of gaps, the small one (<200 m²) have the most abundance with canopy gaps. About 15 % of total gaps were in large gaps group. Meanwhile we found a substantial majority of gaps were formed by death of single trees (Fig. 5).

Table 2: Characteristics of canopy gaps within old growth beech stands in the Gap formation phase

Tabelle 2: Merkmale der Bestandeslücken in Orient-Buchebeständen in der Lückenbildungsphase

Item	Value
Minimum gap size	**70.85 m^2**
Maximum gap size	**751.5 m^2**
Median gap size	**178.2 m^2**
Canopy gap area (as % of total forest)	**24 %**
Most common gap makers	
F. orientalis	**100%**
Other species	**0**
Most common gap fillers	
F. orientalis	**59.5%**
Acer velutinume	**30.4%**
Other species	**10.1%**

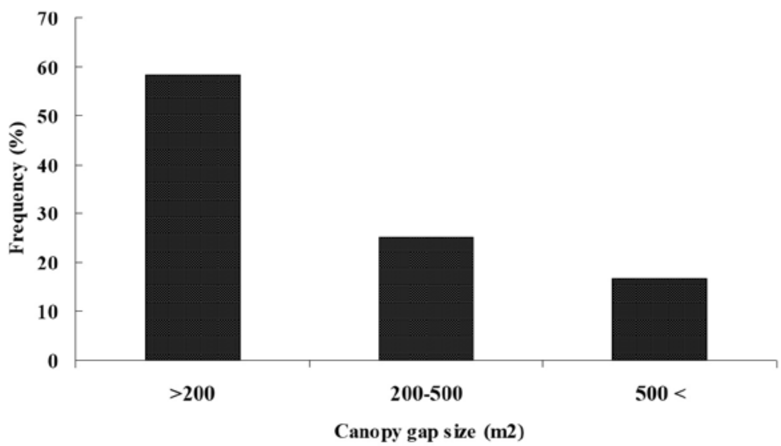

Figure 4: Frequency of canopy gaps across the variety of size classes in the gap formation phase

Abbildung 4: Häufigkeit der Bestandeslücken hinsichtlich der Lückengröße

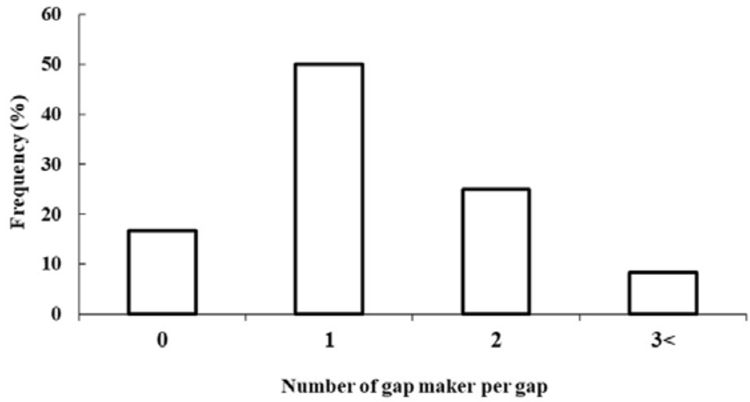

Figure 5: Gap frequency by cause of gap formation with 0 = no obvious gap former,1 = single tree-fall event, 2 = double tree-fall event, and 3 = three or more trees fallen

Abbildung 5: Häufikeit der Bestandeslücken nach der Anzahl der Lückenerzeuger. 0 bedeutet kein offensichtlicher Auslöser für die Lückenbildung, 1 = Wurf eines Einzelbaums, 2 = Wurf von zwei Bäumen und 3 = drei oder mehrere Bäume wurden geworfen.

3.3 Mortality of trees

In total 39 individual dead trees were recorded. The mean of diameter of dead tree within the study sites was 85. ± 1 cm. Mean dead wood volume was calculated as 36.3 ± 4.57 m^3 ha^{-1}. The highest numbers of dead trees and mortality rate recorded in the high diameter class which means the majority of mortality rate occurs in diameter more than 75 cm (27%, Fig. 6). Beech constitutes 91% of the number of dead trees. This amount for maple as second important tree species was 6.1%. Dead tree form was also recorded and results revealed 47% of dead trees were standing dead trees.

