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The influence of gap size on plant species diversity and composition in beech (*Fagus orientalis*) forests, Ramsar, Mazandaran Province, North of Iran

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ABSTRACT

*Pourbabaei H, Haddadi-Moghaddam H, Begyom-Faghir M, Abedi T. 2013. The influence of gap size on plant species diversity and composition in beech (*Fagus orientalis*) forests, Ramsar, Mazandaran Province, North of Iran. Biodiversitas 14: 89-94.*This study was conducted to investigate the influence of gap size on plant species diversity and composition in beech (*Fagus orientalis* Lipsky.) forests, Ramsar, Mazandaran province. Fifteen gaps in small, medium, and large sizes were randomly selected. Abundance of tree saplings, shrubs and herbaceous species were counted on 4 m^2 micro-plots within the gaps. Diversity indices including Shannon-Wiener, Simpson, Mc Arthur's N_1, Hill's N_2, species richness and Smith-Wilson's evenness index were computed. The results revealed that there was significant difference among three gap categories in terms of diversity. The highest diversity values of tree and herbaceous species were obtained in the large gaps, while the highest diversity value of shrub species was in the medium gaps. Species composition of small gaps (28 species: 7 trees and 21 herbaceous), medium gaps (37 species: 7 trees, 5 shrubs and 25 herbaceous) and large gaps (40 species: 7 trees, 4 shrubs and 29 herbaceous) were recognized. Therefore, based on the results of this study, it is recommended that in order to maintain plant diversity and composition up to 400 m^2 gap size cloud be used in this forests.

Key words: *Fagus orientalis*, gap size, plant diversity

INTRODUCTION

The oriental beech (*Fagus orientalis* Lipsky.) is a deciduous tree species (Salehi et al. 2011), distributed from Macedonia, Bulgaria, northwest Turkey (Asia Minor), Azerbaijan, Caucasus to Iran (Rechinger 1963-2010; Komarov 1934-1963). Iranian beech forests are dominant in the Montane and submontane zones of central and western Caspian forests (Mobayen and Tregubov 1970; Asli and Nedialkov 1973). These forests occupy approximately 18% of the forested area (Bayramzadeh et al. 2012) and comprise the most productive and important commercial forests in the Caspian zone (Salehi et al. 2011). However, these forests are subjected to constant changes (Sampson and DeCoster 1998), a variety of natural and anthropogenic perturbations (Odum and Barrett 2004; Thompson 2010; Alongi 2007). Several researches were carried out on forest structural changes, silvicultural system and especially gap silviculture system (Tuomela et al. 1996; Albanesi et al. 2005; Boudreau and Lawes 2005; Renato and De Lima 2005).

A planned program of silvicultural treatments (British Colombia 2003) ensures the conservation and maintenance of biological diversity and richness for sustainable forestry (Torras and Saura 2008; Schumann et al. 2004; Battles and Fahey 2000; Simila et al. 2006). Whenever one or several number of trees fall in the forest, certain physical space is created this is called gap (Denslow 1987; Runkle 1991). Based on Gray and Spies (1996) gaps are two types: I) Natural gaps formed by falling single tree or a small group of trees, produced by windfall or broken trunk and II) Artificial gaps created by man as a result of single or group cutting of trees.

Several investigators reported the effect of gaps on maintaining and enhancing biological diversity (Poulson and Platt 1989; Coates 2002; Gray and Spies 1996; Albanesi et al. 2005), their importance to the species dynamics of forests types (White and Pikett 1985; Platt and Strong 1989) and their impact on soil (Haghverdi et al. 2012). Several investigations about gap's characteristics especially gap size (Sagheb-Talebi 1995; Mousavi et al. 2003), shape, dynamics (e.g. McCarthy 2001; Fujita et al. 2003; Zeibig et al. 2005; Kenderes et al. 2008) and its relation to plant diversity and species richness (Gray and Spies 1996; Goleij 2006; Scheller and Mladenof 2002; Heywood and Watson 1995) have been carried out in different forests of the temperate regions.

Many outstanding studies have been done in the Caspian forests. Tabari et al.(2003, 2007), Tabari (2008) Amanzadeh et al. (2009), Esmailzadeh et al. (2011), Fallahchai et al. (2011), Parhizkar (2011a, b) and Sefidi et al. (2011). However, there is no information about effect of selective cutting method gap size on plant species diversity in Ramsar's beech forests. So, the main objectives of the present study were to investigate plant species diversity and compositions among different gap categories created by this method of forest management and identify the best gap size which can help achieving sustainable diversity in these forests.

