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The Effect of Canopy Gaps on Biodiversity of Herbaceous Species in an Oriental Beech (*Fagus orienatlis* Lipsky) Stand

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ABSTRACT

This study was conducted to investigate the diversity of herbaceous species in harvest-created gaps and its comparison with the adjacent closed stands in beech forest of Alandan, compartment No. 3 and 4 (Mazandaran, Iran). To achieve this purpose, 16 gaps were selected including 4 classes of gap size with 4 replicates for each. In the centre of each gap and its cardinal points as well as the adjacent closed stands, sub-plots of 2/5×2/5 m size were placed and then the number of herbaceous species and beech seedlings was counted. Some features of overstory beech trees in the cardinal points of gap edge were measured. The results revealed that there was no significant difference between gaps in terms of diversity, richness and evenness indices. Moreover, the t-test indicated that there was no significant difference between gaps and the adjacent closed stand in terms of most diversity indices. The Pearson correlation results pointed that there is positive significant correlation between Simpson and Shanon-Wiener indices with crown radius toward gaps and also Margalef richness index with length of crown and crown radius toward gaps. In general, it can be stated that there is no difference among harvest- created gaps by single-tree selection method and its comparison with unharvested stand in regard to biodiversity indices of herbaceous species after 8 years of harvesting.

Key words: Oriental beech, gap size, diversity, herbaceous species, single-tree selection method

INTRODUCTION

Considering the importance of biodiversity protection and its leading role in natural resource management, familiarity with the fundamental concepts of biodiversity is of great significance for foresters and natural resource managers (Pourbabaei and Dado, 2005). Generally speaking, disturbances of any kinds can cause injuries to trees or even end in their removal and this, in turn, create an opening in the forest which is called canopy gap (Yamamoto, 2000). It is a long time that the gap is mentioned as an important element in forest ecosystem (York *et al*., 2003; Xian *et al*., 2008; Fahey and Puettmann, 2008) and a myriad of studies are conducted on different aspects of gaps, including regeneration (Felton *et al*., 2006; Huth and Wagner, 2006; Kukkonen *et al*., 2008; Von Couwwenberghe *et al*., 2010), diversity (Zanne and Chapma, 2005; Naaf and Wolf, 2007; Sapkota *et al*., 2009), soil properties (Ritter and Vesterdal, 2006; Zhang and Zhao, 2007; Sharenbroch and Bockheim, 2008) and micro-climate (Sharenbroch and Bockheim, 2008; Promis *et al*., 2009; Muscolo *et al*., 2010). Gap formation causes biological and physical changes in

the forest which increases environmental disparities (Zhao *et al*., 2006). Just like natural forests, a managed forests which are harvested under silvicultural methods have different gap size (Dobrowolska, 2006). In Hyrcanian forests of Iran which are natural mixed broadleaf (Hosseini, 2005) and commercial ones (Bavaghar *et al*., 2010), harvest-created gaps by different silvicultural methods can be observed. Harvesting is believed to be a kind of interference in forest ecosystem and a major influential factor on distribution pattern of biodiversity (Qiu *et al*., 2006). Extensive studies are conducted about the effect of harvesting on the plant species diversity with the purpose of better forestry management and diversity protection (Wang *et al*., 2005; Ghomi Avili *et al*., 2007; Poorbabaei and Ranjavar, 2008; Burke *et al*., 2008; Falk *et al*., 2008). One of the important goals in sustainable forest management is protection of plant diversity in managed forests (Ito *et al*., 2006). The purpose of this research was to determine the effect of harvest-created gaps by single-tree selection system on herbaceous plant species in beech stand 8 years after harvesting and its comparison with undisturbed stand. The hypothesis is that gap size influences on the diversity of plant species in understory of beech stand.

