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Dynamics and Structural Characteristics of a Natural Unlogged Oriental Beech (*Fagus orientalis* Lipsky) Stand during a 5-year Period in Shast Kalate Forest, Northern Iran

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Abstract

Investigation on structure and dynamics of natural forest ecosystems is an important issue for silvicultural decisions. The aim of this study was to analyse the dynamics and structure of a beech stand during a 5-year period in the Shast Kalateh forest in eastern Caspian region, North of Iran. Data were collected from a 16.9ha permanent research plot established in a natural unlogged stand from the year 2006 to 2011. All living trees with a diameter at breast height ≥7.5 cm were measured. The permanent research plot was dominated by six species (beech, hornbeam, ironwood, velvet maple, Caucasian alder and date plum). The analysis of results showed that the total living stand density and volume fluctuated between 302 and 287 trees per ha and 504 to 472 m^3ha^{-1} over the 5-year period, respectively. Results also showed that the total density of deadwood increased from 21 to 27.7 Nha^{-1} over the 5 years. During the study, the volume of dead trees was 15.3 m^3ha^{-1}, equal to 3% mortality in the volume of living trees in the year 2006. Live trees of beech, hornbeam and ironwood illustrated reverse J distribution, both for 2006 and 2011. The maximum proportion of stem number was found in the small diameter class (≤30 cm), whereas the maximum volume of trees was found in the largest diameter class (>75 cm). Another remarkable change was related to the amount of total volume in the diameter class (35-50 cm), which was 37.4 and 40.3 m^3ha^{-1} in 2006 and 2011, respectively. The proportion of stem number in diameter classes of 35-50 and >75 cm increased from 2006 to 2011, while the stem number of ≤ 30 cm and 55-70 cm diameter classes decreased with values of -8.18 and -2.72 regarding the year 2006. Also, the highest volume was calculated in the diameter class >75 cm in the years 2006 and 2011 (248.3 and 254.3 m^3ha^{-1}), respectively. The results showed that the highest mortality happened among young trees with diameter ≤ 30 cm. It can be concluded that Shast Kalateh forest as a part of beech forests is passing through a degradation phase, due to the significant number and volume of dead trees.

Keywords: Forest Dynamics, Structural characteristics, Oriental beech, Caspian region, Shast Kalateh

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1. Introduction

The study of structure and dynamics of the beech natural forest ecosystems is one of the important issues for silviculture, due to the importance of beech forests in the Caspian Forests representing a large resource for timber production, biodiversity conservation and environmental protection. Study of forest dynamics is concerned with the changes in forest structure and composition over time, including its behaviour in response to anthropogenic and natural disturbances (Oliver and Larson, 1996; Pretzsch, 2005). Changes in forest structure may occur naturally and from human intervention (e.g. utilization, application of silvicultural treatments, etc.). Understanding stand structure and development is useful in prediction of the effects of interventions for the management objectives. Management objectives may include habitat improvement, restoration and reconstruction of ecosystem functions or growth of trees as production wood (Sharma *et al.*, 2003). The increasing public awareness of the landscape, recreational and ecological aspects of forest ecosystems has been a major influence on forest management in the last few decades. As a result, there is growing interest in uneven-aged silviculture as an option to combine environmental and productive aspects of forest management (Schütz, 1997). Dynamics complexity is one of characteristics of natural forests. Stand composition and structure are under the influence of environmental conditions such as climate, geology, and physiography, interactions of tree species, and by disturbances characteristic (e.g. types, sizes, and intensities) (Parish and Antos, 2004).

Observation of changes over time using permanent plots is an efficient method not only for analysing community-level patterns of succession, but also for measuring properties of populations such as growth and survival rates (Austin, 1981). Long-term observation is of great importance for understanding forest dynamics and mechanisms of species coexistence due to change of forest ecosystems over time and space in terms of size structure, species composition and spatial distribution (Woods, 2000). Measurement of recruitment rate, mortality and population growth rate provide useful information to analyse factors affecting population dynamics and species coexistence (Nakashizuka, 1991). Natural and undisturbed forests provide a rare opportunity to study dynamics and the structure of vegetation after cessation of human management (Mayer *et al*., 1987; Leibundgut, 1982; Vacik *et al*., 2009). Natural forests also serve as references for biodiversity assessments and ecological monitoring, as they are not affected by any human activities (Frank and Kock, 1999; Frankand Muller, 2003). Conservation of biodiversity has become an important goal in sustainable forest management (Hansen *et al*., 1991; Franklin, 1993; Lindenmayer, 1999; Piussi and Farrell, 2000). Stand structure and composition are main stand attributes that affect ecosystem function which are interdependent (Oliver and Larson, 1990; Crow *et al*., 2002). Therefore, there is a need for studies of stands composition and structure to analyse the productivity and ecosystem sustainability (Oliver and Larson, 1990; Noss, 1993; Lindenmayer *et al*., 2000; Carvalho, 2011). Stand composition affects forest biota through provision of resources and shelter. Trees also affect microclimate conditions and ecosystem processes like nutrient cycling (Bormann and Likens, 1994; Hunter, 1996). Stand structure is related with the habitat of animal and plant species, and therefore is a convenient indicator for biodiversity. For example, the diversity of insect and bird species living in a stand is related to the stand diversity and structure complexity (Traill, 1993; Tanabe *et al*., 2001). In addition, structural components related with trees sizes, decaying standing and fallen trees and logs, have an important effect on forest diversity and functioning (Lindenmayer *et al*., 2000; Mac Nally *et al*., 2001). Thus, structural complexity can be used as an expression of species diversity, because structural complexity generates different ecological conditions that favor different species (Schoonmaker and McKee 1988; Hunter, 1996). Information about natural forest composition and structural pattern is important to understanding the source of biodiversity and provide useful information for sustainable management with regard to environment changes (Lindenmayer and Franklin, 1997; Hagan and Whitman, 2004; Spies *et al*., 2006). The analysis of the diversity and spatial distribution of trees can be used to assess and understand the underlying processes controlling the observed spatial structure and forest dynamics patterns (Spies, 1998; Miller *et al*., 2000). The implementation of nature-based silviculture should be based on knowledge about natural processes and structures. However, in Iran, due to lack of a comprehensive and updated database, and a short history of forest utilization, it is hard to find appropriate reference forests to study the characteristics of intact forests. Nowadays, it is generally accepted that natural forests are a good model for the realization of nature-based silviculture (Parviainen *et al*., 2000). However, the necessary information on the long-term observations of forest dynamics is required.