MATERIALS AND METHODS

The study area is components No. 13 and 14 of district No. 5 locate in watershed No. 30 of Ramsar's Safaroud forest management plan, Mazandaran, Iran (Figure 1). This area has approximately 140 hectare. Altitude range from 1000 to 1200 m asl. and the slop is 25% to 50%. General aspect is northwest. This area locate at 50° 35´12˝ E and 36° 55´ 8˝N. Safaroud forest has moderate to cold temperate climate according to the Emberger formula. The mean annual temperature is 15.8 °C (the hottest month is June (24°C) and the coldest is January (7°C)). Mean annual rainfall is 1366 mm. The parent material of the region is limestone, with moderate to good permeability. Soil type is washed brown with Argillic horizon containing loam-clay and coarse and polygonal structure. This region has moderate to deep soil depth (60-70 cm) and mull humus (OFRW 2007).

The components were identified by forest surveying. Gaps derived from logging which are located at north west aspect, with approximately similar slope were identified and divided into three size categories (small, medium and large) (Table1). Then, 5 gaps were randomly selected from each category (totally, 15 gaps) (Berg and Van Lear 2004). 2 m×2 m sampling plots were systematically taken along two diameters of each gap in with 1m interval (Figure 2). Gaps areas were calculated using ellipse method based on the following equation (Runkle 1991; Renato and De Lima 2005).

$$S = R_1 \times R_2 \times \pi /4$$

S = ellipse area, R_1 = Large diameter, R_2 = Small diameter

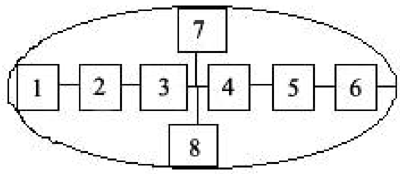

Figure 2. Position of sampling plots in the gaps

The number of individuals of tree saplings and shrubs were counted and coverage percent of herbaceous species were estimated using Domin's criteria in each sampling plot (Mueller-Dombois and Ellenberg 1974). Then, number of species within each gaps were measured and the Simpson (1-D), Shannon-Wiener (H'), Mc Arthur's N_1 and Hill's N_2 indices, species richness and Smith- Wilson's evenness index (E_{var}) were calculated in different vegetation layers using ecological methodology software (Krebs 1999). The Kolmogrov-Smirnov test was used to study the normality of diversity; richness and evenness data in different gaps, then ANOVA and Tukey's tests were performed using SPSS software.