MATERIALS AND METHODS

Study area: The study area is located in the beech forest of Alandan district, compartment 3 and 4 (36° 13'-36° 12' N, 53° 23-53° 03' E) in Northern Iran, Sari (Fig. 1). All the fieldwork has been performed in spring and early summer 2009. The area of site is 113 ha and lies in the western aspect between 1300-1610 m asl. Forest type is dominated by beech (*Fagus orientalis* Lipsky) which is uneven-aged. Other less frequent species present in this forest are hornbeam, maple and elder. The parent material is limestone and dolomitic limestone which belong to upper jourasic and lower cretaceous period. The soil type is forest brown with suitable penetration and biological activities. The mean annual temperature, rainfall and relative humidity are 10.5°C, 858 mm and 75.2%, respectively. The climate is humid based on Domarten method. To investigate diversity indices in harvest-created gaps by single-tree selection system in 2000 and undisturbed stand (in distance 20 m from edge gaps), 16 gaps were selected. The area of expanded gaps was calculated by measuring its long and short axes as ellipse shape (Runkle, 1981). The gaps classified into four size classes: small (60-150 m^2), Medium (151-241 m^2), Large (242-332 m^2) and Very large (333-550 m^2) with four replications for each class. To determine the diversity of herbaceous plants and regeneration quantity (height less than 130 cm), 2/5×2/5 m subplots (Chiarucci *et al*., 2008) were used. These subplots were located in the centre of the gap and its cardinal points as well as in the undisturbed stand (Fig. 2). The following formulas were applied to calculate biodiversity indices: richness (Margalef: $R_2 = (S-1)/\ln(n)$, Menhinick: $R_1 = S/\sqrt{n}$), Diversity (Simpson: $D=1-\sum_{i=1}^{s}P_i^2$ Shanon-Wiener: $H'=-\sum_{i=1}^{s}(p_i)(\ln p_i)$ Evenness (Pielou : $E_1 = H'/\ln(S)$, Hill: $E5 = (1/\lambda-1)/(e^{H'}-1)$) where n is number of individuals, N is total number of individuals, S is number of species and p=proportion of individuals in ith species.

Past (Hammer *et al*., 2001) and Ecological Methodology (Kenney and Krebs, 2001) softwares were applied. By the way, some features of the trees bordering the gap were measured.

Statistical analysis: To analyze the difference among different gap sizes in term of diversity indices one-way ANOVA and to analyze difference between gaps and undisturbed stand independent t-test were applied. Moreover, Duncan test was used to compare the means at 1%