Oriental beech forests (*Fagus orietalis* Lipsky) represent the most important forest communities in natural forest in the north of Iran. These forests account for approximately 17.6% of the total forest area, 30% of the standing volume and 23.6% of stems number in Hyrcanian forests of Iran. The mean volume per ha varies between 480 and 740m^3ha^{-1}in pure stands and 600 and 700 m^3ha^{-1} in mixed stands. Moreover, about one third of the total volume of the existing trees fall into the large size trees (dbh>55 cm) comprising two third of the total stand volume (Resaneh *et al*., 2001; Sagheb-Talebi *et al*., 2004; Eslami *et al*., 2007). Studies on oriental beech forests indicated that the structure of such undisturbed beech stands are more or less irregular and uneven-sized (Fallah, 2000; Sagheb-Talebi and Schütz, 2002) and that natural regeneration normally occurs in small gaps (Ghourshbeigy, 2002; Shahnavazi *et al*., 2005). Similar results have been reported in other studies on the beech virgin forests of Europe (Korpel, 1995; Burger *et al*., 2001). According to literature many studies have been conducted in the field of structural characteristics of forest stands, both natural and managed, at the same time in the North of Iran but there has been less attention to the study of changes in stand structural features over time (such as the studies of Taheri-Abknar, 2000; Fallah, 2000; Sagheb-Talebi and Shühtz, 2002; Delfan-Abazari *et al*. 2004b; Eslami and Sagheb-Talebi, 2007; Eslami *et al*., 2007; Habashi *et al*. 2007; Delfan-Abazri and Sagheb-Talebi, 2007; Tabari *et al*. 2007; Hassani and Amani, 2009; 2010; Amini *et al*., 2010; Parhizkar *et al*., 2011a,b; Sefidi and Marvie-Mohajer, 2010; Sefidi, 2012) (Tab. 6). It is understood from reviewing the literature that studying dynamics and structural characteristics of natural forest is necessary in Iran. Also, a comprehensive study has not been reported in Iran summarizing all those studies. Thus, the issue of structural alterations and stand dynamics over time in the north of Iran is a new idea for the area, which can provide valuable in formation for management and of Iranian oriental beech natural stands. The aim of this study is describing the structural characteristics in an intact oriental beech stand at Shast Kalateh Forest in the eastern Caspian region of Iran.

2. Materials and Methods

This study was carried out in the 79 ha natural unlogged oriental beech (*Fagusorientalis*) stand in compartment 32, district 1, located at Shast Kalateh Forest in the eastern Caspian region, North of Iran between 36° 43′ 27″N, 54°24′ 57″E. A general view and location of the study area is given in Fig. 1. Elevation of the study area varies from 820 to 960 meters above sea level, with an average monthly temperature of 15.4°C, with maximum and minimum temperature in July (28.7°C) and in February (8.71°C), respectively. Mean annual precipitation is 650 mm. According to the De Martonne and Emberger classifications, the climate of the study area is cold and wet, having a temperate summer with short dry season. Stand total height is about 30 m and the canopy cover varies between 60 and 100 percent (Habashi *et al*., 2007). Soil texture is loam to clay-loam with a pH of 5.5 and soil is classified as a forest brown soil. Mean stand density and standing volume are 235 ha^{-1} and 463 m^3ha^{-1}, respectively (FRWO, 1995, 2008). The compartment consists of a natural, mixed, uneven-aged deciduous old-growth forest dominated by shade-tolerant Oriental beech with minor components of other broad-leaved species including hornbeam (*Carpinus betulus* L.), velvet and cappadocian maple (*Acer velutinum* Boiss. and *Acer cappadocicum*), Caucasian alder (*Alnus subcordata*), iron wood (*Parrotia persica*), date plum (*Diospyrus lotus*) and elm (*Ulmus glabra* Huds.). The compartment has experienced very limited human intervention and disturbance and has seen no silvicultural activity in the last 50 years since forest management plans started in Iran. Therefore, this stand could be regarded as an example fan in tact and un managed natural forest.

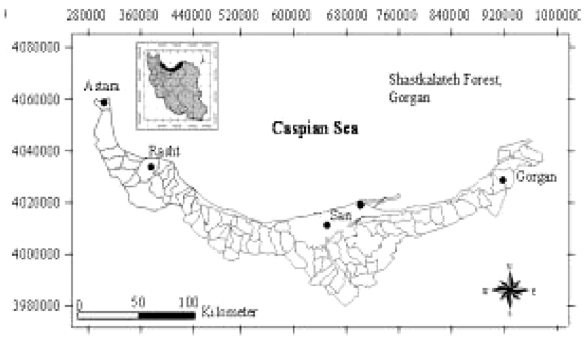

Figure 1. Location of the study site in the Caspian region

2.1. Living Trees Measurement

Selection of the 16.9 ha (406×416 m) permanent research plot in the compartment 32, District1 Shast Kalateh forest beech stand was made according to (i) long term intactness, that is about 50 years and (ii) homogeneity of the permanent plot regarding slope and aspect. The permanent plot was divided into 64 subplots of 50×50 m. All living trees with a diameter at breast height (dbh) of ≥7.5 cm (Delfan-Abazari *et al*., 2004a; Daneshvar *et al*., 2007) were identified by species and their dbh (cm), total height (m) and crown height (m) were measured. The position of the trees was determined by measuring their coordinates (distance and azimuth) in each subplot (Habashi *et al*., 2007; Mataji *et al*., 2007; Akhavan *et al*., 2011). Distance and height measurements were made with Laser Distance Meter (Leica Disto D5). The vertical profile of the stand was divided into three height layers (lower, medium and upper) according to the dominant height that reached 34 m. All of the measured trees were assigned to one of four diameter size classes: small size (dbh ≤ 32.5 cm, S), medium size (32.5 < dbh ≤ 52.5, M), large size (52.5 < dbh ≤ 72.5, L), and very large size (dbh ≥ 72.5 cm, VL) (Sagheb-Talebi and Schutz, 2002; Sagheb-Talebi *et al*., 2005; Eslami *et al*., 2007).

