Spatial distribution of regeneration patches in old growth oriental beech forests in northern Iran

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Abstract. Regeneration patches have key role in forest stand dynamic, new findings about the structural properties of patches can be useful in forest ecosystem management. We quantified the spatial and structural pattern of regeneration patches in old growth beech stands in a Gorazbon forest in the northern Iran. 461 patches were measured that covered 8.3% of total forest area. Patch size varied from 55 m^2 to 2987 m^2. The majority of the patches were small; 71.6% were less than the mean patch area of 1330 m^2 and were belonged to sapling patches (N = 295), also 166 seedling patches were recorded. The results showed that the major distribution pattern of patches in different compartments was random and patchy. These results confirm this fact that human activity and natural disturbances should be providing a homogenous spatial distribution pattern of patches in the high spatial scale. However among different forest stand and compartments spatial pattern of patches change randomly, that can create the natural situation and near to nature structure in beech stands.

Key words: forest regeneration, forest structure, Iran, regeneration patches, spatial disturbance, oriental beech.

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Introduction

Spatial pattern is one component of forest structure that may reveal insights about the historical and environmental processes, such as regeneration, climate, mortality and competition, which have shaped current stand structure (Pretzsch, 1997; Boyden *et al*., 2005; Sapkpta *et al*., 2009). The importance of the spatial component of regenerating patches has been recognized for some time (Watt, 1947). The patches forming the mosaic are distinguishable on the basis of stand volume accumulation, age and size structure, canopy openness, occurrence of regeneration, and/or eventually, species composition (Leibundgut, 1979; Korpel, 1982; Podlaski, 2004).

The importance of regeneration patches of stand regeneration processes in temperate forests has received much attention from ecologists (Podlaski, 2004; Stephen & Fry, 2005; Paluch, 2005; Sefidi *et al*., 2011a). Gap formation by single tree-fall events is often noted as the dominant process driving forest dynamics beech forests of central Europe, (Leibundgut, 1982; Prusa, 1985; Korpel, 1995), Japan (Tanaka & Nakashizuka, 1997) and in the North of Iran (Delfan Abazari *et al*., 2004; Sefidi *et al*., 2011a). This

process in natural forests caused to formation regeneration patches. Structure of patches can be considered as a feature of forest stand structure. The establishment, development, and composition of recruitment are determined in large part by the spatial pattern of larger trees, along with the variation in biophysical site factors, particularly in natural ecosystems (Duncan & Steward, 1991; Haase *et al*., 1996; Mast & Veblen, 1999; Szwagrzyk *et al*., 2001).

The basic spatial unit of the mosaic, characterized by a certain structural homogeneity, is an area corresponding to the crown width of large canopy trees. However, some authors have argued that structural similarity may be attributable to much larger areas, ranging from one to a few thousand square meters (Leibundgut, 1979; Korpel, 1995; Emborg *et al*., 2000; Sefidi, 2012). Canopy gap disturbances often result in patches of similar-aged trees, though more variable aged cohorts of advanced regeneration may be released in many forest types (Webster & Lorimer, 2002). The size and spatial configuration of canopy openings and regeneration patches have long been reported to potentially influence both the amount and species composition of regeneration, particularly for more light-demanding tree species in mesic forests (Fajardo & de Graaf, 2004). In a slowly decaying stand, shade tolerant tree species regenerate underneath a spatially opened canopies and dominate throughout the entire cycle of development (Parviainen *et al*., 1999).

Fagus orientalis Lipsky as the dominant species in the Caspian forest region in the northern Iran covers about 1 000 000 ha area (Knapp, 2005). This productive and commercial forest was being far from human manipulation in long-term history, so have a high value form ecological and conservational point of view. Studies in oriental beech forests indicated that the structure of such undisturbed beech stands is more or less irregular and uneven-sized (Eslami & Sagheb-Talebi, 2007; Sagheb-Talebi & Schütz, 2002) and that natural regeneration normally occurs in small gaps (Mousavi *et al*., 2003; Ghourchibeigy, 2002; Shahnavazi *et al*., 2005). Similar results have been reached in other studies on the beech virgin forests of Eastern Europe (Korpel, 1995, Nagel *et al*., 2006). Oriental beech is a shade tolerant species and regenerate in a small patch formed by canopy gaps (Delfan Abazari *et al*., 2004; Sagheb-Talebi *et al*., 2005; Sefidi *et al*., 2011a).

The Gorazbon district according to the aim of the forestry plan divided into different compartments that differ in stand structure and composition.in this research we try to detect structural properties of regeneration patches at landscape context (all of Gorzabon districts) and in class level (compartments). The results of this research can be helpful for forest mangers according to new strategies. Manning forest ecosystems based on landscape ecology concept need to quantify the structural pattern of stands in compartment and landscape levels.

The objective of this study was to explore a near-virgin forest composed of climax shade-tolerant species in terms of the spatial distribution of regeneration patches in the landscape and compartment level. Addressing this objective within a patch-mosaic framework raised the following question: Is there any differences among compartments as a managing unites within a landscape context in term of spatial distribution of regeneration patches and related spatial metrics?