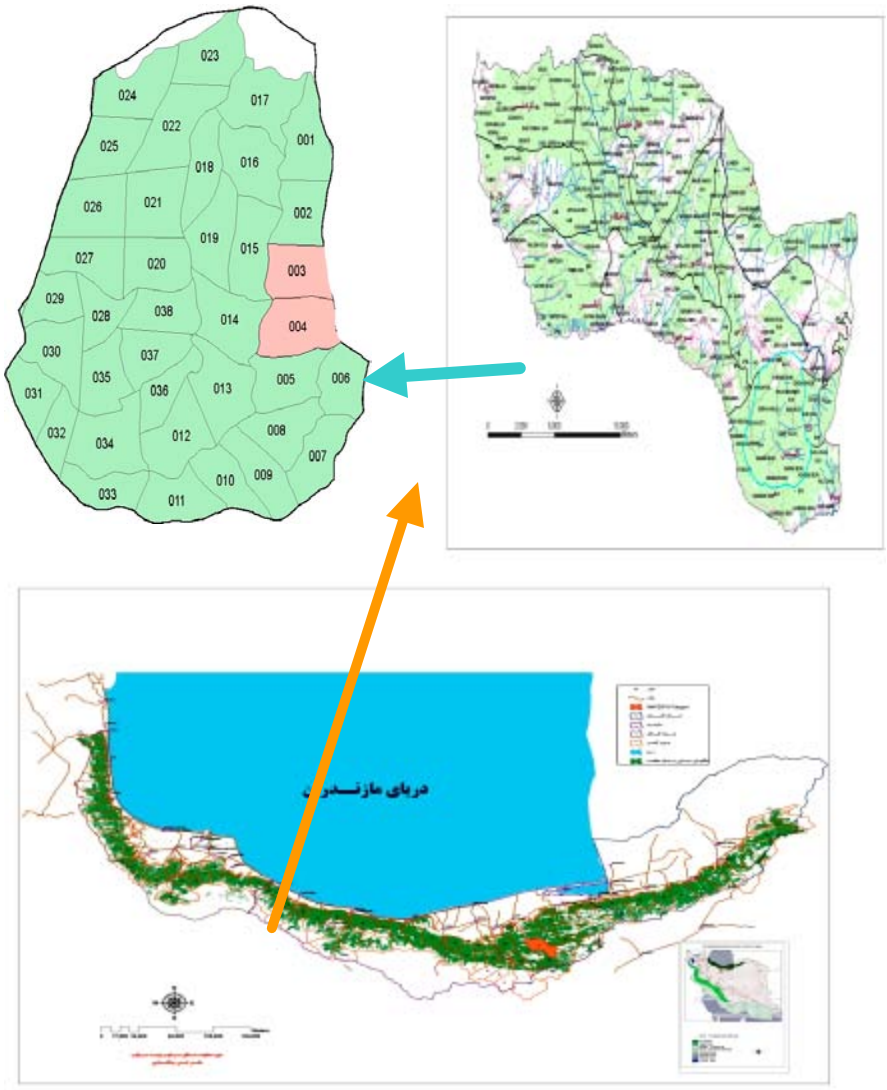

Fig. 1: Location of study area (compartments 3, 4) in Alandan district (Northern Iran)

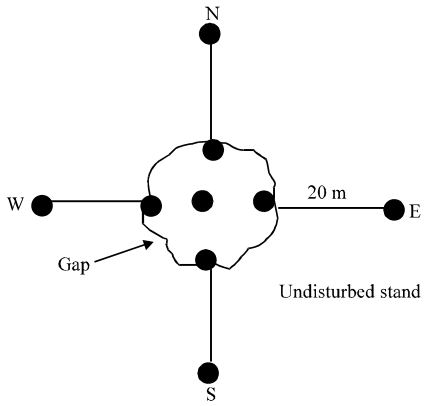

Fig. 2: Layout subplots in gaps and undisturbed stand

probability level. Pearson correlation coefficient was used to determine the correlation between diversity indices with some features of trees bordering the gaps.

RESULTS

Total area of gaps was 0.42 ha which covered 0.37% of the total area of stands. We identified 33 herbaceous plant species which belonging to 26 families (Table 1) in gaps and adjacent undisturbed stand and life forms of them including phanerphyte (18.18%), hemichryptophyte (3.03%), geophyte (66.67%) and therophyte (12.12%). The following plants were presented in gaps as well as adjacent undisturbed stand: *Lathyrus laevigatus* (Jacq.) Grake, *Viola alba* Bess., *Circaea lutetiana* L., *Rubus hyrcanus* Juz., *Cardamine impatiens* L., *Mercurialis perennis* L., *Solanum dulcamara* L., *Polystichum aculeatum* (L. Roth.), *Galium odoratum* (L.) Scope. The numbers of

Table 1: Plant species list in beech forest

Scientific name	Family	Life form
Euphorbia amygdaloides L.	Euphorbiaceae	Ph
Phylitis scolopendrium (L.) Newn.	Aspleniaceae	Ge
Polystichum aculeatum (L.) Roth.	Aspidiaceae	Ge
Carex sylvatica Huds.	Cyperaceae	Ge
Vincetoxicum scandens Sommier and Levier	Asclepiadaceae	Ph
Sanicula europaea L.	Umbelliferae	Ge
Mercurialis perennis L.	Euphorbiaceae	Ge
Dryoptris filix-mas (L.) Schott.	Aspidiaceae	Ge
Galium odoratum (L.) (Scope.)	Rubiaceae	Ge
Viola alba Bess.	Violaceae	Ge
Fragaria vesca L.	Rosaceae	Ge
Brachypodium sylvaticum (Huds.) P. Beauv.	Graminae	Ge
Campanula rapunculus L.	Campanulaceae	Ge
Calystegia sepium (L.) R. Br.	Convolvulaceae	Ge
Lamium album L.	Labiatae	Ge
Primula heterochroma Stapf.	Primulaceae	Ge
Cephalenthera longifolia (L.) Fritsch.	Orchidaceae	Ge
Solanum dulcamara L.	Solanaceae	Ph
Polygonatum orientale Desf.	Liliaceae	Ge
Cyclamen coum Mill.	Primulaceae	Ge
Carex pendula Huds.	Cyperaceae	Ge
Cardamine impatiens L.	Cruciferae	Th
Hypericum androsaemum L.	Hypericaceae	Ph
Ruscus hyrcanus Woron.	Liliaceae	Ph
Rubus hyrcanus Juz.	Rosaceae	Ph
Oplismenus undulatifolius (Ard.) L. P. Beauv.	Graminae	Th
Urtica dioica L.	Urticaceae	Ge
Hesperis hyrcana Borm.	Cruciferae	Th
Geranium montanum Habl. ex Pall.	Geraniaceae	Ge
Circaea lutetiana L.	Onagraceae	Ge
Pteris cretica L.	Pteridaceae	Ge
Lathyrus laevigatus (Jacq.)Grake.	Papilionaceae	Th
Rhynchochoris elephas (L.)Grifeb.	Scrophulariaceae	He