2.2. Dead Wood Measurements

Dead wood consisted of standing and fallen dead wood. Standing dead wood comprised trees with a dbh ≥7.5 cm that died standing or snapped dead trees with a stump height >1.3 m (high stumps). Fallen dead wood included logs (dbh ≥ 7.5 cm), pieces of trunk and large branches with a height >1.3 m. Fallen parts of trunk and branches were included with a diameter ≥7.5 cm at the larger end and a minimum length of 3 m (Atici *et al*., 2008; Sefidi *et al*., 2010). In order to estimate volume, the height and dbh of all standing dead trees and the length and dbh of logs and also the length and diameter at top thin, mid and end of fallen trees were measured.

3. Results

3.1. Changes of stand composition

The studied permanent plot contained 4834 and 4590 stems in the 2006 and 2011, respectively. In total, eight and ten tree species (≥7.5 cm dbh) were identified in the years 2006 and 2011 in the permanent research plot, respectively. Nevertheless, forest was dominated by six species (beech, hornbeam, ironwood, alder, and velvet maple and date plum) that accounted for 95% of the total density and volume in both 2006 and 2011 (Fig. 2). Beech accounted for 37% of stem number in 2006, while this rate raised to 40% in 2011. The proportion of hornbeam in the year 2006 (25%) was greater than in 2011 (21%). Also, the results showed that mean of differences in species frequency increased in all of the species, with the exception of hornbeam and date plum that showed a decreased species frequency of about (-3%) and (-1%), respectively over the study period (Fig. 2).

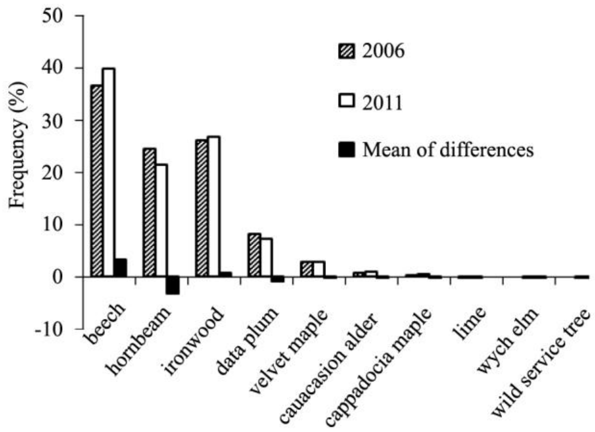

Figure 2. Changes in the abundance of tree species from 2006 to 2011 in the permanent research plot

3.2. Changes of stand structure; quantitative characteristics

Stand characteristics varied in all tree species. Caucasian alder showed the largest dbh and basal area at the beginning and end of the study period, while beech had the highest density and volume. Beech, Caucasian alder and velvet maple were identified as upper story and canopy species, while hornbeam, ironwood and date plum were as under story species. Almost half of the basal area and volume of the stand in both 2006 and 2011 was made up of beech (Tab. 1). Total stem number decreased from 302 in 2006 to 287 Nha^{-1} in 2011. Mortality in total was 17.34 ha^{-1} in the 5 year period (Tab. 1).The density and basal area of beech increased over the 5 years, while its volume decreased from 2006 (284.40 m^3ha^{-1}) to 2011 (263.3

m^3ha^{-1}). The initial density, basal area and volume of hornbeam in 2006 were 75.5 ha^{-1}, 8.21 m^2ha^{-1} and 125.17m^3ha^{-1}, respectively, but their values were 61.5 ha^{-1}, 8.07 m^2ha^{-1} and 113.8 m^3ha^{-1} in the 2011, respectively which showed a decreasing trend (Tab. 1). The density of ironwood, date plume, velvet maple and alder decreased during the study period. In contrast, the density of cappadocian maple was increased from1.25 (in 2006) to 1.38 (in 2011). Also, iron wood showed a decrease in the basal area and volume from 2006 to 2011 (Tab. 1).

Table 1. Structural characteristics of the permanent research plot of intact mixed beech stand at Shast Kalateh Forest, Iran during 2006 to 2011.

Species	Nha^{-1}		D.B.H (cm)		basal area(m^2ha^{-1})		volume (m^3ha^{-1})	
	2006	2011	2006	2011	2006	2011	2006	2011
Beech	110.2	114.7	44.0	45.61	16.8	17.1	284.40	263.3
Hornbeam	74.5	61.5	37.4	40.87	8.21	8.07	125.17	113.8
Ironwood	79.1	77.2	27.5	27.88	4.73	4.70	51.09	48.99
Date plum	25.7	20.9	13.0	13.31	0.33	0.29	2.56	2.67
Velvet maple	8.94	8.13	48.1	42.45	1.63	1.66	24.96	25.85
Caucasian alder	2.56	2.50	66.7	69.32	0.90	0.94	15.35	15.81
Cappadocian maple	1.25	1.38	27.7	29.4	0.08	0.09	1.08	1.06
Lime	0.13	0.13	20.1	48.5	0.00	0.02	0.05	0.20
Elm	0	0.31	0.00	22.8	0	0.01	0.00	0.14
Wild service tree	0	0.06	0.00	12.0	0	0.003	0.00	0.003
Total	302	287			32.73	32.97	504.65	471.7