Material and Methods

Study area

This research was carried out at the University of Tehran's Experimental Forest in northern Iran. The Kheyrud Experimental forest has about 8000 ha area and is located at latitude from 36°27′ N to 36°40′ N and in longitude from 51°32′ E to 51°43′ E. The climate is sub-Mediterranean with a mean annual temperature of 9 °C and total annual precipitation of 1380 mm (Marvie-Mohadjer, 1976). Mature forests are domi-

nated by beech (*F. orientalis* has an average volume of 187 m^3 ha^{-1}, which represents 74% of the total stand volume), structurally, these forests have high volumes of coarse woody debris with mature forests averaging 51 m^3 ha^{-1} (Sefidi & Marvie-Mohadjer, 2010). The presence of coarse woody debris often indicates a present or a past canopy gap and therefore seedling density is positively correlated with volume of coarse woody debris (Sefidi *et al*., 2008). University of Tehran's Experimental Forest divided into eight districts. The Gorazbon district had chosen for quantifying regeneration patch properties. Also this district encompasses 27 compartments that named 301–327. We should mention compartment 301–304 are protected and had considered out of my research area. The compartments differ from each other based on forest stand composition and structure. In fact compartments are managing units in Gorazbon district.

Field sampling

A field study conducted during the summer of 2010 all regeneration patches in the study area had measured and their location recorded by GPS. The accuracy of GPS was 5 meters or betters both vertically and laterally, 95% of the time. All established regeneration quantified by sapling and seedling patches. Regeneration patches had defined as patches by a minimum area 50 square meters. Regeneration patches had classified in two classes including (1) seedling patches involved area that occupied dominantly by seedling smaller than 50 cm and (2) sapling patches including patches which occupied dominantly by saplings and seedlings taller than 50 cm. In addition to recording the coordinates using marking corners of patches using GPS, patches environmental characteristics such as aspect, slope and patches elevation were recorded. For all patches area and other spatial properties such as edge, density per hectare, minimum and maximum area were calculated and spatial data such as area and coordinate of patches import to the Arc Map software to a change format of data to suitable format for analysis in Fragstats software. Afterward spatial structure and analysis of different metrics of regeneration patches was quantified using FRAGSTATS 3.3 software (McGarigal & Marks, 1995).

Data analysis

In order to study spatial patterns of regeneration patches Fragstats software used for metrics quantifying. This software provides quantity metrics in three levels including: 1) a patch alone; 2) at each the class level; 3) at the level of landscape. In this research metrics analysis was done at landscape level. Analysis at landscape level had done in high spatial scale which includes all compartments in Gorzabon district, so in landscape level we have 23 compartments that analyzed together.

Spatial metrics were analyzed at landscape level analyses for total patches in Gorazbon forests. Metric analysis at this level was done to each category patches on different compartments. Compartments are area with homogenous landscape that prepares suitable condition for design and implement of forestry plans which cover about 50 ha area in maximum cases. The metrics used in this level were defined as: Patch number (NP), this metric calculates the number of patches in each class (compartment). Cover Percentage each category of patches (PLAND), Percentage ratio of each type of patches, Patch density (PD), this metric show number of patches per unit area for each category and provides possibility the comparison between different categories. Edge density (ED) as a borderline density of patches per hectare in each class was calculated. Largest patch index (LPI), largest patches were calculated in each class this metrics help us in managing forest stands in the nature's way, this number is the highest area that we allowed to open the canopy to support regeneration groups. Landscape shape index (LSI), the amount complexity and different shape

shows patches on each class level. Class area (CA), the area each class makes calculating and its units are hectare, Mean nearest-neighbor distance (ENN_MN), also average of variation is calculated between 2 similar patches and Mean area of patches (area_MN) as an average size of patches were calculated in the class-level, Simpson (SIEI) and Shannon diversity (SHDI) metrics were used to calculate the patches diversity and uniformity. Simpson and Shannon metrics are the most important metrics for study spatial diversity of regeneration patches. Simpson metrics are sensitive more to the most frequent patches and Shannon metrics for the rarest patches. These metrics calculated in Fragstats software that interpretation of mathematical equations relating to the each metric is summarized in Table 1, it should be noted that the selection of appropriate metrics was done based on previous studies and a review of credible resources (Ahern & Andre, 2003; Terzioğlu *et al*., 2009; Gharehaghaji *et al*., 2013). Two categories of metrics including composition and spatial distribution metrics were used in both class and landscape. Due to inherent differences in data structure and dispersion pattern of regeneration patches, using of multiple metrics seems to be necessary to increase the flexibility results and evaluation of more comprehensive regeneration patches (Leitao & Ahern, 2002).

