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Natural changes in stand structure in the permanent plot of Hyrcanian forests (North of Iran)

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Abstract

This research was aimed to investigate natural changes in stand structure of Hyrcanian forests. Forest structure, proportion of dead wood, and proportion of tree species were studied in 2006 and 2012. Results of the inventory of total 2375 trees in 2012, showed 3 layers and uneven-aged structure in a forest type of *Fagus orientalis-Carpinus betulus*. Other results are as following: mean tree number 389 ha^{-1}, mean basal area 43 m^2ha^{-1}, mean stand volume 538 m^3ha^{-1}, and De' Liocourt factor is 1.38. Dead trees were counted about 3.1% of the tree number and 5.7% of the stand volume. Comparison of the two inventories showed that beech trees are gaining more proportion among the tree species in almost all diameter classes, while hornbeam is losing more presence in the diameter classes. In DBH classes lower than 30 cm the proportion difference between beech and hornbeam is more obvious. Volume of damaged trees (broken, hollow, snag and log) was counted about 97 m^3ha^{-1}; while for dead woods was 30.6 m^3ha^{-1}. Within the six years of study, the hollow large trees have been fallen down. Dying of trees in DBH classes of lower than 50 cm provides a lot of scattered small gaps within the stand and caused establishment of younger individuals and cohorts. Almost 9.6 m^3ha^{-1}, comprising 1.6% of total volume, 28% of dead tree and 8.9% of damaged trees, was decomposed. In general view this forest is tending from the senility to juvenility in forest succession.

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Introduction

Study of the forest structure includes the identification of constituent elements of the stand and to investigate the type and amount of the elements relationship together. In practice, the structure is studied if the items are examined as: the frequency of each value of the number of trees, stand volume, basal area, canopy cover or height per diameter classes, age or height profile associated with the type of contribution of each factor (Amini, 2001). The study of forest stand structure is done in horizontal and vertical structure individually or combined (Marvimohajer 2013).

In the natural forest monitoring the ecological changes process (Sylvics) should be executed in long term, with repeated sampling at fixed locations. Also, it should be under natural conditions where external and abnormal factors have the lowest effect in site dynamics. To achieve scientific findings of Sylvics such as studying the structure and composition of forest stock, the quantity, composition and percentage of dead trees, the study of mathematical relationships and the distribution of trees' number, stand volume and basal area in diameter classes and their changes over time, the Permanent Forest Study Plot (PFSP) is necessary (Amanzadeh *et al.*, 2013).

PFSPs in Hyrcanian forests: for the first time PFSP was established in 1982 in Chalus, Iran with one hectare plots (Daneshvar *et al.*, 2008). As the results of the inventory of 258 forest plots and comparing data between interval of two inventories (2003 and 2012) the number of beech trees increased 4 percent and hornbeam trees decreased with the same ratio. During this period a total of 5 M^3ha^{-1} (about 5.2 percent) is added to the volume of beech trees (Bayat *et al.*, 2014a & b). The PFSP established in Sari forest in 1998. According to inventory of 2012 and the study of the structure of the forest, height of trees makes up most of the 39 percent of volume. About 15 percent of the number and 20 percent of beech trees, which are in upstage, belongs to hollowed tree and head broken. Beech trees include 27 percent of the number and 38 percent of the total volume, respectively. About 59 percent of the number and 77 percent of the hornbeam trees are hollowed trees (Amini, 2006; Amini *et al.*, 2010; Amini, 2012). The PFSP in the Research and Educational Forest of Gorgan University of Agriculture Science and Natural Resources was established in 2003 with an area of 17 ha (Daneshnar *et al.*, 2008). The results of the study (2005 to 2010) showed that the volume of dead trees have decreased from 58.76 to 51.28 M^3ha^{-1} and their number increased from 27 to 29. About 70 percent of the number and volume of dead trees were fallen and others were standing. Hornbeam had the highest number and beech had the highest volume of dead trees (Yaghoobi, 2011). Another study in the same place shows that the number of dead trees was 27.7 and their volume was 45.4 M^3ha^{-1} consisting about 9 percent of the total stand and volume per hectare. From total standing dead trees 61.5 percent were fallen and 28.5 percent was standing. Diameter classes of less than 30 cm by 17 dead trees and 8.1 M^3ha^{-1}, and diameter classes of 55 to 70 cm with 2.75 had the minimum number of dead trees and the diameter classes more than 75 cm with 32.5 M^3ha^{-1} have formed the highest rate of the volume of dead trees (Amiri *et al.*, 2015). In a study on the structure of this forest (Amiri *et al.*, 2013) during a 5 year period the number of trees decreased from 302 to 278 and the volume increased from 472 to 502 M^3ha^{-1} and according to these result, forest is tending through a stage of destruction.