As noted above in total, density of all species decreased from 302.2 (in 2006) to 287 Nha^{-1} (in 2011). Density of beech increased from 110.8 (36.6%) to 114.7 (40%) Nha^{-1}, while density of hornbeam changed from 74.2 (24.7%) to 61.5 (21.4%), ironwood changed from 79.2 (27%) to 77.2 (26.2%), date plum changed from 24.7 (8.2%)to 20.9 (7.3%) and velvet maple changed from 8.9 (3%) to 8.12 (2.8%) during the study period: 2006 to 2011. Density of deadwood in all species increased from 21.15 to 27.75 Nha^{-1} over the 5 years (Tab. 3). During the study period, the total volume of dead trees was 15.37 m^3ha^{-1}; this was equal to 3.07% mortality according to the living trees volume of 2006. The mortality of beech (7.44 m^3ha^{-1}) was higher than hornbeam (4.73 m^3ha^{-1}) compared with its volume in 2006 (Tab. 2). However, deadwood volume of hornbeam (23.1%), alder (4.2%) and other species (4.3%) decreased in the 2011, whereas deadwood volume of beech (61.2%), ironwood (9.76%), date plum (0.78%) and velvet maple (0.84%) decreased during the study period.

Table 2. Changes in volume of trees species from 2006 to 2011 in a permanent research plot of Shast Kalateh forest, Iran

Species	stand volume 2006		stand volume 2011		Mean of difference		Dead wood 2006		Dead wood 2011		Mortality 2006-2011	
	m^3ha^{-1}	Relative volume (%)	m^3ha^{-1}	Relative volume (%)	m^3ha^{-1}	% of 2006 volume	m^3ha^{-1}	Relative volume (%)	m^3ha^{-1}	Relative volume (%)	m^3ha^{-1}	% of 2006 volume
Beech	284.40	56.06	263.3	55.81	-17.1	6.1	23.64	62.87	27.78	61.20	7.44	2.65
Hornbeam	125.17	25.02	113.8	24.12	-11.4	9.1	7.75	20.63	10.48	23.10	4.73	3.78
Ironwood	51.09	10.21	48.99	10.38	-2.1	4.1	3.75	9.99	4.43	9.76	2.15	4.22
Date plum	2.56	0.51	2.67	0.57	0.1	4.4	0.66	1.78	0.35	0.78	0.29	11.32
Velvet maple	24.96	4.99	25.85	5.48	0.9	3.6	0.43	1.14	0.39	0.86	0.064	0.26
Alder	15.35	3.07	15.81	3.35	0.5	3.0	1.35	3.59	1.91	4.21	0.67	4.36
Other species*	16.6	3.58	17.21	3.94	0.7	4.2	1.35	3.59	1.950	4.27	0.7	4.21
Total	504.63	100.09	471.8	100	-33.7	5.7	37.61	100	45.40	100	15.37	3.07

Table 3. changes in density of trees species from 2006 to 2011 in a permanent research plot of Shast Kalateh forest, Iran

Species	Density 2006		Density 2011		Mean of difference		Dead wood 2006		Dead wood 2011		Mortality 2006-2011	
	Nha^{-1}	Relative density (%)	Nha^{-1}	Relative density (%)	Nha^{-1}	% of 2006 density	Nha^{-1}	Relative density (%)	Nha^{-1}	Relative density (%)	Nha^{-1}	Relative density (%)
Beech	110.81	36.7	114.75	40.0	3.9	3.6	5.48	25.93	7.93	28.6	3.69	21.31
Hornbeam	74.56	24.7	61.5	21.4	-13.1	17.5	3.88	18.35	8.25	29.7	5.43	31.37
Ironwood	79.13	26.2	77.18	26.9	-1.9	2.4	3.73	17.64	6.25	22.55	3.932	22.71
Date plum	24.75	8.2	20.93	7.3	-3.8	15.4	7.62	36.05	4.5	16.21	3.87	22.35
Velvet maple	8.94	3.0	8.12	2.8	-0.8	9.1	0.12	0.59	0.31	1.15	0.187	1.08
Alder	2.56	0.8	2.5	0.9	-0.1	2.4	0.31	1.47	0.43	1.6	0.125	0.72
Other species*	1.38	0.5	1.87	0.7	0.9	10.0	0	0	0.06	0.22	0.06	0
Total	302.13	100	286.88	100	-15.3	5.1	21.15	100	27.75	100	17.37	5.74

Other species: *Acer cappadocicum, Tiliabigonifolia, Ulmusglabra andSorbustorminalis*

3.3. Stand structure based on diameter classes

The dbh distribution of living trees of date plum, velvet maple and alder were bell-shaped, both in 2006 and 2011. The mode value for alder was 60-70 cm and this value for velvet maple was 20-30 cm and for date plum was 10-20 cm (Fig. 3). Live trees of beech, hornbeam and ironwood exhibited reverse J or L-shape distribution, both in 2006 and 2011. Distribution of number of diameter classes of beech showed that the highest frequency belonged to diameter class 10 cm (about 38 Nha^{-1}) and the lowest frequency belonged to diameter classes 110 to 150 cm (about 2 Nha^{-1}) in both years (Fig. 3). The highest number of living trees was found in the small diameter class (≤30 cm) over the 5 years, whereas the highest volume of living trees was found in the largest diameter class (>75 cm). Another large change occurred in the diameter class (35-50 cm) over the 5 years, namely from 37.4 m^3ha^{-1} (2006) to 40.3m^3ha^{-1} (2011) (Tab. 5). Mean differences of density in all diameter classes was negative during the 5 years period (-15 m^3ha^{-1}). While the largest mean differences of density was in the smallest diameter class ≤30 cm having value of -17.54 Nha^{-1} in comparison with 2006.

The density diameter classes of 35-50 and >75 cm increased from 2006 to 2011, while the diameter classes of ≤30 cm and 55-70 cm decreased in the value of -8.18 and -2.72 since 2006. The results showed that the total volume was decreased from 504.7 to 471.4 m^3ha^{-1} during the study period. The highest volume belonged to diameter class >75 cm from 2006 to 2011 (248.3 and 254.3 m^3ha^{-1}), respectively. Also the highest and the lowest changes in volume were in the diameter class >75 cm with (-24.19 m^3ha^{-1}) and ≥30cm with (+1.15 m^3ha^{-1}), respectively (Tab. 4).