Results

461 regeneration patches had counted in the Gorazbon district (Figure 1 and Table 2) that covered 8.3% of total forest area. Regeneration patch size varied from 55 m^2 to 2987 m^2. The majority of the patches were small; 71.6% were less than the mean patch area of 1330 m^2 (Figure 2). The majority of patches were belonged to sapling patches (N = 295) and 166 seedling patches were recorded. According to the metric analysis distribution pattern and the abundance of regenerating patches were different among compartments. For example, distribution of patches in the compartment level according

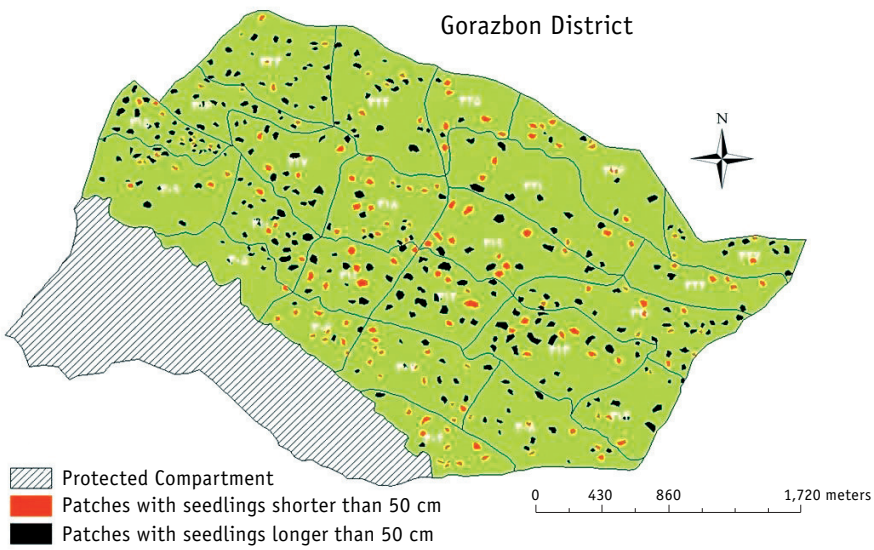


Figure 1. Distribution and spatial pattern of regeneration patches in the compartment level in Gorazbon district.

to the Simpson's Evenness Index (Tables 1 and 3) in compartment Number 311 exhibited an aggregated or random, whereas in compartment 304 distribution of patches showed regular and uniform pattern. The average of area fraction with patches calculated 4.22 ± 0.37, whereas the maximum and minimum amount of fraction calculated 1.34 and 8.22, respectively.

At the landscape level each compartment was considered as a distinct landscape, in this level, metrics analysis were done regardless of patches classification for of all patches in each compartment level.

Table 1. Description of landscape metrics (McGarigal & Marks, 1995).

Character Formula and abbreviations	Description	Unit	Range of changes
$NP = n$	Number of Patches	—	NP > 0
$PLAND = P_i = \frac{\sum_{j=1}^{a} a_{ij}}{A}(100)$	Area fraction with Patches	Percentage (%)	0 < PLAND < 100
$PD = \frac{n_i}{A}(1000)(100)$	Density of Patches	Meter In 100 hectares area	PD > 0
$ED = \frac{\sum_{k=1}^{m} e_{ik}}{A}(1000)$	Edge density	Meter per hectare	ED > 0
$SHDI = -\sum_{i=1}^{m}(P_i \ln P_i)$	Shannon's diversity index	—	SHDI ≥ 1
$SIDI = 1 - \sum_{i=1}^{S} Pi^2$	Simpson's diversity index	—	0 ≤ SIDI ≤ 1
$LPI = \frac{\max(a_{ij})}{A}(100)$	Largest patch index	Percentage (%)	0 < LPI < 100
$LSI = \frac{e_i}{\min e_i}$	Landscape shape index	—	LSI ≥ 1
$MNN = \frac{\sum_{i=1}^{m} h_i}{m}$	Mean nearest-neighbor distance	(mu)	MNN > 0
$NNSD = \sqrt{\frac{\sum_{i=1}^{m}(h_i - MNN)^2}{m}}$	Nearest-neighbor standard deviation	(mu)	NNSD > 0
$TE = \sum_{K=1}^{m} e_{iK}$	Total edge	(mu)	TE ≥ 0
$SHEI = \frac{-\sum_{i=1}^{m}(P_i \ln P_i)}{\ln m}$	Shannon's evenness index	—	0 ≤ SHEI ≤ 1
$SIEI = \frac{1 - \sum_{i=1}^{m}(p_i^2)}{1 - \left(\frac{1}{m}\right)}$	Simpson's evenness index	—	0 ≤ SIEI ≤ 1
$CA = \sum_{j=1}^{n} a_{ij}\left(\frac{1}{10{,}000}\right)$	Class area	(ha)	CA > 0

Analysis of metrics showed the most of the patches were sapling patches including seedling and sapling taller than 50 cm (N = 295), in contrast regeneration patches with seedlings shorter than 50 cm height made up 36% of total patches number (N = 166). The highest and lowest density of regeneration patch (PD) recorded 124.8 and 4.54, respectively. The results of largest patch size (LPI) metrics analysis showed the largest patch area for seedling patches was 0.9 hectares and the sapling patches occupied area about 0.73 hectares in maximum, respectively (Table 2). The results of the patch shape metric analysis (LSI) showed with changing in patch size shape of patches also will change, also the high value of shape metric tend to be different from circle shape and change to more angles and complicated shape. Results showed patches area index significantly correlated ($P < 0.000$, $r = 0.79$) by shape index (Figure 3). According to this fact the most complexity in regeneration patch shape was in a compartment 319 having seedlings taller than 50 cm, and lowest complexity was in compartment number 305. The edge density analysis showed regeneration patches in compartment 315 have a maximum of the perimeter that was 139.84 meters per hectare. Lowest patch parameter with a value of 5.91 meters per hectare also calculated from the compartment number 305 (Table 2).