Another study was executed in unmanaged forests of Vaz-rood (Amol). As the results dead trees with 24 trees Nha^{-1} was about 9.3 percent and 7.32 M^3ha^{-1} about 5.3 percent of the forest stand volume of it 77 percent was fallen dead trees (Habashi, 1997). In 100 ha of Nushahr forests the amount and quality of dead trees were investigated in two parcels with different management experiences. In the forest with longer period forest management 2.5 Nha^{-1} dead trees with a volume of 5.17 M^3ha^{-1} and 64 percent of the dead trees volume belong to the fallen trees. In forest with short period management, 21 Nha^{-1} dead trees with

the volume of 3.17 M^3ha^{-1} and 68 percent include the volume of fallen dead trees (Sefidi and Marvimohajre, 2009; Sefidi and Etemad, 2014). Another study in the same forest showed the volume of standing dead trees 1.26 M^3ha^{-1} and 70 percent of dead trees volume which are in diameter classes of more than 40 Cm (Sefidi *et al.*, 2008). In Nushahr forest, the dead tree volume was 16.5 M^3ha^{-1} which 74 percent of it belongs to fallen dead trees (Zolfaghari, 2003). In another study in Guilan the quantity and quality of dead trees with a diameter larger than 50 cm in the control plot (unmanaged) was compared with two managed plots. The ratio of fallen dead trees in the control plot was 58 percent and in managed forest was 61.4 percent (Akbari, 2010).

This research was aimed to investigate natural changes in stand structure of Hyrcanian forests.

Materials and methods

Study area

This Permanent Forest Study Plot (PFSP) is located in the north of Iran, Neka-Zalemrud forest project, in 45 kilometers of south of the Sari city (Fig. 1).

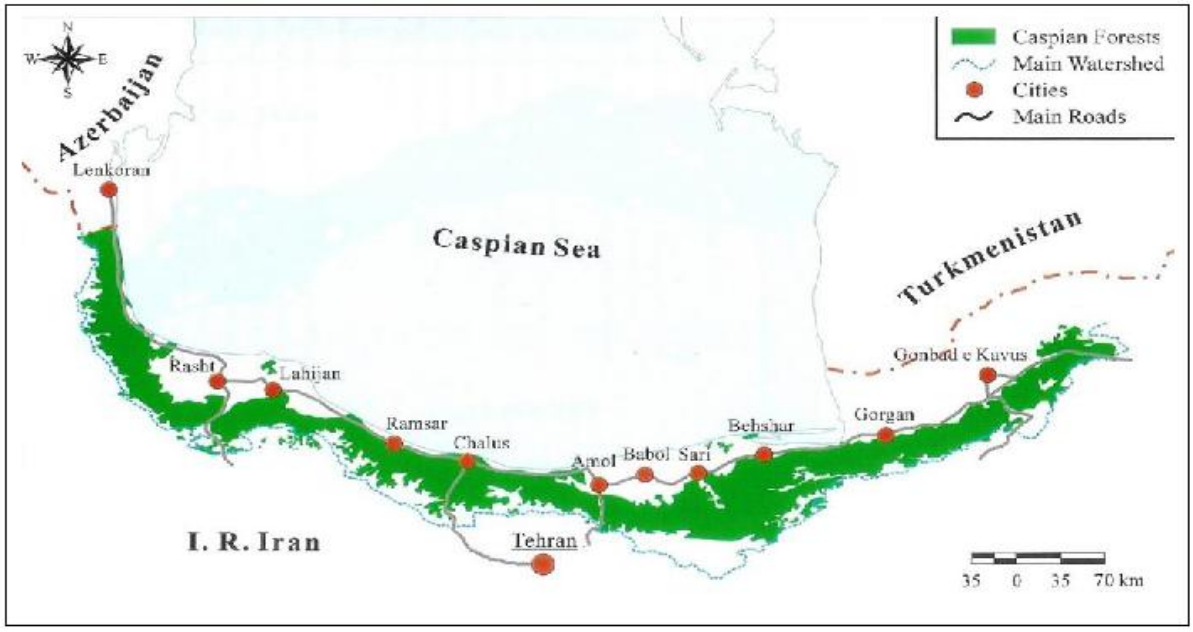

Fig. 1. The Location of the project in northern part of the Iran south of Sari city.

The PFSP was studied in the present research with an area of 6.1 ha located on 700 to 750 meters above sea level, with latitude of 36°, between 20-29 minute and longitude of 53°, between 8-17 minute and in the revised forest project (2005) parcel 27 Series 3 section 5 of the Nekazalemrud watershed.

Field study

Vegetation cover contains *Fageto-carpinetum*, there Beech and Hornbeam and various forest types were irregularly mixed and rare species can be seen such as wild Cherry and Elm (Amini, 2006). Based on primary forest project the estimated annual increment of the *Fageto-Carpinetum* association is 3.5 M^3ha^{-1}. It can be increased up to 6 M^3ha^{-1} with proper management (anonymous, 1969).

According to the data of the meteorological station, the average of the monthly temperature is 16 C° and during the two months of the year was over 22 C°. Annual rain is 837 mm and in any of the months of the year less than 50 mm of precipitation was observed, snow depth changed from 5 to 50 cm it rains in winter and will melt soon. In climate meteorological data (Omberotermic curve) there is not dry period or dry season in all months of the year and there are humid forest areas.

Based on the result of the field description and inventory, the structure and composition of the forest have appropriate capacity for the present studies. Because of distance to the village and the lack of farms, nearby this PFSP it remained secure from human and animal interference and optimal protection can be applied on it.