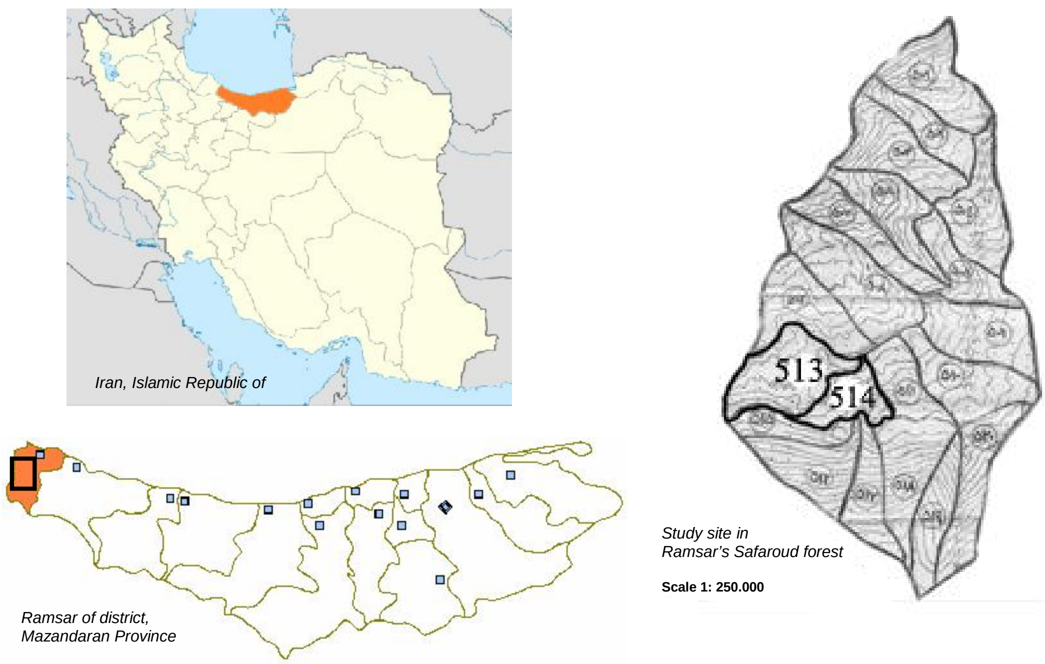

Figure 1. Location of study area in the *Ramsar's Safaroud forest*, Mazandaran Province, Iran

RESULTS AND DISCUSSION

Totally 8 trees, 5 shrubs and 30 herbaceous species were identified in the studied area. The species composition of three different gaps categories were as follows: Small gaps include 28 plant species (including 7 trees and 21 herbaceous species), medium gaps include 37 species (including 7 trees, 5 shrubs, and 25 herbaceous species) and large gaps include 40 species (including 7 trees, 4 shrubs, and 29 herbaceous species) (Table 2).

Tree saplings had maximum diversity in large and minimum diversity in small gaps, respectively. Tukey's test revealed that there were no significant differences among diversity values of sampling layer in different gaps (P>0.05) (Table 3).

The diversity values of shrub species were significant differences among different gaps (P<0.05) and had maximum amount in the medium gaps (this values were not calculated in small gaps because no shrubs were observed) (Table 4).

Herbaceous layer indicated maximum diversity value in large gaps and minimum diversity value in small gaps. Tukey's test showed that there were significant differences in herbaceous species diversity values among the gaps (Table 5).

The highest species richness was observed in herbaceous layer and the lowest was found in shrub layer. The large gap indicated the highest mean species richness (Table 6).

Maximum evenness value was obtained in tree saplings and shrub layers, and minimum was found in herbaceous layer in the medium gaps. There were significant differences between large and medium gaps in shrub layer and also between three gaps categories in herbaceous species layer (Table 7).

The Jaccard's index indicated that there were maximum similarity between woody species in large and medium gaps, and minimum similarity was between medium and small gaps. In the herbaceous layer, maximum similarity was obtained between medium and large gaps and, minimum similarity was between small and large gaps (Table 8).

Table 1. Characteristics of gaps derived from selection logging

Gaps	Area (m^2)	Number of identified gaps	Number of selected gaps
Small	100-200	13	5
Medium	200-300	11	5
Large	300-400	6	5

Table 2. List of plant species in the gaps

Scientific name	Family	Gaps		
		Small	Medium	Large
Tree layer				
Acer cappadocicum Gled.	Aceraceae	+	+	+
Acer insigne Boiss.	Aceraceae	+	+	+
Alnus subcordata C. A. Mey.	Betulaceae	+	-	+
Carpinus betulus L.	Betulaceae	+	+	+
Fagus orientalis Lipsky.	Fagaceae	+	+	+
Fraxinusexcelsior L.	Oleaceae	+	+	+
Tilia begonifolia Stev.	Tiliaceae	-	+	-
Ulmus glabra Huds.	Ulmaceae	+	+	+
Shrub layer				
Crataegus microphylla (Wild) Jac.	Rosaceae	-	+	+
Ilex spinigera Loes.	Aquifoliaceae	-	+	-
Mespilus germanica L.	Rosaceae	-	+	+
Prunus divaricata Ledeb.	Rosaceae	-	+	+
Ruscus hyrcanus Juz.	Asparaginaceae	-	+	+
Herbaceous layer				
Acalypha australis L.	Euphorbiaceae	-	+	+
Atropa belladonna L.	Solanaceae	+	+	+
Carex oreophila L.	Cyperaceae	+	+	+
Ceterach officinarum DC.	Aspleniaceae	-	-	+
Epipactis atrorubens Hoffm.	Orchidaceae	+	+	+
Equisetum sp.	Equisetaceae	-	+	+
*Euphorbia heliscopia*L.	Euphorbiaceae	+	+	+
Galium rotundifolium L.	Rubiaceae	+	+	+
Geranium robertianum L.	Geraniaceae	+	+	+
Hypericum fursei N. Robson.	Hypericaceae	+	+	+
Melissa officinalis L.	Lamiaceae	-	-	+
Mentha pulegium L.	Lamiaceae	+	+	+
Mercurialis annua L.	Guphabaceae	-	+	+
*Nepeta involucrata (*Bunge)Bornm.	Lamiaceae	+	-	-
Oplismenus undulatifolius (Ard.) P. Beauv.	Poaceae	+	+	+
Periploca graeca L.	Asclepiadaceae	-	+	+
Phlomis ghilanensis C. Koch.	Lamiaceae	+	+	+
Phyllitis scolopendrium L.(Newm.)	Aspleniaceae	+	+	+
Potentilla reptans L.	Rosaceae	+	+	+
Primula heterochroma Stapf.	Primulaceae	+	+	+
Pteridium aquilinum (L.) Kuhn.	Hypolepidaceae	+	+	+
Rubus hyrcanus Juz.	Rosaceae	+	+	+
Sambucus ebulus L.	Caprifoliaceae	-	-	+
Sanicula europaea L.	Apiaceae	-	+	+
Scopolia carniolaca L.	Solanaceae	+	+	+
Scutellaria velenovskyi L.	Lamiaceae	+	+	+
Urtica dioicia L.	Urticaceae	+	+	+
Veronica sp.	Scrophulariaceae	+	+	+
Viola alba Bess.	Violaceae	+	+	+
Xanthium strumarium L.	Asteraceae	-	-	+