Analysis total area metric (TA), the highest and lowest compartment surfaces

Table 2. Metric analysis of Landscape level among different management units.

Number of Compartment	Metrics													
	CA		NP*		PD*		LPI*		ED*		LSI*		PLAND*	
	B**	A	B	A	B	A	B	A	B	A	B	A	B	A
304	0.16	0.58	2	11	8.28	45.59	0.44	0.51	11.93	52.72	1.77	4.15	0.67	2.41
305	0.20	0.05	6	1	27.29	4.54	0.21	0.25	26.86	5.91	3.20	1.38	0.94	0.25
306	0.18	0.40	3	9	15.62	46.78	0.41	0.37	19.47	51.55	2.14	3.86	0.96	2.13
307	0.58	0.68	13	10	31.63	24.33	0.23	0.27	32.21	33.67	4.52	3.98	1.66	1.41
308	0.77	0.23	13	7	31.33	16.87	0.35	0.16	36.94	15.17	4.35	3.21	1.86	0.57
309	0.94	0.28	15	7	31.66	14.77	0.28	0.12	40.67	15.23	4.94	3.37	1.99	0.59
310	1.64	0.24	18	8	70.37	31.27	0.90	0.31	100.94	20.07	5.02	2.57	6.43	0.96
311	1.09	0.84	11	7	39.55	25.17	0.65	0.73	59.39	43.30	3.93	3.27	3.94	3.02
312	2.22	0.50	16	6	47.16	17.68	0.88	0.73	87.68	23.08	4.97	2.76	6.55	1.48
313	2.18	0.64	18	7	37.70	14.66	0.58	0.33	69.03	23.33	5.56	3.45	4.57	1.35
314	0.74	0.19	9	4	33.65	14.95	0.81	0.35	46.90	17.32	3.60	2.63	2.80	0.72
315	1.34	0.19	25	7	124.86	34.96	0.76	0.28	139.84	28.13	6.01	3.20	6.74	0.96
316	0.92	0.07	14	3	65.60	14.05	0.56	0.15	85.66	11.90	4.73	2.22	4.32	0.36
317	1.5	0.30	16	4	45.29	11.32	0.53	0.30	71.01	15.23	5.11	2.44	4.24	0.85
318	0.70	0.81	11	15	29.83	40.67	0.49	0.32	35.91	45.18	3.93	4.58	2.22	1.91
319	1.17	0.08	7	10	16.37	23.38	0.53	0.36	35.06	38.99	3.45	3.99	2.54	2.74
320	1.57	0.55	22	11	52.11	26.05	0.29	0.27	72.00	28.45	6.03	4.00	3.74	1.32
321	1.13	0.38	10	5	18.97	9.48	0.54	0.20	35.29	12.73	3.94	2.70	2.63	0.72
322	0.31	0.32	3	5	11.89	19.82	0.54	0.40	18.76	25.65	2.11	2.84	1.23	1.27
323	1.32	0.17	26	5	59.05	11.35	0.24	0.15	65.04	10.40	6.19	2.79	0.40	3.03
324	1.30	0.19	18	5	36.04	10.01	0.45	0.13	48.77	9.84	5.32	2.79	2.61	0.38
325	0.19	0.53	3	6	13.40	26.80	0.33	0.55	16.87	42.13	2.12	3.21	0.86	2.38
326	0.45	0.61	6	9	14.67	22.00	0.40	0.31	19.20	29.27	2.91	3.81	1.49	1.10
327	0.71	0.15	10	4	43.91	17.56	0.55	0.34	60.95	17.47	4.08	2.48	3.16	0.69
Total	23.33	8.98	295	166	906.23	524.06	11.6	7.89	1236.3	616.7	99.9	75.6	68.26	30.05

***** CA = Class area, NP = Patch number, PD = Patch density, LPI = Largest patch index, ED = Edge density, LSI = Landscape shape index, PLAND = Cover Percentage each category of patches.
** A = Regeneration patches by seedling smaller than 50 cm, B = Regeneration patches by seedling taller than 50 cm.

were in compartment 321 and 315 by area 52.7 hectares and 20.2 hectares, respectively (Table 3). Patch density Metric (PD) analysis showed maximum patch density in compartment 315 and 310, and the minimum patch densities were observed in the compartment 322 with amount 31.72% (Table 3). According to largest patch size metric (LPI) the largest patch recorded in compartment 310 with an area of 0.9 hectares, also the minimum amount for patch area had recorded in compartment 305 about 0.05 hectare area. According to the landscape shape metric, patch were highly complex in shape were in of compartment 315, 320, 313, 310, 316 and 312 and patches with less complexity were observed in the compartment 316, 322 and 314 (Table 3). Patch edge density Metric (ED) showed maximum and minimum of these metrics in compartment 315 and 324, respectively.

Analysis of patch richness density (PRD) showed the highest patches diversity in compartment 306 and 315 and the minimum amount of diversity was in compartment 321. Simpson diversity metric is more sensitive to frequency, according to the results of this metric (Table 3), the maximum frequency recorded 0.49. In this study, the maximum and the minimum patch area were calculated in the different compartment of Gorazbon district 0.9 and 0.015 ha, respectively. Also maximum and the minimum distance between patches in the all compartments in Gorazbon district were 480 and 27 m, respectively. According to

Table 3. Diversity metric analysis results in Landscape level.