The PFSP bordered by woody piles and five rows of barbed wire. To record the address of each tree with diameter more than 10 cm (ID number), it was numbered by installing metal tags (aluminum with dimensions of 12 × 8 cm) on the stumps; also the numbers was written on the trunk of each tree with white color. Forest inventory was conducted by method of Census (100 percent) in 2006 and 2012 (Amini, 2006; Amini, 2012). In the inventory, tree species name, ID number, diameter at breast height (DBH) of all trees with 7.5 Cm DBH were measured by caliper and trunks quality specifications were recorded in the form. Physiologically or environmentally injured trees including standing damaged trees, (head broken, hollow and fallen) were measured as the same method for healthy trees. The volume of the healthy Beech trees extracted from the volume tables. About the other species it was done by using the volume table (tariff) of the forest project (Anonymous, 1994; Amini, 2006). The volume of unhealthy (standing, fallen and hollow) trees were calculated by geometric equations (Zobeiri, 2005). After calculating the basal area (BA) at breast height of each tree, basal area per hectare was calculated, respectively.

Studying the forest layering was done through measuring the total height of 104 Beech and Hornbeam trees. Then, all trees in PFSP with total height more than two third of the dominant (emergent) trees were recorded as over storey (first class), all trees with total height between one third and two third of the dominant trees were recorded as middle storey (second class), and the others with lower size were recorded as under storey (Marvimohajer, 2013).

Tallness index calculated by (100* tree height / tree diameter).

Results

Forest structure

The most important results of the inventory at the end of the growing season in 2012 of 2375 trees in the PFSP are as follow: the volume of standing trees 538 M^3ha^{-1}, BA is 43 M^2ha^{-1} and the number 389 trees per hectare. Distribution curves of the number of trees in diameter classes with five centimeters interval show a decreasing trend as the natural mixed and uneven aged forests (Fig. 2).

Calculated results and distribution of the number of trees based on species and diameter classes are presented in Table 1 and Fig. 3.

Table 1. Distribution of the number of trees in diameter classes and the species recorded in 2012.

Tree species	Diameter classes (centimeter)											
	All classes		lower than 30		30 to 50		55 to 75		80 to 100		more than 100	
	No	%	No	%	No	%	No	%	No	%	No	%
Beech	1573	66.2	1212	71.7	163	54	107	50.5	63	53.4	28	52.8
Hornbeam	320	13.5	151	8.9	55	18.2	68	32.1	30	25.4	16	30.2
Alder	38	1.6	1	0.1	11	3.6	14	6.6	12	10.2	0	0
Cherry tree	2	0.1	1	0.1	1	0.3	0	0	0	0	0	0
Lime	15	0.6	3	0.2	2	0.7	4	1.9	3	2.5	3	5.7
Iron wood	73	3.1	35	1.2	31	10.3	4	1.9	3	2.5	0	0
Persimmon	297	12.5	270	16	26	8.6	0	0	1	0.8	0	0
Maple	44	1.9	8	0.5	10	3.3	14	6.6	6	5.1	6	11.3
Cappadocian Maple	6	0.3	3	0.2	2	0.7	1	0.5	0	0	0	0
Mountain Elm	7	0.3	6	0.4	1	0.3	0	0	0	0	0	0
Walnut tree	1	0	1	0.1	0	0	0	0	0	0	0	0
Total	2376	100	1691	100	302	100	212	100	118	100	53	100
Percent per classes	100		71.2		12.7		8.9		5		2.2	

According to the results, beech trees (*Fagus orientalis*) consisted 66 percent of the number of the trees and 54 percent of the standing volume, Hornbeam (*Carpinus betulus* L.) 13.5 percent of the number of trees and 25 percent of the standing volume, Iron wood (*Parrotia persica*) and Persimmon (*Diospyrus lotus*) species 15.6 percent of tree numbers and 3.8 percent of standing volume. So, the dominant type of the studied forest is Beech – Hornbeam (Table 1 and Fig. 3).

Table 2 shows the distribution of trees frequency and stand volume in diameter classes in 2006 and 2012 statistics. The results of the changes in volume and number of trees per hectare and their distribution in diameter classes during the two inventories show that: the D'Liocourt factor is 1.27 in the inventory of 2006 and 1.38 in 2012. In diameter classes smaller than 30 cm, there was more than 17.2 percent increasing in trees numerous and for volume it was 0.03 (Table 2).

Table 2. Frequency distribution of the number and the volume of trees in diameter classes in two inventories (cubic meter per hectare).

Diameter Classes (Cm)	Inventory Years								The difference between 2006-2012			
	2006				2012							
	Volume		Numerous		Volume		Numerous		Volume		Numerous	
	M3	%	N	%	M3	%	N	%	M3	%	N	%
Lower 30	29.8	4.97	788	54	27.1	5	1690	71.2	-2.6	+0.03	+902	+17.2
30-50	88.7	14.8	290	19.9	65.5	10.3	302	12.7	-23.2	-4.5	+12	-7.2
55-75	194.2	32.6	232	15.9	142.4	26.5	212	9	-51.8	-6.1	-20	-6.9
80-100	205.1	34.3	123	8.3	156.8	29.1	118	4.9	-48.3	-5.2	-5	-3.4
105-150	77.9	13.1	25	1.8	145.9	27.2	53	2.3	+68	+14.1	+28	+0.5
Total	595.3	100	1458	100	537.8	100	2375	100	-57.5		+917	

Table 3. Change of species frequency in diameter classes between the two inventories.