Ph: Phanerophyte, Ge: Geophyte, Th: Therophyte, He: Hemicryptophyte

Table 2: Number of plant species in gaps and adjacent stand

Small		Medium		Large		Very large	
S	G	S	G	S	G	S	G
25	23	24	26	21	21	22	23

S: Stand, G: Gap

Table 3: Statistical analysis of gaps in terms of diversity indices

	MSS		DF		
Index	Gap size	Error	Gap size	Error	F
Simpson	0.050	1.049	3	74	1.187^{ns}
Shanon-wiener	2.620	25.304	3	76	2.623^{ns}
Margalef	2.169	24.285	3	76	2.263^{ns}
Menhinick	0.692	6.415	3	75	2.697^{ns}
Pielou	0.116	1.589	3	76	1.850^{ns}
Hill	0.056	1.125	3	75	1.249^{ns}

^{ns}: No significance

Table 4: Comparison means (±SE) of diversity indices of plant species among gaps

	Diversity		Richness		Evenness	
Gap	Simpson	Shanon-wiener	Margalef	Menhinick	Pielou	Hill
Small	0.64±0.03^{a}	1.96±0.16^{a}	1.44±0.15^{a}	0.92±0.07^{a}	0.68±0.04^{a}	0.37±0.14^{a}
Medium	0.69±0.03^{a}	2.05±0.13^{a}	1.59±0.12^{a}	0.97±0.07^{a}	0.75±0.03^{a}	0.38±0.13^{a}
Large	0.69±0.03^{a}	2.05±0.10^{a}	1.55±0.12^{a}	0.98±0.07^{a}	0.76±0.31^{a}	0.40±0.11^{a}
Very large	0.76±0.12^{a}	2.37±0.10^{a}	1.92±0.07^{a}	1.16±0.04^{a}	0.78±0.02^{a}	0.33±0.09^{a}

The same letter indicates non-significance

Table 5: Independent t-test result in regard to diversity indices

	Simpson			Shanon-Wiener		
Position	df	t	Sig.	df	t	Sig.
Small gap stand	34	1.631	0.112^{ns}	34	1.710	0.096^{ns}
Medium gap stand	34	0.216	0.830^{ns}	34	0.498	0.622^{ns}
Large gap stand	34	1.843	0.074^{ns}	34	2.481	0.018*
Very large gap stand	34	0.158	0.876^{ns}	34	0.707	0.484^{ns}

^{ns}: No significance

species are shown in Table 2. The result revealed that there is no significant difference among gaps in terms of diversity indices (Table 3). Means comparison of diversity indices among gaps are observed in Table 4. Results of independent t-test for comparing between gaps and adjacent undisturbed stand determined that there is no significant difference in regard to many diversity indices (Table 5-7). Pearson correlation coefficient (Table 8) showed that there is positively significant correlation between diversity indices and crown radius of trees toward gaps also Margalef richness index to crown radius toward gap and length of crown of trees.