Number of Compartment	Result statistical analysis FRAGSTATS			
	TA*	PRD*	SHDI*	SIDI*
304	24.12	8.29	0.65	0.46
305	21.98	9.09	0.62	0.43
306	19.20	10.41	0.69	0.49
307	41.09	4.86	0.68	0.49
308	41.48	4.82	0.69	0.49
309	47.36	4.22	0.59	0.40
310	25.57	7.81	0.38	0.22
311	27.80	7.19	0.68	0.49
312	33.92	5.89	0.53	0.34
313	47.74	4.18	0.53	0.35
314	26.74	7.47	0.50	0.32
315	20.02	9.98	0.52	0.34
316	21.34	9.37	0.35	0.20
317	35.32	5.66	0.61	0.42
318	36.87	5.42	0.67	0.48
319	42.75	4.67	0.69	0.49
320	42.21	4.73	0.59	0.40
321	52.71	3.79	0.61	0.42
322	25.21	7.93	0.65	0.45
323	44.02	4.54	0.41	0.24
324	49.94	4.00	0.35	0.22
325	22.38	8.93	0.58	0.39
326	40.89	4.89	0.58	0.39
327	22.77	8.78	0.60	0.41

* TA =Total landscape area,
PRD = Patches richness index and SHDI = Shannon diversity index.

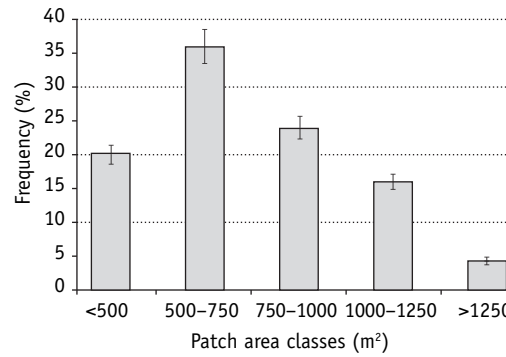


Figure 2. Distribution of patches in different size classes.

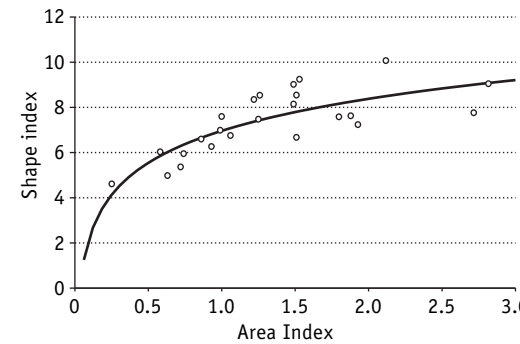


Figure 3. The relationship between the patch size and patch shape.

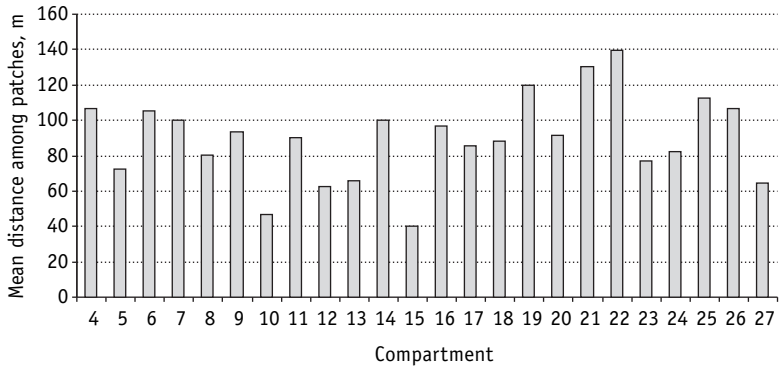


Figure 4. Distance mean metric between patches in the different compartments.

distance mean metric at the landscape level, the minimum (40.01 m) and maximum (139.63 m) of the mean distance between patches recorded in compartment 315 and 322, respectively (Figure 4). Generally, this metric showed the mean distance between patches among all compartments were about 80 meters.

Discussion

Spatial patterns and structural analysis of regeneration patches is essential in sustainable forest management. Data obtained from natural beech stands can be considered as a reliable source for managing forests in natural ways. In this study we try to quantify spatial properties of sapling and seedling patches in old growth beech stands. The basic spatial unit of the mosaic, characterized by a certain structural homogeneity, is an area corresponding to the crown width of large canopy trees. However, some authors have argued that structural similarity may be attributable to much larger areas, ranging from one to a few thousand square meters (Leibundgut, 1979; Korpel, 1995; Emborg *et al*., 2000; Sefidi, 2012).