Inventory years	species	diameter classes (centimeter)											
		All classes Lower than 30		Lower than 30		30 to 50		55 to 75		80 to 100		More than 100	
		No	%	No	%	No	%	No	%	No	%	No	%
2006	Beech	838	57.5	491	62.3	155	52.9	116	50	62	50.4	14	56
2012	Beech	1573	66.2	1212	71.7	163	54	107	50.5	63	53.4	28	52.8
2006-2012	Beech	+735	+8.7	+721	+9.4	+8	+1.1	-9	+0.5	+1	+3	+14	-3.2
2006	Hornbe am	307	21	126	12.6	65	22.2	71	30.6	39	31.7	6	24
2012	Hornbe am	320	13.5	151	8.9	55	18.2	68	32.1	30	25.4	16	30.2
2006-2012	Hornbe am	+13	-7.5	+25	-3.7	-10	-4	-3	+1.5	-9	-6.3	-10	-4
2006	Iron wood &Persimmon	211	14.5	154	19.5	48	16.4	9	3.9	0	0	0	0
2012	Iron wood &Persimmon	370	15.6	305	18	57	18.9	4	1.9	4	3.4	0	0
2006-2012	Iron wood &Persimmon	+159	+1.1	+51	-1.5	+9	+2.5	-5	-2	+4	+3.4	0	0
2006	Other species	105	7.2	17	2.2	25	8.5	36	15.5	22	17.9	5	20
2012	Other species	113	4.8	23	1.4	27	8.9	33	15.6	28	23.7	9	17
2006-2012	Other species	+8	-2.4	+6	-0.8	+2	+0.4	-3	+0.1	+6	+5.6	+4	-3
Percent in classes			100		71.2				8.9		5		2.2

The number of trees in 10 cm diameter class increased 28 percent and volume 0.3 percent. In diameter classes of 30 to 100 cm the percentage of number and volume per hectare showed decreasing trend over the diagram in 2012 inventory to 2006. By increasing the trees diameter for changes in the number volumes is decreased. So that, in diameter classes of 80 to 100 cm, reducing the number of trees was equal to 3.4 percent between the two inventories the factor of volume decreases 48 percent. In contrast, in the upper diameter classes of 100 cm 0.5 percent increasing in tree density the volume of the diameter classes increased 14 percent. Table 3 and figure 4 show the percent change in the inventory of

species in diameter classes in two inventories.

In the present PFSP the dominant height is 38-40 meter, thus trees with total height of 26 m and more was recorded as over storey which was equal to 35 cm in DBH and more. Table 4 shows the results of tallness index in diameter classes for Beech and Hornbeam trees.

Dead and damaged trees

The number of the dead and damaged (lost) trees (include: fallen trees, standing dried, head broken and hollow) measured in PFSP in 2006 and 2012 inventories were 76 and 138 one. They consisted of 5.2 percent and 6.1 percent of the total number of the PFSP trees and 59 and 97 M^3ha^{-1} equal to 9.9 and 18 percent of stand volume. The portion of damaged trees in all types of trees and the share of each groups from total are presented in table 5.

Table 4. Mean of height of the sample tree in diameter classes and H/d factor.

Beech						Hornbeam					
dia	H	H/d	dia	H	H/d	dia	H	H/d	dia	H	H/d
15	13.3	89	70	36.1	52	15	17.6	117	70	31.6	45
20	18.3	91	75	36.8	49	20	21.2	106	75	32	43
25	22.1	88	80	37.4	47	25	23.7	95	80	32.3	40
30	25.1	84	85	37.9	45	30	25.6	85	85	32.6	38
35	27.5	79	90	38.4	43	35	27	77	90	32.8	36
40	29.5	74	95	38.8	41	40	28.1	70	95	33	35
45	31.1	69	100	39.2	39	45	29	64	100	33.2	33
50	32.4	65	105	39.6	38	50	29.7	59	105	33.4	32
55	33.5	61	110	39.9	36	55	30.3	55	110	-	-
60	34.5	58	115	-	-	60	30.8	51	115	-	-
65	35.4	54	120	-	-	65	31.3	48	120	33.8	28

Table 5. Portion of the lost trees in PFSP in the two inventories.

Years	of Factor	Share of the lost trees	Type of lost (unhealthy)				
Inventory		in PFSP (%)	Hollow	Top Brocken	Fallen	Standing Dead	Sum
2006	Stand Volume	9.9	52	21	15	12	100
	Trees number	5.2	33	34	18.5	14.5	100
2012	Stand Volume	18	19.6	27.3	41.6	11.5	100
	Trees number	6.1	8.7	25.3	45.3	20.3	100
2006-2012	Stand Volume	+8.1	-32.4	+6.3	+26.6	-0.5	+8.1
	Trees number	+0.9	-24.3	-8.7	+26.5	+6.2	+0.9

About 6.1 percent of the number of trees, 16.6 percent of basal area and 18 percent of the volume are related to dead and fallen trees. The proportion of dead trees is 3.1 percent of the number and 5.7 percent of the forest stand volume (Table 6).

Value and rate of the trees number, basal area and volume of lost trees, per hectare by species are shown in Table 7. Comparing the results showed that broken, unhealthy and fallen trees of Iron wood and Persimmon species with 24 percent of the trees number supply 3.2 percent of the volume .While Beech trees with 42.5 percent of number include 42.2 of the volume of losses trees. Hornbeam and Alder have the same situation. The two species of Lime and Maple, against Alder and Hornbeam have their most losses in higher diameters and both are the solitary species in the forest.

Table 6. Frequency and portion of injured trees number, basal area and volume per hectare in the 2012 inventory.