The diameter class ≤30 cm had the highest amount of density in 2011 (68.5%), while the >75 cm diameter class had only 9% of the total density 2011. Also, it included only 8% of the total volume of all living trees. In constant, it counted about 54% of the total volume in the 2011. Of the stand volume of living trees found in 2006 (504.7 m^3ha^{-1}), about 498.3 m^3ha^{-1} (96.9%) were still living in 2011, while 2.29 m^3ha^{-1} (0.45%) had become standing deadwood, and 13.05 m^3ha^{-1} (3%) had become fallen deadwood (Tab. 5).

The proportion of surviving trees was 96.5% for diameter class ≤30 cm, 98.3% for diameter 35-50 cm, 97.8% for diameter class 55-70 cm and 96.3% for diameter class >75 cm. The proportion of deadwood from diameter class >75 cm (4.64%) was higher than the diameter class ≤30 cm (3.73%). Also, of the measured deadwood in 2006, 79.8% remained deadwood and 20.16% was lost until 2011. The loss of deadwood for ≤30 cm, 35-50, 55-70 and >75 cm diameter classes were 71.2%, 18.24%, 17.25% and 24.16%, respectively (Tab. 5). The highest loss rate of deadwood (71%) was in the diameter class small (≤ 30cm), followed by the >75 cm (24.14%) and the most of the lost deadwood (6.57 m^3ha^{-1}) was in the > 75 cm dbh class, followed by the ≤ 30 cm class (1 m^3ha^{-1}).

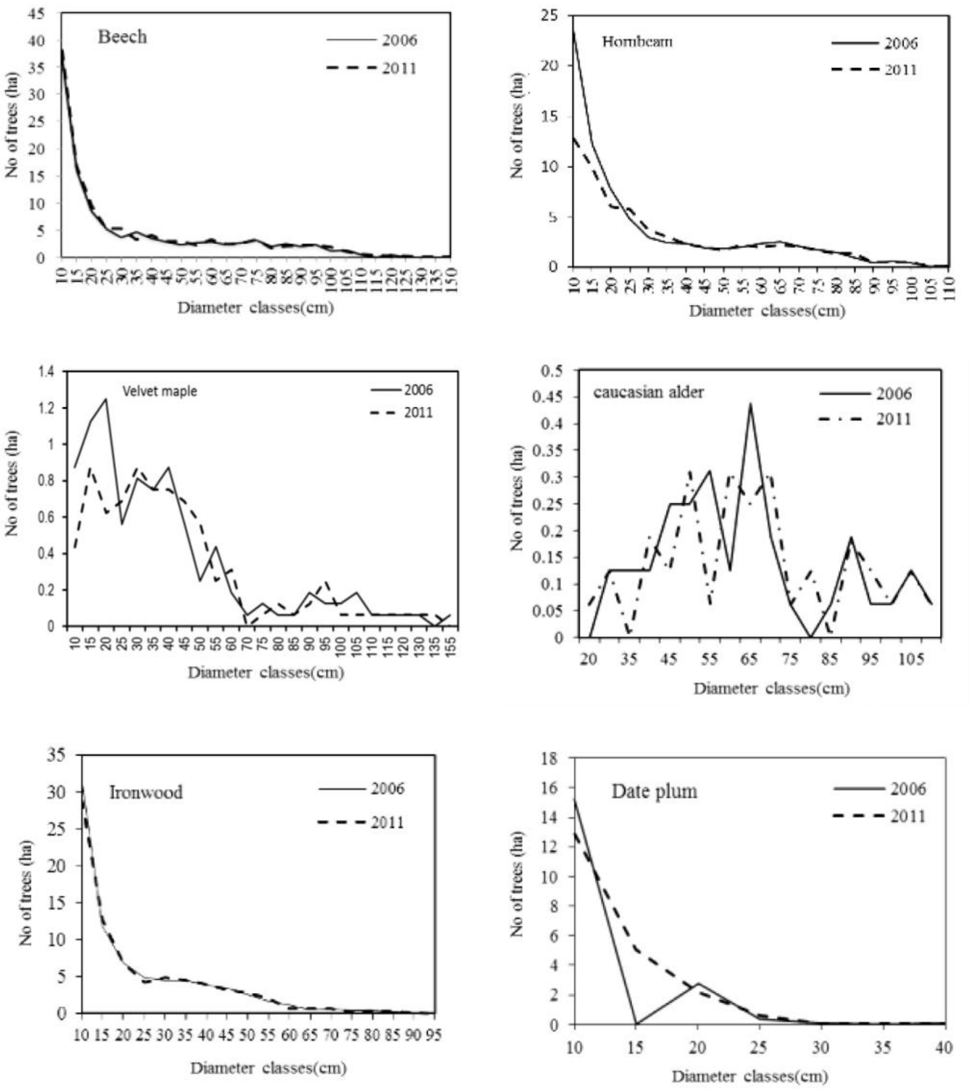

Figure 3. dbh distribution classes for the six main species in the permanent research plot of intact mixed beech stand at Shast Kalateh Forest, Iran

Table 4. Changes in volume of tree species from 2006 to 2011 in the permanent research plot of intact mixed beech stand at Shast Kalateh forest, Iran

Diameter class	No of trees/ha						Volume/ha					
	2006		2011		Mean difference		2006		2011		Mean difference	
	n/ha	Relative number (%)	n/ha	Relative number (%)	n/ha	% of 2006 number	v/ha	Relative volume (%)	v/ha	Relative volume (%)	v/ha	% of 2006 volume
≤30	214.7	71	197.1	68.5	-17.56	-8.18	36.5	7	37.5	8	1.10	3.01
35-50	37.4	12	40.3	14	2.88	7.68	71.3	14	70.3	15	-1.07	-1.50
55-70	25.3	8	24.6	8.5	-0.69	-2.72	118.3	23	109.2	23	-9.05	-7.65
>75	24.7	8	25.8	9	1.13	4.56	278.3	55	254.3	54	-24.19	-8.69
Total	302.1	100	287.9	100	-14.25	-4.72	504.7	100	471.4	100	-33.21	-6.58