The number patches were 461 that equal 56 patches per 100 m^2 in the oriental beech forest as shade tolerant species forest regeneration depends on small scale disturbance such as formation and closure of canopy gaps. Sefidi *et al.* (2011a) reported that regeneration of oriental beech stands related to formation medium and small size gaps on canopy layer and the number of gaps reported 3 gaps per hectare, in contrary our results showed less than one (0.55) regeneration patches per hectare. Different ecological and environmental factors can be effected establishment of regenerating in the opened area by gaps in oriental beech stands (Sefidi *et al*., 2011b; Wagner *et al*., 2010), regeneration patch structure and pattern highly affected by seed dispersal and regeneration mechanism. Explanation of tree species coexistence in the gaps is based on niche partitioning along a gap-size gradient, whereby shade-intolerant species are more competitive in larger gaps (Whitmore, 1989). Results showed that regeneration patches in the compartment level exhibited an aggregated or random distribution, whereas in compartment 304 distribution of distribution was regular and uniform, the same results reported in other study in the north of Iran (Mataji *et al*., 2008). Patchy establishment of beech in forest stands can be explain by depending beech regeneration to formation gaps in canopy layer (Nakashizuka *et al*., 1992; Delfan Abazari *et al*., 2004; Nagel *et al*., 2010), also we find the majority of regeneration patch size was smaller than mean, the reason is that beech is shade tol-

erant species and small and medium size of gap are favorable for regeneration oriental beech that recognized in previous studies in European and Iranian beech forests (Kenderes *et al*., 2009; Sefidi *et al*., 2011a; Parhizkar *et al*., 2011).

Beech seedlings often undergo multiple suppression-and-release episodes before reaching the upper canopy (Nagel *et al*., 2006; Collet *et al*., 2008). Even after a long period of suppression, height growth increases following each canopy disturbance (Canham, 1990; Collet & Chénost, 2006) and particularly after the second and third release (Leak, 2003).

The largest patch size calculated 2987 m^2 or near to 0.3 ha that is larger than studies especially in compare with researches from conifer forest (Morrow, 1985; Stephen & Fry, 2005). It should be noted that patch definitions varied among studies. The same study had not reported for broad leave forest. Sefidi (2012) in study of beech stands dynamics showed that the median size of gaps in Iranian oriental beech forest are 180 m^2 and the maximum gap recorded 0.13 ha, there are differences between these two studies, that caused by different definition for gaps and regeneration patches, in study of gap dynamics, when gap filler reach to the half of stand height, the assume closed gap and out of gap definition, but patches define by presence of seedling and sapling inner the gap area on the forest floor.

Analysis spatial distribution of regeneration patches in class and landscape level revealed distribution patches shown a random and irregular pattern in shape, size and distribution. The same results reported for distribution of elm trees in the north of Iran (Alavi *et al*., 2005). It should be mentioned in our study area was far from human based disturbances for long term period and forest structure are irregular and uneven aged (Marvie-Mohadjer, 1976), also regeneration mechanism of beech as shade tolerant species highly depend on patchy canopy gaps that provide opportunity for release such trees from under canopy layer (Sefidi *et al*., 2011a). According to these facts diversity and variation of spatial properties of regeneration patches among compartments (class level) can be explained.

Conclusion

The results of this study provide information on the patterns of regeneration patch distribution and the nature of regeneration at the compartment and landscape level. According to the abundance of small patches and high regeneration of beech seedling in the smaller size of gaps (Delfan Abazari *et al*., 2004; Sagheb-Talebi *et al*., 2005; Sefidi *et al*., 2011a), we conclude that silvicultural systems creating small and medium size of gaps followed by formation small size of regeneration patches and the structure of considered as a close to nature.

References

Ahern, J., Andre, L. 2003. Applying landscape ecological concepts and metrics in sustainable landscape planning. – Landscape and Urban Planning, 59, 65–73.

Alavi, S.J., Zahedi Amiri, G.H., Marvie-Mohadjer, M.R. 2005. Determine the spatial pattern of *Ulmus glabra* species in the forests of northern Iran. – Journal of Natural Resources, 58, 804–793.

Boyden, S., Binley, D., Shepperd, W. 2005. Spatial and temporal patterns in structure, regeneration, and mortality of an old-growth ponderosa pine forest in the Colorado Front Range. – Forest Ecology and Management, 219, 43–55.

Canham, C.D. 1990. Suppression and release during canopy recruitment in *Fagus-grandifolia*. Bulletin of the Torrey Botanical Club, 117, 1–7.

Collet, C., Chénost, C. 2006. Using competition and light estimates to predict diameter and height growth of naturally regenerated beech seedlings growing under changing canopy conditions. – Forestry, 79(5), 489–502.

Collet, C., Piboule, A., Leroy, O., Frochot, H. 2008. Advance *Fagus sylvatica* and *Acer pseudoplatanus* seedlings dominate tree regeneration in a mixed

broadleaved former coppice-with-standards forest. – Forestry, 81(2), 135–150.

Delfan Abazari, B., Sagheb-Talebi, Kh., Namiranian, M. 2004. Development stages and dynamic of undisturbed oriental beech (*Fagus orientalis* Lipsky) stands in Kelardasht region (Iran). Iran. – Journal of Forest and Poplar Resources, 12, 307–326.

Duncan, R.P., Steward, G.H. 1991. The temporal and spatial analysis of tree age distributions. – Canadian Journal of Forest Research, 21, 1703–1710.

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

Eslami, A.R., Sagheb-Talebi, Kh. 2007. Investigation on structure of pure and mixed beech forests in north of Iran (Neka-Zalemrud region). – Pajouhesh and Sazandegi, 77, 39–46. (In Farsi (Persian) with English abstract).