Trees situation		Tree number		Basal Area		Volume	
		No per Ha	%	M^2per Ha	%	M^3per Ha	%
Dead trees	Standing	28	1.2	0.87	2	10.44	1.9
	Fallen	46	1.9	1.57	3.6	20.17	3.8
	Sum of dead trees	74	3.1	2.44	5.6	30.61	5.7
Broken		35	1.5	1.8	4.2	24.87	4.6
Wind fallen (uprooted)		17	0.7	1.26	2.9	17.77	3.3
Cut off		6	0.3	0.44	1	6.06	1.1
Hollow trees		12	0.5	1.26	2.9	17.83	3.3
Sum of injured trees		144	6.1	7.20	16.6	97.14	18
Ramose	Two branches	25	1.1	1.26	2.9	16.79	3.2
	Three branches	10	0.4	0.66	1.5	9.31	1.7
Sum of unhealthy and losses		179	7.5	9.13	21.1	123.23	22.9
healthy		2196	92.5	34.19	78.9	414.55	77.1
Total		2375	100	43.32	100	537.78	100

Table 7. The frequency and ratio of the number, basal area and volume per Ha of lost trees in 2012.

Species	Tree number		Basal Area		Volume	
	No per Ha	%	M^2 per Ha	%	M^3 per Ha	%
Beech	76	42.5	3.77	41.3	52.04	42.2
Hornbeam	45	25.1	3.16	34.7	42.2	34.2
Alder	5	2.8	0.28	3.1	3.75	3
Lime	7	3.9	0.86	9.4	12.7	10.3
Iron wood	18	10.1	0.31	3.4	2.86	2.3
Persimmon	25	14	0.14	1.6	1.16	0.9
Maple	2	0.1	0.6	6.5	8.53	6.9
Mountain Elm	1	0.6	0	0	0.002	0
Total	179	100	9.13	100	123.23	100

As the results about 60 percent of the number of dead trees of the species and seven percent by volume are in diametric classes lower than 50 Cm (Table 8).

Discussion

Based on the results of the inventory of 2012, the diagram of the trees distribution in diameter classes show a decreasing trend and it is similar to natural uneven aged (multi aged) forests. Changes between the two inventories in the slope of the diagram and the data in table of the frequency distribution in diameter classes show an extent and rapid growth of young trees in the forest. Although reduction in the trees number from young to middle-aged trees are common among all species, but the gradient reduction in number percentage, subsequent fluctuations in higher diameter classes and changes of these ratios are not uniform across all the tree species.

Table 8. Frequency and rate of number, basal area, volume and the distribution of lost trees per hectare in diameter classes and 2012 inventory.

Diameter classes (Cm)	Tree number		Basal Area		Volume	
	No per Ha	%	M^2 per Ha	%	M^3 per Ha	%
Lower than 30	74	41.3	0.29	3.2	1.894	1.54
30 to 50	32	17.9	0.59	6.5	6.423	5.21
55 to 75	33	18.4	1.84	20.1	22.997	18.66
80 to 100	15	8.4	1.43	15.6	18.753	15.22
More than 100	25	14	4.98	54.6	73.163	59.37
Total	179	100	9.13	100	123.23	100

As the results of analyses of trees composition in diameter classes among young trees (diameter less than 30 centimeters), about 72 percent of the trees number is Beech, 9 percent Hornbeam, 16 percent Persimmon and Ironwood included only 1.2 percent of the trees number. Gradually in the higher diameter classes, Hornbeam and Ironwood had greater proportion and Persimmon showed reduction. In diameter classes more than 50 Cm Persimmons was omitted and the ratio of Hornbeam, Alder and the other species increased. Analysis of the composition of PFSP trees based on species rates showed that Beech occupied over 50 percent in all diameter classes.

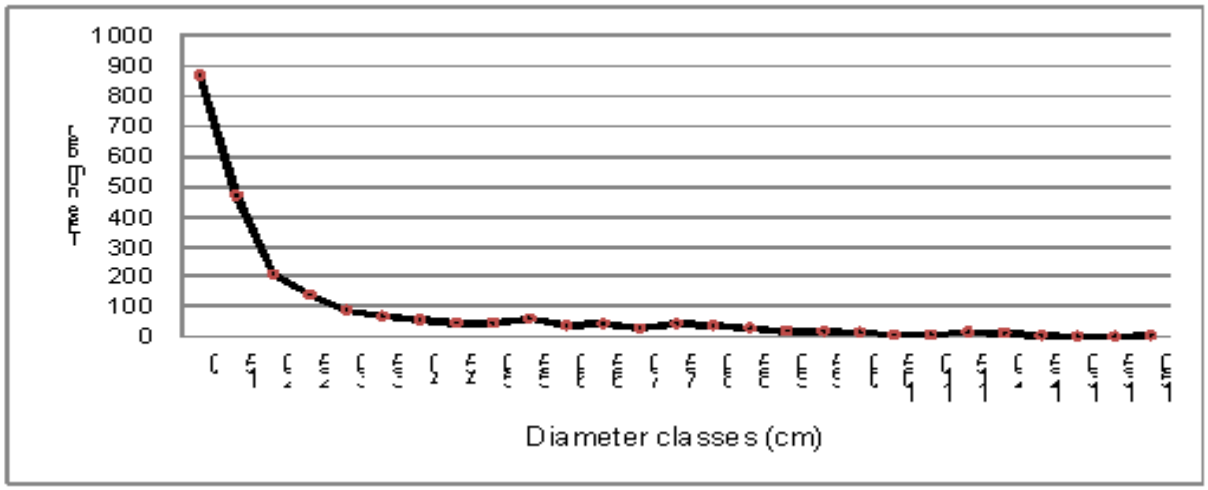

Fig. 2. Diagram of the tree No distribution in diameter classes in inventory of 2012.