Table 6: Independent t-test result in regard to richness indices

	Margalef			Menhinick		
Position	df	t	Sig.	df	t	Sig.
Samll gap stand	34	1.248	0..221^{ns}	34	2.253	0.031*
Mediumgap stand	34	1.502	0.142^{ns}	34	0.581	0.565^{ns}
Large gap stand	34	2.009	0.053^{ns}	34	0.942	0.353^{ns}
Very large gap stand	34	1.522	0.137^{ns}	34	1.147	0.260^{ns}

^{ns}: No significance, *: Significant difference at probability 5% level

Table 7: Independent t-test result in regard to evenness indices

	Hill			Pielou		
Position	df	t	Sig.	df	t	Sig.
Small gap stand	34	0.119	0.906^{ns}	34	1.972	0.057^{ns}
Medium gap stand	34	0.126	0.900^{ns}	34	1.099	0.28^{ns}
Large gap stand	34	0.639	0.529^{ns}	34	0.866	0.393^{ns}
Very large gap stand	34	1.068	0.293^{ns}	34	0.590	0.559^{ns}

^{ns}: No significance

Table 8: Pearson correlation coefficient of diversity indices with some features of beech trees

Index	Number of seedling (m^2)	Crown radius toward gaps (m)	Crown length (m)
Simpson	-0.140^{ns}	0.387**	0.106^{ns}
Shanon-Weiner	-0.020^{ns}	0.390**	0.208^{ns}
Margalef	0.064^{ns}	0.337**	0.249*
Menhinick	0.180^{ns}	-0.130^{ns}	0.122^{ns}
Hill	-0.219^{ns}	0.050^{ns}	0.223^{ns}
Pielou	-0.138^{ns}	0.162^{ns}	0.076^{ns}

^{ns}: No significance, *, **: Significant correlation at probability 5 and 1% level

DISCUSSION

The results of the present study indicate that the species composition is similar between the harvest-created gaps and the adjacent undisturbed stand and this is in agreement with the results obtained by Naaf and Wulf (2007). Furthermore, the herbal species composition in gaps is consistent with Shabani *et al.* (2009). The result of ANOVA showed that there is no significant difference among gaps in regard to diversity, richness and evenness indices ($p>0.01$). According to the results, single-tree selection system had no major effect on diversity of herbaceous plants. However, some indices have increased with an increase in gap size. Galhidy *et al.* (2006) reported that herbaceous plants richness in larger gaps is more than that in smaller ones. In the harvest-created gaps by single selection, an increase in light, soil moisture and the nutrient was observed which resulted in the rise of the number of plants in the understory (Von-Oheimb and Hardtle, 2009). The plant species in the gaps are different depending on the size and the quality of the gaps (Nakashizuka, 1989; Abe *et al.*, 1995). The same results were obtained by the present study, too. The comparison between the diversity indices of gaps with that of the adjacent stand showed no significant difference for Simpson, Hill and Pielou indices (Table 5-7). For the Shanon -Wiener index, however, a significant difference was observed between the large gap (2.05±0.10) and its surrounding stands (1.66±0.11) that is consistent with the studies of Degen *et al.* (2005) and Wang *et al.* (2005).

Overall, the correlation between certain characteristics of beech trees at the edge of gaps and the number of beech seedlings with diversity indices, except for a few cases, were not significant. Based on the calculated correlation coefficients, a significant positive correlation was observed between the Simpson, Shannon - Weiner and Margalef diversity indices and the crown radius towards the gaps (Table 8). According to Table 8, there is a positive correlation between Margalef richness index and crown length of beech tree at the edge of gaps.

In hine with the determined correlation coefficients, it can be concluded that the characteristic of the radius of the crown towards gaps and the crown length of beech trees are appropriate to assess the diversity of herbaceous in gaps resulted from the harvesting operations. According to the results, it can be acknowledged that single-tree selection method in the studied compartments 3 and 4 after eight years of formation of gaps with specified area had no negative effects on diversity of herbaceous and consequently can be considered as a suitable method in beech forest. It is essential to evaluate the relationship between silvicultural system and biodiversity of plant species in forest management and these results should be applied in forestry projects.

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