Fajardo, A., de Graaf, R. 2004. Tree dynamics in canopy gaps in old-growth forests of *Nothofagus pumilio* in southern Chile. – Plant Ecology, 173, 95–106.

Gharehaghajia, M., Alizadeh, A., Feghhi, J., Danekar, A., Kaboli, M., Ashrafi, S. 2013. Effects of landscape context on bird species abundance of tree fall gaps in a temperate deciduous forest of Northern Iran. – Forest Ecology and Management, 67, 182–189.

Ghourchibeigy, K. 2002. Qualitative and quantitative study of beech regeneration related to different gap size .Ph.D thesis, Islamic Azad University. 214 pp.

Haase, P., Pugnaire, F.I., Clark, S.C., Incoll, L.D. 1996. Spatial patterns in two tiered semi-arid scrubland in southeastern Spain. – Journal of Vegetation Science, 7, 527–534.

Kenderes, K., Kral, K., Vrska, T., Standovar, T. 2009. Natural gap dynamics in a Central European mixed beech–spruce–fir old growth forest. – Ecoscience, 16, 39–47.

Knapp, H.D. 2005. Die globale Bedeutung der Kaspischen Wälder. (The global importance of the Caspian forests). – Nosrati, K., Mohadjer, R.M., Bode, W., Knapp, H.D. (eds.). Schutz der Biologischen Vielfalt und integriertes Management der Kaspischen Wälder (Nordiran). (Protection of biodiversity and integrated management of Caspian Forests (North of Iran). Naturschutz und Biologische Vielfalt, BFN 12, 45–63. (In German).

Korpel, S. 1982. Degree of equilibrium and dynamic change of the forest an example of natural forest of Slovakia. – Acta Facultatis Forestalis, Zvolen, Czechoslovakia, 24, 9–30.

Korpel, S. 1995. Die Urwälder der Westkarpaten. (The forests of the Western Carpathians). Gustav Fischer Verlag/Jena, Stuttgart/New York. (In German).

Leak, W.B. 2003. Regeneration of patch harvests in even-aged northern hardwoods in New England. – North Journal of Applied Forestry, 20(4), 188–189.

Leibundgut, H. 1979. Über die Dynamik europäischer Urwälder. (About the dynamik of European forests). – Schweizerische. Zeitschrift für Forstwesen, 130 (9/10), 906–916. (In German).

Leibundgut, H. 1982. Europäische Urwälder der Bergstufe: dargestellt für Forstleute, Naturwissenschafter und Freunde des Waldes. (European primeval forests of the mountain stage: presented for foresters, scientists and friends of the forest). Bern, Stuttgart, Verlag Paul Haupt. 308 pp. (In German).

Leitao, A., Ahern, J. 2002. Applying Land scape Ecological Concepts and Metrics in Sustainable Landscape Planning. – Landscape and Urban planning, 59, 65–93.

Marvie-Mohadjer, M.R. 1976. Some qualitative characteristics of Iranian beech forests. – Iranian Journal of Natural Resources, 34, 77–96.

Mast, J.N., Veblen, T.T. 1999. Tree spatial patterns and stand development along the pine-grassland ecotone in the Colorado Front Range. – Canadian Journal of Forest Research, 29, 575–584.

Mataji, A., Kafaki, S.B., Safaee, H., Kiadaliri, H. 2008. Spatial pattern of regeneration gaps in managed and unmanaged stands in natural beech (*Fagus orientalis*) forests. – Iranian Journal of Forest and Poplar Research, 16, 149–157.

McGarigal, K., Marks, B.J. 1995. Fragstats: Spatial pattern analysis program for quantifying landscape structure. Reference manual. Forest Science Department. Oregon State University. Corvallis Oregon, 62 p.

Morrow, R.J. 1985. Age structure and spatial pattern of old growth ponderosa pine in Pringle Falls Experimental Forest, central Oregon. M.Sc. Thesis, Oregon State University, Corvallis, OR, US.

Mousavi, Z.R., Sagheb-Talebi, K., Tabari, M., Pour Majydyan, M.R. 2003. Determine the size of gaps level for improved breeding beech canopy. – Iranian Journal of Natural Resources, Natural Resources Faculty of Tehran University Journal, 56, 39–46.

Nagel, T.A., Svoboda, M., Diaci, J. 2006. Regeneration patterns after intermediate wind disturbance in an old-growth Fagus-Abies forest in southeastern Slovenia. – Forest Ecology and Management, 226, 268–278.

Nagel, T.A., Svoboda, M., Rugani, T., Diaci, J. 2010. Gap regeneration and replacement patterns in an old-growth Fagus-Abies forest of Bosnia- Herzegovina. – Plant Ecology, 208, 307–318.

Nakashizuka, T., Iida, S., Tanaka, H., Shibata, M., Masaki, T., Niiyama, K. 1992. Community dynamics of Ogawa Forest Reserve, a species rich deciduous forest, central Japan. – Vegetation, 103, 105–112.

Paluch, J. 2005. Spatial distribution of regeneration in West-Carpathian uneven-aged silver fir forests. – European Journal of Forest Reserarch, 124, 47–54.