Frequency percentage of the young Hornbeam trees is few even less than Persimmon, in higher diameter classes, gradually; it showed greater proportion, in diameter classes more than 100 cm, with 30 percent of the all trees and in ranking it is in second grade after Beech. Alder includes 1.6 percent of trees in stand. This species cannot occupy more than 1 percent of the young trees. But these very few young trees with minimal loss and good mortality, gradually found their space in stand. So that their frequencies percentage in diameter classes of 55 to 75 Cm reached to 6.6 percent and in 80 to 100 Cm increased to 10.2 percent.

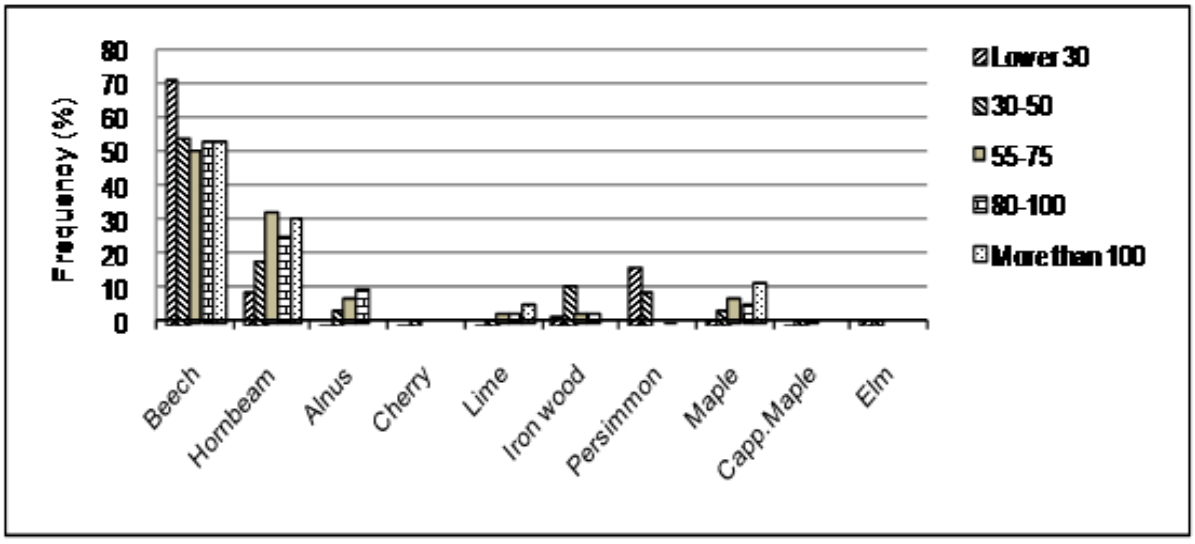

Fig. 3. Distribution the trees number in diameter classes of different species (percent per diameter classes).

Frequencies percentage of the Maple and Lime trees showed similar trend to Alder with a gentler slope. Other species such as Cherry, Cappadocian maple and Mountain elm trees have a little percentage in the forest trees. These rates have more reduction in diameter classes greater than 50 Cm. Ironwood species showed it's higher competitive and frequency in 30 to 50 Cm diameter classes with a significant percentage of 10.3. Then it reduced gradually and was omitted in diameter classes more than 100 Cm.

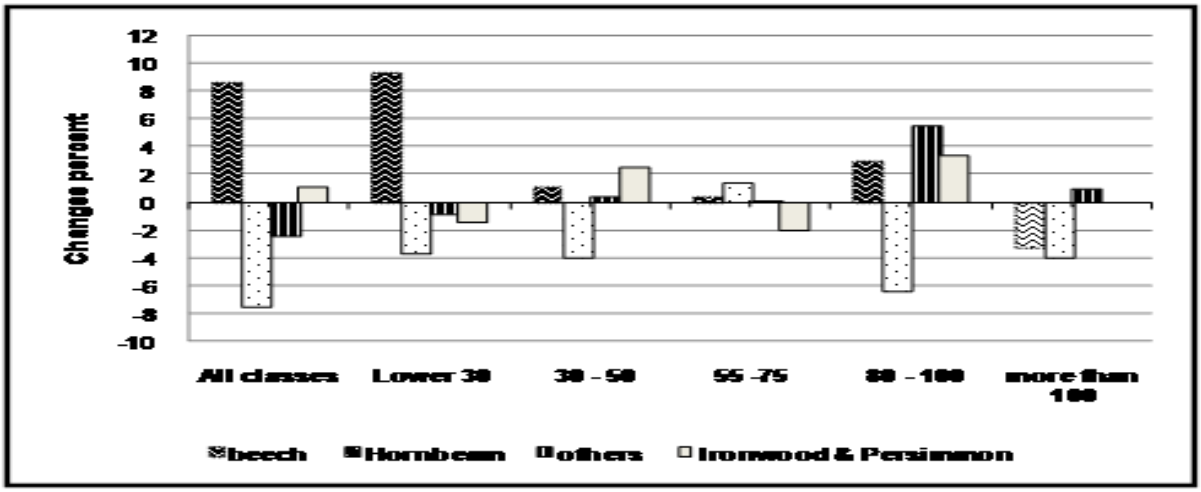

Fig. 4. Diagram of percentage change of the various species in PFSP during the inventory period.