Table 5. Changes in density of tree species from 2006 to 2011 in the permanent research plot of intact mixed beech stand at Shast Kalateh forest, Iran

diameter classes	live trees in 2006						deadwood in 2006			
	Still live $_{2011}$		SD $_{2011}$		FD_{2011}		Remained $_{2011}$		loss $_{2011}$	
	Volume (m/ha)	%	Volume (m/ha)	%	Volume (m^3ha^{-1})	%	Volume (m^3ha^{-1})	%	Volume (m/ha)	%
≤30	35.18	96.49	0.63	1.73	0.65	2	0.404	28.8	1.00	71.18
35-50	70.16	98.33	0.58	0.81	0.61	1	2.67	81.76	0.60	18.24
55-70	115.73	97.83	0.623	0.53	1.94	2	4.75	82.75	0.99	17.25
>75	268.24	96.30	0.46	0.17	9.85	4	20.61	75.84	6.57	24.16
Total	489.31	96.96	2.293	0.45	13.05	3	30.02	79.84	7.58	20.16

Table 6. Comparison of structural character is tics of beech stand forests in different study areas

Country	Forest type	Forest area (ha)	Minimum DBH (cm)	Density of living trees (N.ha^{-1})	Basal area living trees (m^2)	Living trees volume (m^{3}ha^{-1})	Total dead wood volume (m^{3}ha^{-1})	Dead wood/ living trees ratio (%)	Author(s)
Poland	Fagus-Abies-Picea	-[a]	8 8	183 189	32 33	547 578	306 289	-	Jaworski and Kolodziej, 2002
Germany	Fagus sylvatica	8	7	263	33	608.5	107	17.58	Von Oheimb *et al.*, 2005
Slovakia	Fagus sylvatica (pure stand)	-	16	112-272	-	490-778	65-201	-	Korpel, 1989
Slovakia, Stuzica	*Fagus sylvatica (pure stand)*	-	7	-	-	481-677	60-200	-	Saniga and Schutz, 2002
Slovakia	Fagus sylvatica (Beech-dominant)	5	8	394	42.3	793.7	163.8	20.63	Kucbel *et al.*, 2010
Iran	Fagus orientalis *(pure stand)*	-	7.5	-	32	484	-	-	Sagheb-Talebi and Schütz, 2002
Iran	Fagus orientalis (mixed stand, Optimal stage)	5	7.5	347	46.8	588	0.9	0.15	Delfan-Abazari, 2004
Iran	Fagus orientalis (pure stand) (mixed stand)	4 4	7.5	167 336		483.6 603.1	-	-	Eslami and Sagheb-Talebi, 2006
Iran	Fagus orientalis (mixed Beech-Hornbeam)	6.1	7.5	243.2	38.93	595.3	59	9.9	Amini *et al.*, 2010
Iran	Fagus orientalis (mixed stand)	16.9	7.5	302.13	32.73	504.6	37.63	7.45	This work (inventory, 2006; Habashi *et al.*, 2007)
Iran	Fagus orientalis (mixed stand)	16.9	7.5	286.88	32.97	471	45.40	9.63	This work (inventory 2011)

[a] data not available

The smallest diameter class (≤ 30 cm) consisted largely of date plum in 2006 and 2011, whereas this species did not occur in the diameter classes (55-70 and >75 cm). The volume of beech, hornbeam and ironwood were observed in all diameter classes, which with high size class, their amount increased. The volume of alder species was observed in the lowest dbh class for the years 2006 and 2011.Date plum and other species did not occur in the largest diameter class (>75 cm) (Fig. 4).

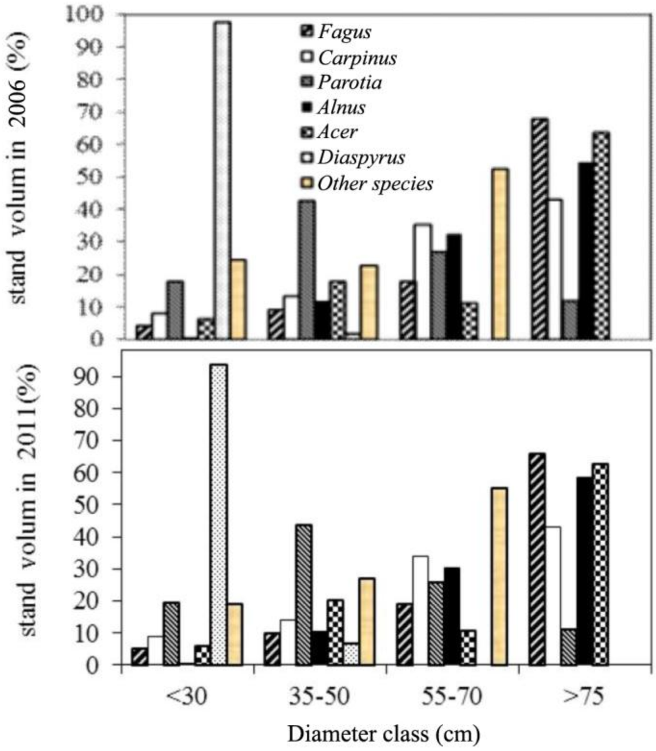

Figure 4. Diameter distributions of living trees in 2006 and 2011 according to stand volume and tree species per dbh class (% of total stand volume)