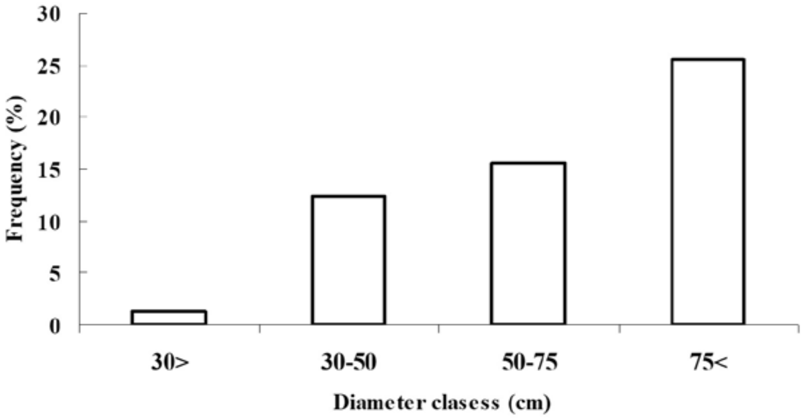

Figure 6: Frequency of dead trees over diameter classes in the mixed beech stands in the north of Iran

Abbildung 6: Verteilung abgestorbener Bäume nach Durchmesserklassen in Orient-Buchenbeständen im Nord-Iran

4. Discussion

While established trees have a fixed location, the structure of forest stands changes substantially over space and time. These changes are made by some effective factors such as natural disturbances (Frelich, 2002). Therefore, it could be stated that the structure of forest has mutual relation with processes such as regeneration, growth, and mortality. The study of temporal and spatial changes of forest structure not only is attractive for ecologists, but also is very useful from the economists' point of view. The results of stand dynamics research (Sefidi et al., 2014a) revealed the cycle of oriental beech stand development occurs in stages and phases. The process of development initiate by formation and expanding of gaps in the forest canopy layer that cause to growing up seedling from under story, so we tried to demonstrate some structural properties of this phase using structural indexes in the unmanaged stands in the north of Iran. Structural indexes often used as an indicator for quantification of structural properties of forest stands (Pretzsch,1995; Pommerening, 2002; Sefidi et al., 2014b). Investigation in the three, unmanaged, oriental beech-dominated stands, in the gap formation phase through the natural development of beech stands showed the median of gap size is 183 m² that often formed by single tree-fall events. The size of gaps is obviously closely linked to the number of trees involved in its creation. The same results reported in the Hyrcanian beech forest (Sefidi et al., 2011; Tabari et al., 2005), that revealed the successful regeneration of oriental beech occurred in the small or medium size of canopy gaps. Nagel et al. (2010) in the Slovenian beech forests found that maple requires large gaps to successfully reach the overstory, but *F. sylvatica* L.was able to reach the canopy in all gap that were < 400 m², so in this phase the presence of beech recorded in the all gaps, but the *F. orientalis* is a dominant gap filler in the small gaps. according to our measurements from the natural stands do not tend to be mixed in species composition, have slightly heterogeneous diameter distributions, uniform tree height, and the average distance between trees was 4.87 m. The median of diameter at breast height was 20.66 cm demonstrate the half of trees within stand have a diameter smaller than 20.66 cm. Stands in this phase are developed, and the next development cycle initiate with gap creation in this phase. The most of trees are in the late physiological longevity. The mortality of trees in the large trees affect the mean of tree diameter within stands.

The diameter and height differentiation allow one to interpret the relationship between the reference tree and its neighboring trees in respect to competition (Ruprecht et al., 2010). The most frequency of diameter differentiation index (TDi) was in class 0.3 to 0.5 that means the moderate level of diameter differentiation and average size of a neighbor is 30-50% larger or smaller than beech trees and also had slightly heterogeneous diameter. The mean value of TDi for all of sample points was 0.43 and this indicates moderate differentiation among trees in terms of diameter at breast height that represents a broadly homogeneous trees diameter. Pommerening (2002) stated that, in addition to age and development stages of the stands, forest management histories also affect the size differentiation of trees. The mean value of height differentiation index (HDi) was 0.87 and According to the results, 41 % of sampling point showed HDi more than 0.7 that means around 70% of trees were smaller than reference tree that indicates high level of tree height differentiation. Therefore, this indicates the heterogeneity of trees in terms of their height and formation of vertical structure of stands and layering trees in different stories. In fact, in this phase, competition among trees for better light condition is higher than the competition in to gain space for increasing the diameter growth.