Persimmon species in young diameter classes (less than 30 Cm), competes with other species with a significant percentage (16%). But it was omitted in diameter classes more than 50 Cm.

Other Beech and Hornbeam trees settle in the middle storey. Trees in 15 and 20 Cm DBH start competition to reach to middle storey. The tallness index of the trees lower than 35 Cm DBH proved this result.

Comparison of the results of the 2006 and 2012 inventories about the changes in share percentage in diameter classes of all Species indicated that Beech has a larger share than the other species and occupied more area in forest stand. These results are like to (Bayat, 2014 a & b) and (Kakavand *et al.*, 2015) in Nushahr. As (Habashi *et al.*, 2007) reported, this development and the elimination of competitors could be related to negative socialization of Beech trees. On the contrary, Hornbeam lost more shares in all diameter classes. In diameter classes Less than 30 Cm, the difference of share of Beech and Hornbeam is a considerable subject. Persimmon and Ironwood species in classes of 30 to 50 Cm had more stable situation than Hornbeam.

Comparison the contents of table 4 and figure 5 about tallness index of the Beech and Hornbeam showed that Hornbeam trees, because of their nature such as sunlight demanding, in juvenility take place in middle or over storey more quickly and then with a slower height growth, spend most of energy for increasing their diameter increment. On the contrary Beech trees with shade tending (tolerance) in juvenility live in lower storey, in the next period take place in middle and over storey and in higher diameter classes have both height and diameter increment (Amini, 2012).

The dominant height factor was 38-40 meter, thus trees with total height of 26 meter and more, recorded as over storey which is equal 35 Cm DBH and more.

Based on the inventory of 2012, the total volume of damaged trees (standing or fallen dead, broken head and hollow tree) was 97.14 cubic meters per hectare, which value of dead trees was 30.61 cubic meters per hectare. The dead tree ratio to total volume of the forest trees was 5.7 percent and 3.1 percent of their

numbers. This result is like to Habashi (1997) in unexploited forest of Vazrood (Amol) and (Sefidi and Marvimohajer, 2009) from a forest which was exploited in a long time. Also others have reported the amount of dead trees in Hyrcanian forests. (Zolfaghari, 2003) in Nushahr forest 16 cubic meters per hectare, (Yaghoobi, 2011) in Gorgan forest 51.3 and (Amiri, 2015) in the same place 45.4. Changes in range of the results are related to the situation of habitat, succession phase of the forest stand and the statistics method. The results of present study in PFSP were inside this range. In the present study, 42 percent of the damaged Beech trees contained 42.2 percent of the stand volume, because of their focus on the middle age diameter classes. Hornbeam and Alder also more or less had the same situation. About 51 percent of the number and 77 percent of the volume of Hornbeam which established in over storey are hollow trees (Amini, 2012). This has an important role in state change of the dead trees or their falling.

Broken, fallen and injured trees of Ironwood and Persimmon with 24 percent of the trees number make up 3.2 percent of the stand volume with this situation. The opposite of Ironwood and Persimmon were the two species of Lime and Maple which their major losses were occurred in higher diameters, they were both in the group of single trees in forest. Frequency distribution of various species of damaged trees was like the distribution of all the trees in the forest.

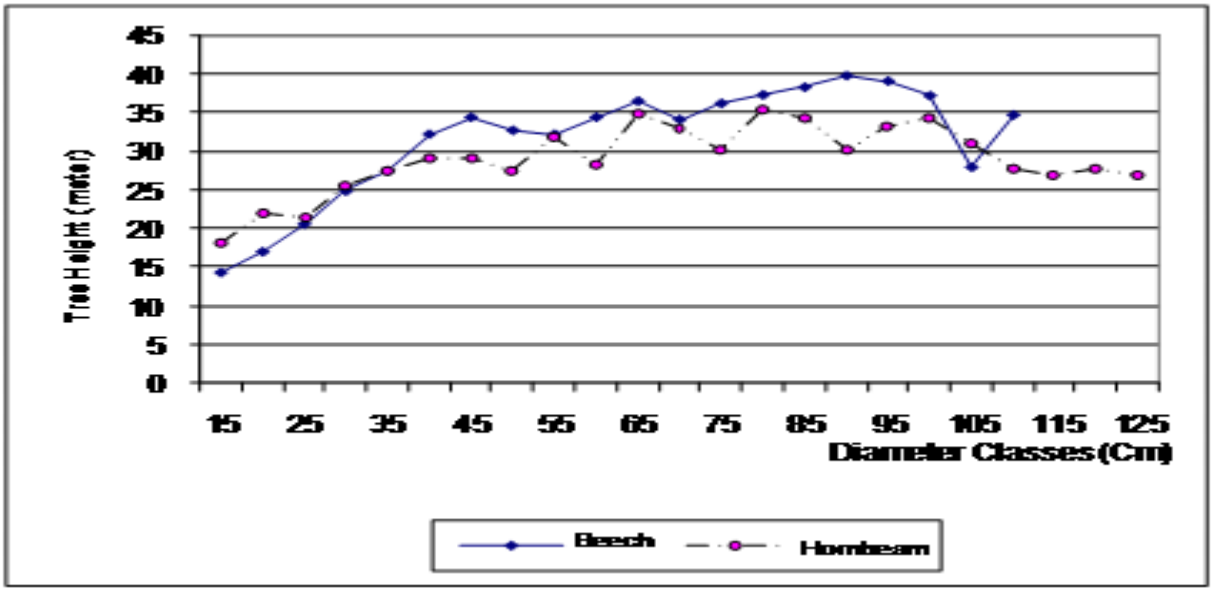

Fig. 5. Height diagram of Beech and Hornbeam.

