Environmental Resources Research
Vol. 5, No. 1, 2017

GUASNR

Spatial pattern and characteristic of tree-fall gaps to approach ecological forestry in Northern Iran

M.H. Moayeri[*1], A.R. Hajivand[2], Sh. Shataee Joybari[1], S. Rahbari Sisakht[3]
[1]Associate Prof., Dept. of Forestry, Gorgan University of Agricultural Sciences and Natural Resources
[2]M.Sc. Graduated Student, Faculty of Forest Science, GAU
[3]Ph.D. Candidate, Dept. of Forestry, Faculty of Forest Science

Received: December 2015 ; Accepted: February 2017

Abstract

Gaps created by falling trees (tree-fall gaps) are natural in forest ecosystems. Understanding scale, pattern and the effect of gaps on regeneration is important to current and future forest management. The aim of this study was to determine the size, shape and spatial pattern of tree-fall gaps and the associated forest regeneration. The study was carried out in three parcels (No. 15, 18 and 19) of the second District in Shastkalateh Forest in northern Iran. The size, location and regeneration of all tree-fall gaps were measured in the parcels. One way ANOVA was used to compare gap features and regeneration and Spearman's rank correlation coefficient was used to test the relationship between gap size and regeneration density. The results showed that the total area of gaps created by tree-fall in the three parcels was 13.72 ha, or 7.4% and on average there were 1.06 gaps per hectare. Gap size ranged from 49 m^2 to 1827 m^2, with mean gap size being 658.2 m^2. Most (69.2%) gaps were 200 m^2 to 1000 m^2 in size. Results of the spatial pattern analysis showed both uniform and irregular shapes for gaps in three parcels. ANOVA analysis showed a statistically significant difference between gap size and regeneration density and the Spearman rank correlation showed a direct relationship between gap size and the number of seedlings. These results provide useful information to manage forests according to ecological principles.

Keywords: Spatial pattern, Tree-fall Gaps, Ecological forestry, QCM, Biodiversity.

---

[*] Corresponding author; moayeri@gau.ac.ir

Introduction

Tree-fall gaps are the most frequent small-scale natural disturbances in many forest ecosystems (Pickett and White, 1985) and have been long thought to play a role in the maintenance of biodiversity (Brokaw, 1996; Hubbell *et al.,* 1999; Schnitzer and Carson, 2001; Patrick *et al.,* 2012). Natural disturbances such as fire, wind, flood, insects and snow avalanche, create tree-fall gaps in the forest area (Foster *et al.,* 1998). One proposed management approach to restore and maintain native biodiversity and accelerate forest succession towards old-growth characteristics within managed forests is natural disturbance-based silviculture (Fries *et al.,* 1997; Seymour *et al.,* 2002). Past management practices have led to a simplification of forest structure, resulting in a loss of habitat for a diversity of organisms (Latty *et al.,* 2006). Today, there is increasing global concern regarding the loss of native biodiversity from forest systems (Klenner *et al.,* 2009; Bolton and D'Amato, 2011), particularly within managed forests (Hunter, 1999). Understanding natural patterns and processes, including tree-fall gaps better enables forest managers to use ecological principles, enhancing the conservation of biodiversity in these forests.

Ecological phenomena (e.g. tree-fall gaps), are also characterized through multiple ecological processes that act upon them; these processes often operate at more than one spatial scale (Fortin *et al.,* 2002). Many researchers are of the view that if management is based on the principles of natural distribution pattern and ecological phenomena, then this will benefit forest biodiversity (Strong, 1977; Brokaw, 1996; Hubbell *et al.,* 1999; Schnitzer and Carson, 2001). Natural disturbances within hardwood forests in northern Iran are primarily driven by wind, disease and longevity (inside decay). Much of these forests are now managed for multipurpose uses, including timber production and nature conservation. After many years of implementing forest plans in north of Iran, there are still important questions with respect to ecologically appropriate forest management. These include but are not limited to; what is the spatial pattern and common size (classification) range of tree-fall gaps in virgin forests and which silvicultural methods are suitable to preserve tree-fall spatial pattern gaps in uneven-aged forest in northern Iran? Spatial pattern of tree-fall gaps is a structure, placement, or arrangement of gaps in forest area that exhibits a certain amount of predictability. There are at least three common types of spatial pattern in each ecosystem; uniform, random and clumped (Dale, 1999).