4. Discussion

Beech forests represent one of the most important forest communities in natural forested landscapes in the Caspian region, Iran (Marvi-Mohajer, 2005). Knowledge of forest dynamics can help us better understand changes and make correct decisions in implementation of appropriate management actions and restoration of forests. It requires regular monitoring of permanent research plots in different forest types. Nowadays, any intervention in forest ecosystems requires accurate and up to date information. This research was carried out in an intact mixed beech forests in Shast Kalateh forest in the Caspian region, North of Iran. The results showed that tree species composition has changed over the study period. We found that frequency of beech; ironwood and alder have increased 3.4, 1.2 and 0.87% in 2011, respectively. However, the frequency of hornbeam and date plum showed a decrease from with 3.27 to 1%, respectively (Tab. 1). This could be attributed to competition of the hornbeam and date plum with other species. However, further changes were found in young and old hornbeam trees. Reduction in frequency of date plum was found to be due to light demanding feature of this and other pioneer species, which in most forest stands of the north of Iran, cannot reach high diameter class. This diameter class can be frequently observed in the early period of growth with greater density in places where there is more light to the forest floor. In other hand, places where disturbances such as the creation of a canopy gap, wind fall entrees, uprooted trees, or longevity trees occurred provide a situation for date plum and other species. Comparison of the results of the current study with published studies in European beech dominated stands showed that the changes in species composition was similar to those with stand volume of 0-3.2% (Jaworski and Karczmarski, 1994) and 0.4-2.6% (Jaworski and Podlaski, 2007). The reduction of standing volume of hornbeam between 2006 and 2011 in the permanent research plot occurred due to a high mortality and low ingrowths compared to beech. As mortality of hornbeam took place in the lower diameter classes, it is supposed that inter and intra specific competition were the main reasons for this development. With this continued trend, it can be assumed that approximately after several decades' hornbeam might disappear from this forest. However, the absolute differences in diameter distributions between 2006 and 2011 indicated that the distributions changed more for hornbeam than the oak. The greater growth increment of beech compared to hornbeam justified this discrepancy.

The total density of 302 to 287 species per hectare declined from 2006 to 2011, equal to 5.1% reduction in the original density in 2006. The results showed that average density and basal area of beech has increased during the 5-years period. However, the average volume decreased from 2006 to 2011 (284.5 to 263.3 $m^3.ha^{-1}$), respectively. Also, the density of hornbeam, iron wood, velvet maple and date plum decreased during the 5-years period, and in contrast the volume of other species increased (Tab. 2). It is concluded that the density and volume of stand has increased significantly during the studied period from 17.32 Nha^{-1} to 15.37 m^3ha^{-1}. Therefore, the declined density and volume of live trees was normal. Tab. 3 showed that the highest mean difference of frequency belonged to beech and horn beam, which may have negative growth. At the same time, the date plum, velvet maple and alder did not show much change. This is because the beech and hornbeam include high percentage of the volume and mass of the stand. Hasanjad-Navroudi *et al.* (2009) examined thequalitative and quantitative changes in forest stands of Janbe Sara district of 1993 and 2003. Findings of their study showed that the average diameter of basal area was reduced from 42.63 in 1993 to 37.64 in 2003. Also, a significant difference was detected between average diameter of basal area in 1993 and 2003. The number of regeneration per hectare regarding all species increased during the period. Akhvan *et al.* (2012) analysed an intact old-growth oriental beech in the Caspian region beech stand and found that average density of trees in the initial, optimum and decay stages, was 454, 336 and 302

Nha^{-1}, respectively. In terms of the number of tress per hectare in the optimum and decay stages, the result of our study is in agreement with the research of Akhavan *et al*. (2012) in the Kelardasht Forest of Iran.

Distribution of diameter classes for different species showed that these changes are characteristic for beech and for ironwood is not very evident. However, this change in the hornbeam, alder, maple and date plum species is clear. Small diameter class (≤30 cm) in hornbeam species has changed dramatically in 2011 with respect to 2006. This might be because of following reasons: competition with other species, (especially beech, from 2006 to 2011), the size of land between horn beams increasing in the year 2011, sowed can conclude that the number of trees indifferent diameter classes 10-20 cm during the 5- year period has been reduced significantly and have become stable. Not too much change has been occurred in the diameter of the other classes. For alder and maple species irregular changes in different diameter classes can be observed. As can be found in Fig. 4 for alder in 2006, there is no stem in diameter classes 15 and 20. No diameter classes 35 and 85 of species were found in 2011. For maple species, diameter classes of 10-20 cm in 2006 were more than 2011. Severe changes in the date plum in diameter classes 10-20 cm was observed during the 5-year period, given the fact that this species in 2006 had no trees in diameter class 15 cm. while in the same year, the highest number of trees were in diameter class 10 cm, but it can observed in 2011 that the number of trees with stem ingrowth from dbh 10 to 15 cm have increased in 2011 while the density in the dbh 10 cm in 2011 is less than 2006.

In the study conducted by Sefidi (2012), the average volume was 386 m^3ha^{-1}, and the average number of trees was 189perha. Also, the measured mean and median diameter of trees were 32.3 and 34.2 cm, respectively. Total of tree frequency included beech 66.1%, hornbeam 19%, and velvet maple 6.1% and other species comprised 8.8%.The beech species comprised76% of the total volume of trees. The average diameter of the trees in the present study covering the years 2006 to 2011 were (37.1 to 37.2 cm), respectively. It can be concluded that the Shast Kalateh forest is a mixed forest, where beech is a dominant species and hornbeam is a substantially co-dominated species. The results of our study showed that the relative proportion in volume of beech and hornbeam during the 5-years were decreased. However, the amount of this change for hornbeam was more than the beech over the 5 years under natural conditions. Considering the high number of trees in the diameter class >75 cm, we can say that the Shast Kalateh forest is an old growth, irregular and uneven-aged forest dominated by beech. Thus, small changes in the proportions of the tree species happened while the proportion of hornbeam and date plum (a species with pioneer characteristics and fast growth during youth) decreased and the replacement of beech with velvet maple and alder (a climax tree species in the most Caspian forest) increased. Volume of all living trees in both beech and hornbeam as dominant species in the permanent plot decreased during the 5-years period (Tab. 3), while volume of deadwood for beech and hornbeam increased from (23.5 and 7.43 m^3ha^{-1}) to (27.8 and 10.5 m^3ha^{-1}), during 2006-2011 (Tab. 3).