The comparison results of the inventories in 2006 and 2012 showed that the total share of damaged trees (standing or fallen dead trees, broken head and hollow) increased 0.9 percent of the trees number and 8.1 percent of the trees volume in PFSP. This result showed that trees with larger size had more injuries. Trees with DBH less than 50 Cm generated 60 percent of the total trees number and 7 percent of the total volume of the forest stand. This result showed the injuries to young trees, because of the condensed competition between them and also with larger trees. These injuries prepare some of the trees to be eliminated of the forests in a continually process. Based on Yaghoobi (2011) in Gorgan forest during a period of 5 years the dead trees in the forest showed a decrease of 7.48 cubic meters per hectare. Amiri (2015) in Gorgan forest reported that dead trees with diameter of less than 30 Cm about 60 percent of the trees number and 4 percent of the stand volume, which is close to the results of the present study.

On the basis of the PFSP inventory of 2012 the volume percentage of damaged trees, was: broken

head 4.5 percent, fallen dead 3.8 percent, hollow trees 3.3 percent, Wind fallen (uprooted) trees 3.3 percent and standing dead trees 1.9 percent. The analysis of the changes among damaged trees indicated that in this period: the number and volume of hollow trees have decreased 24.3 and 32.4 percent, respectively. At the same time the number and volume ratio of fallen trees increased to 26.5 and 26.6 percent, respectively. The share of standing dead trees among damaged trees changed 5.8 percent of the trees number and 0.5 percent of their volume. The ratio of head broken trees to total trees in the forest stand decreased to 8.7 percent in trees number and increased 8.7 percent in volume. Therefore, an increasing in number of young and middle-aged trees has dried up. Comparing these two numbers indicated the removal of some of these trees and the reduction of the share of large hollow trees. In contrast, the share of fallen trees has increased. So, during this period situation of the thicker hollow trees changed to fallen trees. Increasing the share of volume of the head broken trees and reduction their share of number of head broken trees showed that the falling of hollow thick trees will breaks down thick trees crowns and trunks of middle storey live in their adjacent. The comparison of the number and volume of damaged trees (hollow, head broken, fallen and standing trees) showed that often hollow trees in higher diameter classes have this problem and low diameter trees show this phenomenon less than others. In other words head broken, fallen and standing trees in lower diameter classes were damaged and placed in these classes.

Dead trees in diameter classes lower than 50 Cm make up about 60 percent of the trees number and 7 percent of the stand volume. Dying some of the trees in the under storey caused small spaces (gaps) with a lot of good dispersion (scattered) in the forest area. Seeds of trees reach to the prepare earth through these small spaces and middle light provided the field for establishment and competition for seedlings and saplings of different species. A considerable increase in diameter classes of 10 and 15 cm shows that during the two inventories the young trees developed, had a fast grow and passed the limit count of the trees. This process perpetuated in replacement of small diameter trees up to 35 cm diameter class. Therefore the Liocourt factor changed from 1.26 to 1.38 through the two inventories. This shows the forest tending to the establishment of young trees. These results with increasing the share of dead and fallen trees were like the results of other researches which the correlation between perpetual establishment of dead trees (decay grade, frequency, and etc.) and seedlings were proved (Sefidi *et al.*,2007; Tavankar *et al.,* 2013).

In the present PFSP trees with a DBH greater than 35 cm take place in over storey. These trees include 42 percent of the trees number and 93 percent of the stand volume (Amini, 2006). Thus accidental, temporal and spatial changes as dying or damage the adult trees, will be decisive in the establishment of seedlings, saplings, thickets and young trees. Trees that normally passed from the middle storey, make up the over storey they are now in diameter classes of 55 to 75 Cm, and then emergent trees. There is balance between the percentage of the number and percent of the volume in dead trees (18.5% of dead trees and unhealthy trees volume). In higher diameter classes (80 Cm or more) about 22 percentage of the number of unhealthy trees and dead trees, make up 75 percent of the volume. In Gorgan forest trees with a diameter greater than 75 cm make up 72 percent of stand volume (Amini *et al.,* 2015). Their falling or breaking causes large gaps in the forest and it has an important role in seed downfall, seedlings establishment and trees growth of target species.

Between the two inventories, the number of trees per hectare has increased from 243 to 389 trees per hectare. The stand volume includes healthy trees and standing dead trees, falling, damaged, decreased 57.5 cubic meters. In the period of 6 years, 9.6 cubic meters per hectare of the forest stock decomposed annually, equal to 6.1 percent of standing inventory and changed to soil (humus). This number was almost half of dead trees (standing and falling) and

showed the activity of biological elements, insects, etc in the forest.

In general, it can be concluded that present PFSP is in a passing period from senility to juvenility phases.

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