Parhizkar, P., Sagheb-Talebi, K., Mataji, A., Nyland, R, Namiranian, M. 2011. Silvicultural characteristics of Oriental beech (*Fagus orientalis* Lipsky) regeneration under different RLI and positions within gaps. – Forestry, 84, 177–185.

Parviainen, J., Little, D., Doyle, M., O'Sullivan, A., Kettunen, M., Korhonen, M. 1999. Research in forest reserves and natural forests in European countries – country reports for the COST Action E4: Forest Reserves Research Network. EFI Proceedings 16, Joensuu, Finland.

Podlaski, R. 2004. A development cycle of the forest with fir (*Abies alba* Mill.) and beech (*Fagus sylvatica* L.) and its species composition in the Świętokrzyski National Park. – Journal of Forest Science, 50, 55–66.

Pretzsch, H. 1997. Analysis and modeling of spatial stand structures. Methodological considerations based on mixed beech larch stands in Lower Saxony. – Forest Ecology and Management, 97, 237–253.

Prusa, E. 1985. Die böhmischen und mährischen Urwälder – ihre Struktur und ökologie. (Bohemian and Moravian forests – their structure and ecology). Verlag der Tschechoslowakischen Akademie derWisenschaften, Praga. (In German).

Sagheb-Talebi, Kh., Delfan Abazari, B., Namiranian, M. 2005. Regeneration process in natural uneven-aged Caspian beech forests. – Swiss Forestry Journal, 156, 477–480.

Sagheb-Talebi, Kh., Schütz, J.Ph. 2002. The structure of natural oriental beech (*Fagus orientalis*) forests in the Caspian region of Iran and the potential for the application of the group selection system. – Forestry, 75(4), 465–472.

Sapkpta, I.P., Tigabu, M., Oden, P. 2009. Spatial distribution, advanced regeneration and stand structure of Nepalese Sal (*Shorea robusta*) forests subject to disturbances of different intensities. – Forest Ecology and Management, 257, 1966–1975.

Sefidi, K. 2012. Late successional stage dynamics in natural mixed beech stands in the north of Iran. PhD thesis. Forest Science Department, Faculty of Natural Resources. 180 pp.

Sefidi, K., Marvie Mohadjer, M.R. 2010. Characteristics of coarse woody debris in successional stages of natural beech (*Fagus orientalis*) forests of Northern Iran. – Journal of Forest Science, 56, 7–17.

Sefidi, K., Marvie Mohadjer, M.R, Mosandl, R., Copenheaver, C.A. 2011a. Canopy gaps and regeneration in old-growth Oriental beech (*Fagus orientalis* Lipsky) stands, northern Iran. – Forest Ecology and Management, 262, 1094–1099.

Sefidi, K., Marvie-Mohadjer, M.R, Etemad, V., Copenheaver. C.A. 2011b. Stand characteristics and distribution of a relict population of Persian ironwood (*Parrotia persica* C.A. Meyer) in northern Iran. – Flora, 206, 418–422.

Sefidi, K., Marvi-Mohajer, M.R., Zobeyri, M., Etemad, V. 2008. Investigation on dead trees effects on natural regeneration of oriental beech and hornbeam in a mixed beech forest. – Iranian Journal of Forest and Poplar Research, 15, 365–373.

Shahnavazi, H., Sagheb-Talebi, Kh., Zahedi-Amiri, G. 2005. Qualitative and quantitative evaluation of natural regeneration in gaps within beech (*Fagus orientalis* Lipsky) stands of Caspian region. – Iranian Journal of Forest and Poplar Research, 13(2), 141–155. (In Farsi with English abstract).

Stephen, S., Fry, D. 2005. Spatial distribution of regeneration patches in an old-growth *Pinus jeffreyi*-mixed conifer forest in northwestern Mexico. – Journal of Vegetation Science, 16, 693 – 702.

Szwagrzyk, J., Szewczyk, J., Bodziarczyk, J. 2001. Dynamics of seedling banks in beech forest: results of a 10-year study on germination, growth and survival. – Forest Ecology and Management, 141, 237–250.

Tanaka, H., Nakashizuka, T. 1997. Fifteen years of canopy dynamics analyzed by 511 aerial photographs in a temperate deciduous forest, Japan. – Ecology, 78, 612–620.

Terzioğlu, S., Zeki Başkent, E., Kadıoğulları, A. 2009. Monitoring forest structure at landscape level: a case study of Scots pine forest in NE Turkey. – Environmental monitoring and Assessment, 152, 71–81.

Wagner, S., Cole, C., Madsen, P., Nakashizuka, T., Myland, R.D., Sagheb-Talebi, K. 2010. Beech regeneration research: from ecological to silvicultrual aspect. – Forest Ecology and Management, 259, 2172–2182.

Watt, A.S. 1947. Pattern and process in the plant community. – Journal of Ecology, 35, 1–22.

Webster, C.R., Lorimer, C.G. 2002. Single-tree versus group selection in hemlock-hardwood forests: are smaller openings less productive? – Canadian Journal of Forest Research, 32 (4), 591–604.

Whitmore, T.C. 1989. Canopy gaps and the two major groups of forest trees. – Ecology, 70, 536–538.

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