Also, result of our study showed that density of beech and other species increased over the cited 5 years, whereas the density of hornbeam, ironwood, date plum and Velvet maple with respect to the year 2006 decreased by 13.2%, 1.9%, 3.8% and 0.8% respectively. Although 5 years is too short to draw conclusions about the general natural dynamics in the forest and other directions in natural development, but according to the results, considerable changes has been occurred in the study area. Hence, further monitoring and repetition inventories will be needed in the permanent research plot of Shast Kalateh forest to draw more concrete results.

Mean density of living trees with >7cm dbh in beech forests of central Europe amounted to $263ha^{-1}$ and about one-third of the trees (95 ha^{-1}) occurred in the upper canopy layer (Oheim *et al*., 2005). Habashi *et al*. (2007) reported that the main species had commonly a continuously reverse L-shaped dbh distribution (live trees). Stand structure of beech forest was dominantly L-shaped in dbh distributions (Marvi-Mohajer, 2005; Oheimb *et al*., 2005). In our study alder, maple and date plum species had Bell-Shaped dbh distributions. The beech, hornbeam and ironwood dominated the canopy layer and also comprised a high amount of stems in the middle understorey layer. Despite their low density in the understorey, their longevity may allow for continued coexistence of these species in canopy layer.

The volume of deadwood ranged from 37.4 to 45.7 m^3ha^{-1}. The average volume of deadwood in natural beech forests varied mainly from 30 to 130 m^3ha^{-1} (Leibundgut, 1993; Korpel, 1995; Tabaku, 2000; Saniga and Schutz, 2001). Ohiem *et al.* (2005) recorded a volume of dead wood of 94 m^3ha^{-1} in Serrahn of Germany Forest (Tab. 6). In Shast Kalateh forest the amount of deadwood increased in recent years due to the high mortality of dominant trees, such as hornbeam. Eslami *et al.* (2006) found that beech stands in the north of Iran are old growth and include a high percentage of the volume in the large diameter classes (>55 cm), while they made up a small percentage of the young classes. Hasanzad-Navroudi *et al.*, (2009) implemented aqualitative and quantitative analysis of changes in Janbe Sara district stands during 1993 to 2003 and found that the average diameter of basal area was reduced. Also, they found a significant difference between average diameter of basal area and Lorey height. Findings of Hasani and Amani (2009) in the Sangdeh forest in the Caspian region showed that the stand has a closed canopy cover and distribution of stem number per diameter class was homogeneous (Bell shaped) with a semi even-aged structure. Also, stem number and volume were 562 ha^{-1} and 677.9 m^3ha^{-1}, respectively. Sagheb-Talebi and Schutz (2002) found that the natural beech stands in the Caspian region illustrate an irregular, heterogeneous and uneven-aged structure at the minimum area of one ha, and all the beech stands in the north of Iran are old and contain a higher proportion of large trees. The low proportion of volume in smaller dimensions in the Caspian beech stands is obvious and this suggested a possible problem with stem recruitment if the structure of forests is not changed. In contrast, the irregular structure of European mixed fir-spruce-beech stands is distinguishable on much smaller areas (Schutz, 1999). In order to maintain the irregularity and the uneven-aged structure of the stands in long term and to accelerate the regeneration process, regeneration is best established in groups. In addition, density and volume of the most species except for velvet maple, decreased during the 5-years period. Thus, we can conclude that the velvet maple forest is still developing and that species composition and size structure of each species are not stable over time. Takashi *et al*. (2007) found that the competitive effect on growth rate of adult trees was not large at low density and cannot be a major structuring force of the tree community. A possible reason for weak competition was the low density of trees due to the dense herbaceous cover and *Ruscus hyrcanus* species in the forest floor. As a conclusion, our study revealed that this forest is not in equilibrium in terms of species composition and size structure, and factors are affecting recruitment processes of which disturbance, crown stratification between trees taller than 34 min the top height stand can be cited here.

5. Conclusion

In spite of availability of some areas of intact beech forests in the Caspian region, no long term studies were found on their structural dynamics and changes. Hence, conclusions regarding the long-term natural dynamics of beech forests is to a certain degree speculative. Longer time series on large sample plots from multiple sites and comparable data from the remaining natural beech forests in the Caspian region are necessary to further improve our understanding of causes and mechanisms involved in long-term beech forest dynamics. Using large sample plots is particularly feasible for studying the structure and dynamics of forests due to a reduction of edge effects, and the possibility of analysing the spatial distribution of structural elements (Meyer *et al*., 2001). A further harmonization of sampling methods would make quantitative comparisons between different studies more straightforward in the future (Oheim *et al*., 2005). On the other hand, the purpose of computation on large areas is estimating sustainable forest characteristics and identification of the forest phase sequence which can be facilitated by those harmonized measurements.

According to the current state of knowledge, gap phase dynamics, old growth and longevity forest (trees) seem to be the prevailing disturbance regime, which causes a small-scale differentiation. However, large-scale disturbances such as wind throw due to catastrophic storms may not play a major role in structuring natural beech forests in this region. In Shast Kalateh forest as well as in other near-natural beech forests, a longer time period of undisturbed development will be needed before forest structure and dynamics; which have been homogenized by human interference, once again attain heterogeneous, virgin-forest-like condition on a small spatial scale. One of the main objectives of establishing permanent research plots in the intact forests is to regularly monitor natural vegetation processes, which will be used as a reference value in near-to-nature management of the same forest types. Due to the number and volume of significant dead wood beech forests, it can be concluded that Shast Kalateh forest is passing through the degradation phase. The results showed that the highest mortality rate happened among young trees with dbh less than 30 cm diameter. We found that the highest density of trees is in this class which comprised about 70 percent of the total density of trees in the permanent plot. Therefore, we conclude that more mortality is due to happen because of the high density of trees in this diameter class and because of ecological competition, soil characteristics and uprooting trees. Also, the young diameter class had the highest mortality among other classes. However, the highest amount of standing volume belonged to very large diameter class. This forest is intact natural and has been developed for many years without human intervention. However, environmental conditions, soil and topography of beech stands across the Caspian region have different features. Finally, the mixed beech of Shast Kalateh forest can be used as a model for other natural beech forests in northern Iran.

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