Most previous studies have focused on tree-fall gap size, shape and its effects on regeneration generally. Working on three 25 ha areas of forest in northern Iran, Sefidi *et al.* (2011) reported an average of 3 gaps/ha with gap sizes ranging from 19 to 1250 m^2. Mountford (2001) reported that in Oriental Beech (*Fagus silvatica)* managed forests in southern England, canopy gaps had irregular shape, the smallest and the largest gap areas were between 75 and 241 m^2, respectively. Gagnon *et al.* (2004) in the Apalachicola National Forest in northwest Florida showed that the tree-fall gap areas were between 32 to 1161 m^2, also they stated that gaps form was irregular and had significant difference with the circle shape. Bolton and D'Amato (2011) examined the effectiveness of natural disturbance-based harvest gaps in maintaining and restoring native tree species diversity within second-growth northern hardwood systems in northeastern Minnesota, USA. They found that seedling and sapling densities increased in harvest gaps; however, results indicated that these gaps did little to increase tree diversity, including the recruitment of shade mid-tolerant species, such as *B. alleghaniensis*. A more complete understanding of tree-fall gap characteristics, spatial patterns and their effect on forest regeneration will also aid in the development of silvicultural systems that are designed to closely mimic patterns of natural disturbance and lead to successful seedling recruitment (Palik and Pederson, 1996; Lertzman *et al.,* 1996; Brockway and Outcalt, 1998; Gagnon *et al.,* 2004). Therefore the aims of this study was to 1. determine the spatial pattern, frequency, size, shape and rate of tree-fall gaps in a virgin forest, 2. assess the impact of tree-fall gaps on tree species regeneration to approach ecological forestry principles in northern Iran.

Materials and Methods

Study area

The study was conducted in the second district of a virgin natural forest of called the research and educational forest of Shastkalateh in Golestan Province in northern Iran. The area is located at approximately 54° 21' 06" to 54° 23' 30" E and 36° 43' 30" to 36° 42' 30" N (Figure 1). The district has 1998 ha drainage area and ranges from 250 to 2000 masl in elevation. The average annual rainfall is 482 mm and the mean annual temperature is 17.8 °C. Table 1 shows characteristics of the study area (According to forest management plan booklet of the second district of Shastkalateh Forest, 1995).

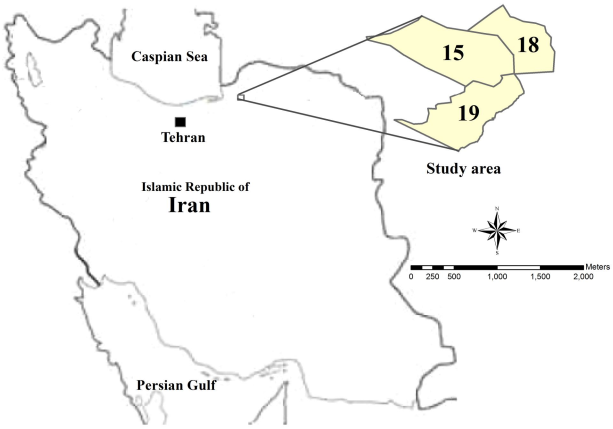

Figure 1. Location of the study area in Shastkalateh Forest.

Table 1. Characteristics of the studied parcels in the second district of Shastkalateh Forest.