Note: +: presence, - : absence

Table 3. Diversity measures and their standard errors of tree species saplings in the gaps

Diversity indices	Gap size		
	Small	Medium	Large
1-D	0.71±0.002	0.70±0.003	0.72±0.001
N2	3.52±0.029	3.48±0.026	3.58±0.012
H'	1.94±0.011	1.97±0.012	2.05±0.002
N1	3.88±0.031	3.91±0.028	4.13±0.007

Table 4. Diversity measures and their standard errors of shrubs species in the gaps

Diversity indices	Gap size		
	Small	Medium	Large
1-D	-	0.43±0.001*	0.18±0.001*
N2	-	1.81±0.003*	0.72±0.003*
H'	-	0.97±0.001*	0.17±0.001*
N1	-	1.89±0.002*	0.76±0.002*

Table 5. Diversity measures and their standard errors of herbaceous species layer in the gaps

Diversity indices	Gap size		
	Small	Medium	Large
1-D	0.89±0.001	0.87±0.001	0.91±0.001*
N2	9.68±0.072	7.80±0.046	11.72±1.022*
H'	3.64±0.010	3.33±0.005	3.76±0.017*
N1	10.89±0.068	10.06±0.038	13.83±1.042*

Table 6. Richness values of different vegetation layers in the gaps

Vegetation layers	Gap size			Mean
	Small	Medium	Large	
Tree	7	7	7	7
Shrub	0	5	4	3
Herbaceous	21	25	27	24.33
Mean	9.33	12.33	12.67	

Table 7. Evenness measures of different vegetation layers in the gaps

Vegetation layers	Gap size		
	Small	Medium	Large
Tree	0.60±0.004	0.59±0.005	0.54±0.006
Shrub	-	0.73±0.001*	0.55±0.003*
Herbaceous	0.73±0.003*	0.37±0.001*	0.61±0.002*

Table 8. Jaccard’s similarity index of woody and herbaceous species among the gaps

Gap sizes	Vegetation Layers	
	Woody	Herbaceous
Small-Medium	0.46	0.76
Medium-Large	0.76	0.79
Small-Large	0.63	0.65

Based on our results, abundance of tree saplings varied in different gaps. The most variation was observed between small gaps and other categories, While the difference between medium and large gaps were not significant. Maximum abundance of tree saplings was found in the medium gaps. The total species abundance (especially *Fagus orientalis*) severely declined with increasing in gap size. Large gaps are exposed to direct sunlight which caused the establishment of invasive herbaceous and shrub species (as competing elements) and increasing soil dryness. Therefore, it will prevent the establishment of beech regeneration (Takeh et al. 2004; Peltier et al. 1997; Mousavi 2001).