The density of trees was 380 stems ha^{-1} that revealed moderate state in comparison with other phases. The same results reported in the oriental beech stands in the north of Iran (Sefidi et al. 2014a; Marvie Mohadjer et al. 2009; Nedyalkov and Asli 1971) and in European beech forest (Meyer and Tabaku, 2004; Cancino and Gadow, 2002). The number of trees decreases from the beginning of stand development in the previous phases including stand re-initiation and stem exclusion. In the canopy formation phase stand is developed and trees are in the late stages of physiological longevity. Trees have large dimension in term of diameter, height and crown diameter but the number of trees per hectare is fewer than previous and the next phases. In previous phases such as stem exclusion some of trees can be grown to the canopy layer that cause to excluding saplings from becoming established and rise down the number of trees within stand in the next following phases such as gap formation. Moridi et al. (2015) reported that in the stem exclusion phase, the number of trees was 410 stems ha^{-1} which is slightly more than this phase. The stem exclusion phase is in the beginning stages of stand development. Accordingly, there are high numbers of trees in this phase that are associated with high mortality and stratification of trees that cause to substantial changes in the stand structure and shift them to next development phases.

The average distance between the trees in this phase calculated 4.8 m, that is the same with the other report from Iranian beech stands, in the old growths phase studies demonstrated that the species grows in stands with high species diversity and has an average distance between trees of 7.9 m (Akhavan et al., 2010; Alijani et al., 2015; Sefidi et al., 2013). The same results reported for other species in chestnut-leaved oak, another common associate of beech, grows in pure or mixed stands and has an average distance between trees of 7.6 m (Alijani et al., 2012) and within Persian ironwood stands this value was 6.0 m (Sefidi et al., 2014b).

According to the results of mingling index in this phase, beech stands are more or less pure and trees compete with the same tree species. Across all three plots (SA1, SA2, and SA3), 70% of the sampling points had reference trees where neighboring trees were beech that demonstrate high interspecies competition. It seems in the late stages of the sand development, beech stands tend to form the pure stands or in the other word the other species be suppressed by beech as a dominant tree and not be able to reach the canopy layer. According to reports from beech stands in the north of Iran, beech is the dominant and canopy tree in the old growth stands (Sagheb-Talebi et al., 2013: Sefidi et al, 2014a; Mattaji & Sagheb-Talebi, 2007). Also, Pommerening (2002) explained that the mingling is directly affected by the spatial pattern of tree distribution. For example, beech species tends to have a clumped spatial pattern, the most of its neighbor trees are of the same species while random spatial pattern of oak species leads to its highly mixed with other tree species.

Moreover, the average tree-to-tree interval (Di) was 4.8 m showing high interspecies competition among beech trees. We have other evidence to prove this fact. The mortality rate of trees also showed the high mortality of beech in the large beech trees (91%). The mortality is a critical part of the natural dynamics of forest. In this phase near to the 28% of dead trees was in the large sized diameter classes (>75 cm) that means in this phase canopy opening derived by large beech trees that facilitate regeneration establishment and stand initiation. The death of a single canopy tree or several neighboring trees creates a canopy gaps. The effects of canopy gaps on tree recruitment patterns had emphasized as major process determining regeneration development (Yamamoto, 1999; Bottero et al., 2011). Gap formation cause to changes in light levels, nutrient availability, litter depth, and regeneration microsites associated with snapped or uprooted trees (Muscolo et al., 2010). *F. orientalis* can adapt high stress in the closed forest stands. As a shade-tolerant tree species beech can grow in the understory stands, facing high intra-specific competition to reach to the canopy layer as a dominant species in the next stand development phases. Researches in the oriental beech forests showed establishment of beech highly depend on gap formation in canopy layer and are able to resistance in the low light condition (Parhizkar et al., 2011; Sefidi et al., 2011).

The investigation of oriental beech stands in the gap formation phase revealed that oriental beech stands are homogenous in term of tree diameter and height. Oriental beeches in this phase don't tend to be mixed with other tree species. The mortality of large sized beech caused to formation of gaps in the canopy layer. The formation of gap as a critical part of the natural dynamics of forest stands development. Awareness of these characteristics is useful for structural interventions to be in accordance with natural process of development of the stands and minimum deviation from nature. We can conclude that timber marking in this phase led to shifting stand to the next phase and accelerate the natural gap phase scale disturbances. Meanwhile removal single or groups of trees in the other phase may be far from the natural stand development ways.

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