Parcels characteristics	*15*	*18*	*19*
Total Area (ha)	65	66	53.5
Sea level height	750-850 m	850-900 m	880 m
Aspect	Northwest	Northwest	Northwest
Slope	Less than 30 percent	Less than 30 percent	Less than 30 percent
Rock Type	Gorgan with green sheet formation	Gorgan Green Schist Formation	Stone formation and green Gorgan Plain
Soil type	Forest washed brown with calcium layer	Forest washed brown with calcium layer	Forest washed brown with calcium layer
Soil Texture	Silt, Silty Clay, Silt clay loam	Silt clay, Silt loam	Silt loam, Silt clay, Silt clay loam
Forest type	Beech (Fagus Orientalis), Beech-Iron wood (Parotia Persica)	Beech (Fagus Orientalis), Iron wood (Parotia Persica)	Beech (Fagus Orientalis), Beech-Iron wood (Parotia Persica)
Canopy Cover	75 percent	76 percent	81 percent
Mixture of species percent (by volume)	Beech 74.2, Hornbeam 15.6, Alder 5.5, Industrial Sp. 2, Rough wood 2.63	Beech 69.94, hornbeam 15.13, Alder 5.19, Industrial Sp. 6.02, Rough wood 3.73	Beech 73.74, hornbeam 13.86, Alder 4.45, Industrial Sp. 3.86, Rough wood 4.1

Methods

Determining spatial pattern of gaps

A 1:25000 topographic map of the study area was used and some parts of the second district that had not any human interference (virgin forest) was selected. After identifying and getting characteristics of all gaps in the three parcels, linear transects with 50 meter distance were located in the South – North direction and all gaps through transects were recorded. To determine position, shape, area and spatial pattern, center of each gap was located on the ground. A hand-held GPS receiver was used to record the center of all gaps. All Gaps border was determined by Azimuth and distance (survey) method. The shapes of gaps were drawn using AutoCAD (V.18) Software. The gap borders were digitized and the areas and perimeters were calculated using Arc.GIS 9.3 software (Gagnon *et al.,* 2004). There are several methods and algorithms that endeavor to describe pattern for a collection of gaps. The most common methods used for spatial pattern analysis are as follows (Cressie, 1993) (Figure 2).

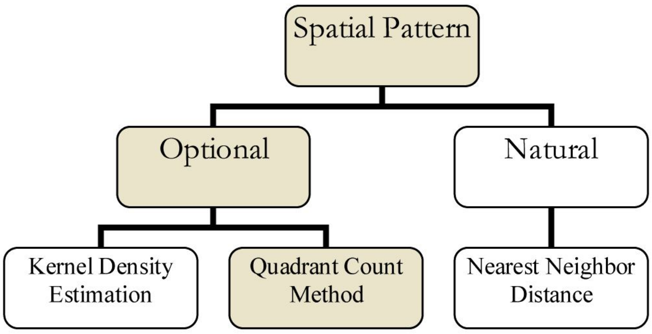

Figure 2. Spatial pattern methods related to sampling units.

The methods are threefold:

1. Quadrant Count Method
2. Kernel Density Estimation (K means)
3. Nearest Neighbor Distance

Quadrant count method (QCM) finds out whether the distribution of the tree-fall gaps is random, clustered or regular. To explain the application of QCM, a small data set was plotted on a square region. The region was divided into equally sized quadrants (250 × 200 m). The variance to mean ratio (VTMR) was then calculated using the following equation:

$$VTMR = \frac{q\sum_{1}^{n} x_i^2 - \frac{q}{n}\left(\sum_{1}^{n} x_i^2\right)}{g(n-1)} \qquad (1)$$

Here x_i is the frequency of gaps in each quadrant q and g are number of quadrants and gaps in the study area respectively.

If the distribution variance is equal to one (VTMR=1), the spatial pattern is random. If the distribution variance is greater than one (VTMR>1), the spatial pattern is clumped. Finally, if distribution variance is less than one (VTMR<1), the spatial pattern is uniform (Upton and Fingleton, 1985; Cressie, 1993; Dale, 1999).