Several researches have reported that some herbaceous species (e.g. *Rubus* sp., *Petris* sp.) influenced the survival of beech saplings by providing canopy (Taheri 2000; Espahbodi and Tabari 2004). But some others claimed that beech saplings were not able to compete with *Rubus* sp. or other herbaceous species (Savill 1991; Harmer 1995). Ersali (1999) reported that presence of competing herbaceous species increases water consumption, and on the other hand reduces the establishment of tree seedlings. However, based on Helliwell (1982), the beech saplings were more successful than the light-demanding plants (e.g. oak and maple species) in competing with herbaceous species.

Diversity

The important impact of cutting in species diversity has been reported in several researches (e.g. Heywood and Watson 1995; Nagaike et al. 1999; Okland et al. 2003). Our results revealed that the high diversity of tree saplings was in large gaps which it is consistent with previous researches of Yamamoto (1989), and Hall et al. (2003). However, the diversity differences among three categories of gaps were not significant.

Shrub species diversity was significantly high in medium gaps and declined in small (with the light shortage) and large gaps (with increasing in light and herbaceous competition). This result is in agreement with previous studies of De Granper and Bergeron (1997), Pourbabaei and Ranjavar (2008).

The herbaceous species diversity was increased in large gaps (300-400 m^2). Vast cutting area and more light penetration favored the growth of light-demanding species, increased species richness and cover percentage. This result supports the previous surveys by Scheller and Mladenoff (2002), Schumann et al. (2004), Nelson and Halpern (2005), Pourbabaei and Ranjavar (2008).

Our findings indicated that the richness of tree species (included 7 species) were similar in three gaps categories, While shrub species richness varied among different gaps size, and it was minimum in small gaps due to lack of light. The herbaceous species richness was different among different gaps.

Species composition

The current result showed that species composition varied in three categories of gaps and supported the previous result of Boudreau and Lawes (2005). However, the medium and large gaps composed of more similar woody and herbaceous species. Many factors including environmental and physical evidences such as soil moisture, texture and fertility (Hutchinson et al. 2007), light variations (Rozenbergar et al. 2007) and selection methods especially single selection (Malcolm and Ray 2000) influence the composition and abundance of plant species.

Species composition changes with increasing in gap size (Coates 2002) and it is often from pioneers in the early successional stage, towards climax species in later successional phases (Mc Evoy 2004). In open canopy, the heliophyte pioneers species will grow very fast and this will cause establishment of shade tolerant species in understory. But very large open canopy the heliophyte pioneers species grow rapidly and change the species composition (Moore and Vankat 1986; Deal 1997; Leniere and Houle 2006). The significant role of gap size in providing rich species composition, diversity and creating desired successional communities were reported earlier (Whitmore 1989; Mc Carthy 2001; Goleij 2006; Liu et al. 2011).

CONCLUSION

The gap size has significant effects on plant species diversity which it has major role in forest stability and sustainable production. Based on the results of present study, gap sizes up to 400 m^2 improve the species diversity and this is recommended for forest harvesting. So, different gap size should be prepared in broad-leaved forest management strategies, which create multiple storey, heterogeneity, species diversity, mixed composition and regeneration to provide ecological stability of these forests.

REFERENCES

Albanesi E, Gugliotta OI, Mercurio I, Mercurio R. 2005. Effects of gap size and within position on seedling establishment in silver fir stands. iForest @2 (4): 358-366.

Alongi DM. 2007. Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change. Est, Coast Shelf Sci 76: 1-13.

Amanzadeh B, Amani M, Hassani M. 2009. Typology of seedling composition and density in regeneration gaps of Ramsar-Safaroud forest. Iranian J For Poplar Res 16 (3): 378-389.

Asli A, Nedialkov ST. 1973. The structure of virgin stands of *Fagus orientalis* in the high forests of northern Iran. Schweizerische Zeitschrift fur Forstwesen 124 (6): 403-414.

Battles JJ, Fahey TJ. 2000. Gap dynamics following forest decline: A case study of Red spruce forests. Ecol Appl 10: 760-774.

Bayramzadeh V, Attarod P, Ahmadi MT, Ghadiri M, Akbari R, Safarkar T. 2012.Variation of leaf morphological traits in natural populations of *Fagus orientalis* Lipsky in the Caspian forests of northern Iran. Ann For Res 55 (1): 33-42.

Berg EC, Van Lear DH. 2004. Yellow-poplar and oak seedling density responses to wind-generated gaps. In: Connor KF (eds). Proceedings of the 12th Biennial Southern Silvicultural Research Conference. Department of Agriculture, Forest Service, Southern Research Station. Asheville, NC. February 24-28, 2003.

Boudreau S, Lawes MJ. 2005. Small understory gaps created by subsistence harvesters do not adversely affect the maintenance of tree diversity in a sub-tropical forest. For Ecol Manag 126: 279-286.

Coates KD. 2002. Tree recruitment in gaps of various sizes, clear cuts and disturbed mixed forest of interior British Columbia, Canada. For Ecol Manag 155: 387-398.

De Granper L, Bergeron Y. 1997. Diversity and stability of understory communities following disturbance in the southern boreal forest. J Ecol 85: 777-784.

Deal RL. 1997. Understory plant diversity in riparian Alder- Conifer stands after logging in southeast Alaska. USDA Forest Service, Pacific Northwest Research Station, Research Note PNW-RN-523.

Denslow JS. 1987. Tropical rainforest gaps and tree species diversity. Ann Rev Ecol Syst 18: 431-451

Ersali A. 1999. Natural breeding of high oak species.[Dissertation].Tarbiat Modares University, Noor, Mazandaran. [Persian]

Esmailzadeh O, Hosseini SM, Tabari M, Baskin CC, Asadi H. 2011. Persistent soil seed banks and floristic diversity in *Fagus orientalis* forest communities in the Hyrcanian vegetation region of Iran. Flora 206: 365-372.

Espahbodi F, Tabari M. 2004. Determining the most suitable shade rate for producing beech (*Fagus orientalis* Lipsky.) seedlings in a mountain nursery. Iranian J Nat Res 57 (3): 439-446.

Fallahchai MM, Hashemi SA, Bonyad A. 2011. Survey of tree species regeneration in canopy gaps forests in North of Iran. Adv Environ Biol 5 (10): 3124-3128.

Fujita T, Itaya A, Miura M, Manabe T, Yamamoto SI. 2003. Long-term canopy dynamics analyzed by aerial photographs in a temperate old-growth evergreen broad-leaved forest. J Ecol 91 (4): 686-693.

Goleij A. 2006. A qualitative and quantitative investigation of natural regeneration in the gaps derived from the first selective cut in Meskeli *Buxus hyrcana* stand. [Dissertation]. Sari University of Agricultural Sciences and Natural Resources, Sari. Mazandaran [Persian]

Gray AN, Spies TA. 1996. Gap size, within-gap position and canopy structure effects on conifer seedling establishment. J Ecol 84: 635-645.

Haghverdi K, Kiadaliri H, Sagheb -Talebi Kh, Kooch Y. 2012. Variability of plant diversity and soil features following gap creation in Caspian Beech forests of Iran. Ann Biol Res 3 (9): 4622-4635.

Hall JS,Harris DJ, Medjibe V, Ashton PM. 2003. The effects of selective logging on forest structure and tree species composition in a Central African forest: implications for management of conservation areas. Fort Ecol Manag 183: 249-264.

Harmer R. 1995. Natural regeneration of broadleaved trees in Britain: Germination and establishment. Forestry 68: 1-9.

Helliwell DR. 1982. Factors influencing the growth of seedling of Sycamore and Norway maple. Quart J For 59: 327-337.

Heywood VH, Watson R. 1995. Global biodiversity assessment. Published for the United Nations environment program. Cambridge University Press, Cambridge.

Hutchinson TF, Kennedy SE, Scott CT. 2007. Composition and abundance of tree regeneration. In: Sutherland EK, Hutchinson TF (eds). Characteristics of mixed-oak forest ecosystems in Southern Ohio Prior to the Reintroduction of Fire. USDA Forest Service, Delaware.

Kenderes K, Mihok B, Standovar T. 2008. Thirty years of gap dynamics in a Central European beech forest reserve. Forestry 81: 111-123.

Komarov VL. 1934-1963. Flora USSR.Vo1.5, Fagaceae, 252-279 Izdatel'stvo Akademii Nauk SSSR Moskva, Leningrad.

Krebs CJ, 1999. Ecological methodology. Benjamin Cummings, Menlo Park, CA.

Leniere A, Houle G. 2006. Response of herbaceous plant diversity to reduced structural diversity in maple-dominated (*Acer saccharum* Marsh.) forests managed for sap extraction. For Ecol Manag 231: 94-104

Liu Y, Liu C, Wei Y, Liu Y, Guo K. 2011. Species composition and community structure at different vegetation successional stages in Puding, Guizhou Province, China. Chinese J Pl Ecol 35 (10): 1009-1018.