Seedling characteristics

We recognized four classes for gap area (less than 200 m^2 or very small, 200-500 m^2 or small, 500-1000 m^2 or medium and 1000-2000 m^2 or large). These classes were selected based on the effectiveness of vegetation cover in gap area according to Davis (2001). All seedlings in each gap were measured to examine relationship among gap classes and seedling characteristics.

Statistical Analysis

Kolmogorov-Smirnov and Shapiro-Wilk normality test (α=0.05) was initially applied to verify normal distributions of the variables considered (Rahbari *et al.,* 2014). Since all of the variables had normal distribution ($P \leq 0.05$), then One-way ANOVA and Duncan tests were used to determine the difference between seedling characteristics in each gap class. Spearman's rank correlation coefficient was used to test the relationship between gap size and regeneration density. STATISTICA software (V.8) was used in statistical analyses.

Results

Gap characteristics

Results showed that there were 195 tree-fall gaps in the three parcels of the study area. Also in parcels 15, 18 and 19, there were 89, 52 and 54 tree-fall gaps and the average number of gaps in each parcel were 1.37, 0.79 and 1.01 per hectare, respectively.

The amount of opened forest area due to natural disturbances in parcels 15, 18 and 19 were 5.07 (7.8%), 3.61 (5.4%) and 5.04 (9.4%) ha and the total opened area in the three parcels was 13.72 (7.4%) ha (Figure 3).

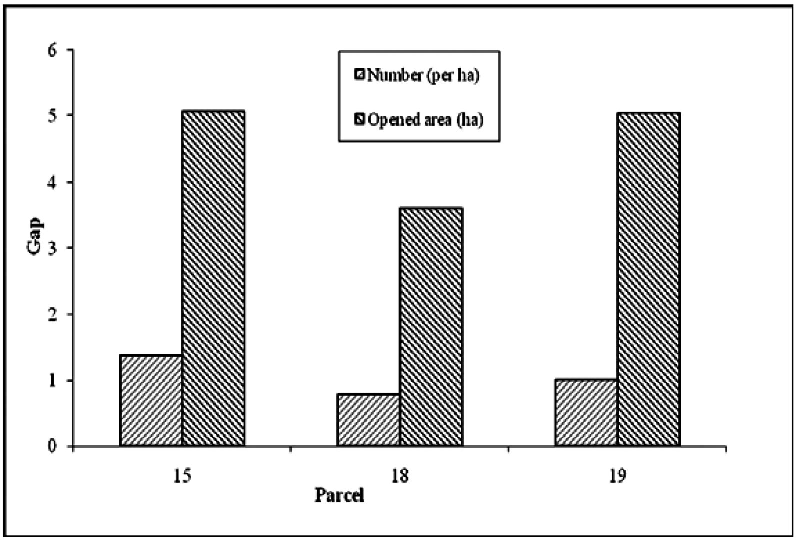

Figure 3. The average number OF gaps due to natural disturbances per hectare.

The results showed no very small gaps in parcel 19. Also our finding showed that the most very small gaps were in parcel 15, small gaps were in parcel 18 and medium and large sizes were in parcel 19 generally. Table 2 shows the percentage of gap distribution in the four size classes (very small, small, medium and large).

Table 2. Distribution of gap (percent) classes in different parcels of the study area.

Parcel	*Gap Number*	Gaps Classes %			
		Very small size (<200 m^2)	Small Size (200-500 m^2)	Medium (500-1000 m^2)	large size (1000-2000 m^2)
15	89	16.9	34.8	32.6	15.7
18	52	3.8	51.9	30.8	13.5
19	54	0	16.7	40.7	42.6
Average	65	6.9	34.5	34.7	23.9

ANOVA test showed that there was significant difference between gaps size in parcel 19 towards parcels 15 and 18 (F=13.89, P<0.001). The mean size of the opened areas was 658.21 m^2 and the median tree-fall gap size was 562.5 m^2 and gap size ranged between 49 and 1827 m^2 in the three parcels. Table 3 shows results of Duncan's test for gap size in the three studied parcels.