Malcolm JR, Ray JC. 2000. Influence of timber extraction routes on central African small-mammal communities, forest structure, and tree diversity. Conserv Biol 14: 1623-1638

Mc Carthy J. 2001. Gap dynamics of forest trees: A review with particular attention to boreal forests. Environ Rev 9 (1): 1-59.

Mc Evoy TJ. 2004. Positive impact forestry: A sustainable approach to managing woodlands. Island Press, Washington DC.

Mobayen S, Tregubov V. 1970. Carte de la vegetation naturelle de l'Iran [Map of the natural vegetation of Iran]. Faculte des Forets et Paturages, Universite de Tehran. Tehran.

Moore MR, Vankat JL. 1986. Responses of the herb layer to the gap dynamics of a mature beech-maple forest. Amer Midland Natur 115 (2): 730-741.

Mousavi SR, Sagheb Talebi KH, Tabari M, Pourmajidian MR. 2003. Determination of gap size for improvement of beech (*Fagus orientalis*) natural regeneration. Iranian J Nat Res 56 (1-2): 39-46.

Mousavi SR. 2001. A silvicultural study on regenerated gaps in the Shurab district of Golband region. [Dissertation].Tarbiat Modares University, Noor. Mazandaran [Persian].

Mueller-Dombois D, Ellenberg H. 1974. Aims and methods of vegetation ecology. John Wiley & Sons. New York.

Nagaike T, Kamitani T, Nakashizuka T. 1999. The effect of shelterwood logging on the diversity of plant species in a beech (*Fagus crenata*) forest in japan. For Ecol and Manag 118: 161-171.

Nelson CR, Halpern CB. 2005. Edge-related responses of understory plant to aggregated retention harvest in the Pacific Northwest. Ecol Appl 15: 196-209.

Odum EP, Barrett GW. 2004. Fundamentals of ecology. W.B. Saunders Co, Philadelphia.

OFRW [Organization of Forests, Rangelands and Watershed Management]. 2007. Forest Management Plan of Safaroud.District No. 5. Department of Natural Resources of Western Mazandaran.Sari.

Okland T, Rydgren K, Okland RH, Storaunet KO, Rolstad J. 2003. Variation in environmental conditions, under-story species number, abundance and composition among natural and managed *Picea abies* forest stands. For Ecol Manag 177 (1-3): 17-37.

Parhizkar P, Sagheb-Talebi K, Mataji A, Namiranian M. 2011a. Influence of gap size and development stages on the silvicultural characteristics of oriental beech (*Fagus orientalis* Lipsky.) regeneration. Caspian J Environ Sci 9 (1): 55-65.

Parhizkar P, Sagheb-Talebi K, Mataji A, Nyland R, Namiranian M. 2011b. Silvicultural characteristics of oriental beech (*Fagus orientalis* Lipsky.) regeneration under different RLI and positions within gaps. Forestry 84 (2): 177-185.

Peltier A, Touzet MC, Armengaul C, Ponge JF. 1997. Establishment of *Fagus sylvatica* and *Fraxinus excelsior* in an old-growth beech forest. J Veg Sci 8 (1): 13-20.

Platt WJ, Strong DR. 1989. Special feature: Gaps in forest ecology. Ecology 70: 535-576.

Poulson TL, Platt WJ. 1989. Gap light regimes influence canopy tree diversity. Ecology 70: 553-555.

Pourbabaei H, Ranjavar AR. 2008. Effect of shelterwood silvicultural method on plant species diversity in beech (*Fagus orientalis* Lipsky.) Forests in Shafaroud, Guilan Province. J Iranian For Poplar Res 16 (1): 61-73.

Rechinger KH. 1963-2010. Flora Iranica, 1-178. Akademsiche Druck- u. Verlagsanstalt und Naturhistorisches Museum Wien. Graz & Wien.

Renato A, De Lima F. 2005. Gap size measurement: The proposal of a new field method. For Ecol Manag 214: 413-419.

Rozenbergar D, Mikax CS, ANI ĆI, Diaci J. 2007. Gap regeneration patterns in relationship to light heterogeneity in two old-growth beech - fir forest reserves in south east Europe. Forestry 80 (4): 432-443.

Runkle JR. 1991. Gap dynamics of old-growth eastern forests: management implications. Nat Areas J 11 (1): 19-25.

Sagheb-Talebi K. 1995. Study of some characteristics of young beech (*Fagus sylvatica* L.) in the regeneration gaps of irregular shelter wood system (Femelschlag). In: Madsen SF (ed). Genetics and silviculture of beech: Proceedings from the 5th Beech Symposium of the IUFRO Project Group, Denmark. Forskingsserien, 24 September 1994.

Salehi SP, Giuseppe VG, Mohsen C. 2011. Altitudinal genetic variations among the *Fagus orientalis* Lipsky. populations in Iran. Iranian J Biotechnol 9 (1): 11-20.

Sampson RN, DeCoster LA. 1998. Forest Health in the United States. Idaho Forest Products Commission. http: //www.idahoforests.org/health2.htm

Savill PS. 1991. The Silviculture of Trees Used in British Forestry. CABI, Wallingford. UK.

Scheller R, Mladenoff D. 2002. Understory species patterns and diversity in old-growth and managed Northern Hardwood forests. Ecol Appl 12: 1329-1343.

Schumann ME, White AS, Witham JW. 2004. The effects of harvest-created gaps on plant species diversity, composition, and abundance in a main oak-pine forest. For Ecol Manag 176 (1-3): 543-561.

Sefidi K, Marvie Mohadjer MR, Mosandl R, Copenheaver CA. 2011. Canopy gaps and regeneration in old-growth oriental beech (*Fagus orientalis* Lipsky.) stands, northern Iran. For Ecol Manag 262 (6): 1094-1099.

Simila M, Kouki J, Monkkonen M, Sippola A, Huhta E. 2006. Co-variation and indicators of species diversity: Can richness of forest-dwelling species be predicted in northern boreal forests?. Ecol Indicat 6: 686-700.

Tabari M, Espahbodi K, Poormadjidian MR. 2007. Composition and structure of a *Fagus orientalis*-dominated forest managed with shelter wood aim (a case study in the Caspian forests, northern Iran) Caspian J Environ Sci 5 (1): 35-40.

Tabari M, Fayaz P, Emadian SFA, Espahbodi K, Pourmajdian MR. 2003. Effect of gap size on survival and activity of Beech (*Fagus orientalis* Lipsky.). J Pajouhesh va Sazandegi 16 (1): 32-36.

Tabari M. 2008. Germination and growth of *Fagus orientalis* seedling under different stand canopies. J Appl Sci 8 (9): 1776-1780.

Taheri AK. 2000. Study on regeneration structure of natural beech forest of Asalem region.[Dissertation]. Tarbiat Modares University, Noor. Mazandaran [Persian].

Takeh G, Jalali SG, Hosseini SM, Tabari M. 2004. Quantity and quality comparison of natural regeneration establishment of *Fagus*, *Acer* and *Carpinus* in forest stands under management of tree and group selection system (Dr. Bahramnia forest management plan). J Agri Sci Nat Res 10 (4): 125-134.

Thompson I. 2010.The role of forest biodiversity in the sustainable use of ecosystem goods and services in agriculture, agro-forestry, and forestry. In: KoizumiT, OkabeK, Thompson I, SugimuraK, Takeshi T, Fujita K (eds). Forestry and Forest Products Research Institute; Proceedings of International Symposium for the Convention on Biological Diversity, Tokyo, Japan, 26-28 April 2010.

Torras O, Saura S. 2008. Effects of silvicultural treatments on forest biodiversity indicators in the Mediterranean. For Ecol Manag 255: 3322-3330.

Tuomela K, Kuusipalo J, Vesa L, Nuryanto K, Sagala APS, Adjers G. 1996. Growth of dipterocarp saplings in artificial gaps. For Ecol Manag 81: 95-100.

Whitmore TC. 1989. Canopy gaps and the two major groups of forest trees. Ecol 70 (3): 536-538.

Yamamoto SI. 1989. Gap dynamics in climax *Fagus crenata* forests. Bot Manag 102: 93-114.

Zeibig A, Diaci J, Wagner S. 2005. Gap disturbance patterns of a *Fagus sylvatica* virgin forest remnant in the mountain vegetation belt of Slovenia. For Snow Landscape Res 79: 69-80.