Table 3. Comparison of gap size in the three studied parcels.

Parcel	*Mean ± Standard error*
15	563.71 ± 435.76^{a}
18	573.47 ± 328.88^{a}
19	909.92 ± 390.30^{b}

Shape and Spatial Pattern

Results of QCM showed that the spatial pattern of tree-fall gaps in the three studied parcels had uniform pattern (VTMR=0.96) (Figure 4).

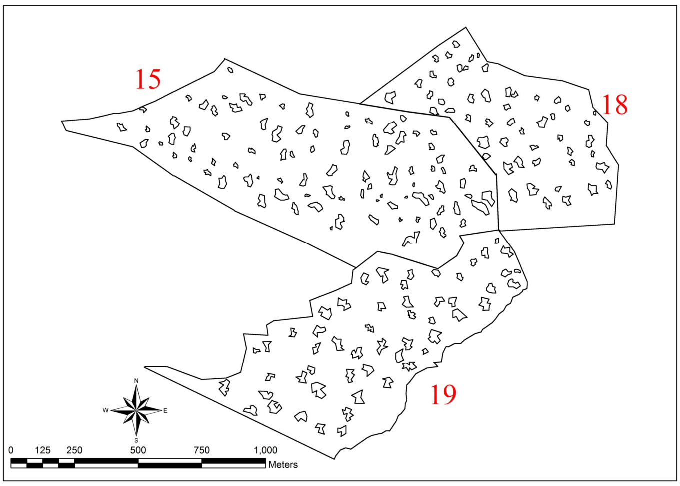

Figure 4. Distribution of gaps in the studied areas.

According to some previous studies (Battles *et al.,* 1996; Gognon *et al.,* 2004; Sefidi *et al.,* 2011) the Perimeter–Area (P/A) ratio is a useful ecological indicator for assessing the irregularity of an opened area and in our results we showed that gap shapes were irregular and differed significantly from that of a circle (Figure 5). The mean P/A ratio in this study was 0.26 ($\frac{1}{m}$).

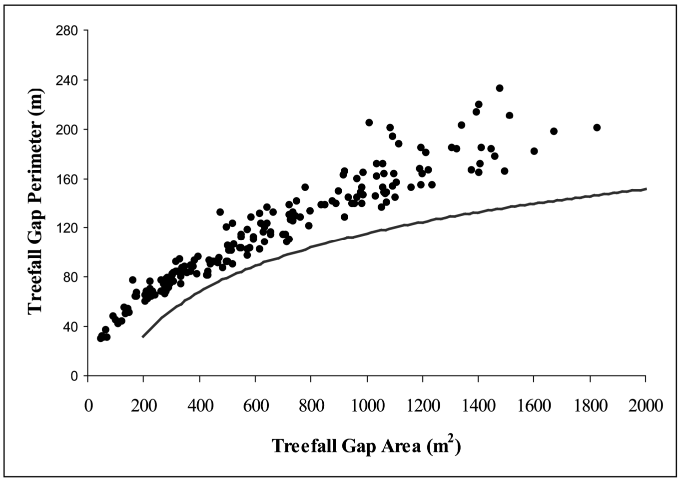

Figure 5. Perimeter to area ratio relationship for treefall gap in the study areas. The line plot (——) show the area–perimeter relationship for a circle.

Regeneration characteristics

Total seedlings inside tree-fall gaps of parcels 15, 18 and 19 were 3177, 685 and 1204 seedlings ha^{-1}, respectively. Also, maximum number of seedlings belonged to *Fagus orientalis lipsky* (Oriental Beech) (38.8%) and then *Carpinus betulus* (Hornbeam) (25.1%), *Acer cpadosicum* (Maple tree) (21.2%), *Diospirus lutus* (Date plum) (5.9%) and *Parrotia persica* (Persian Ironwood) (9%) (Figure 6).

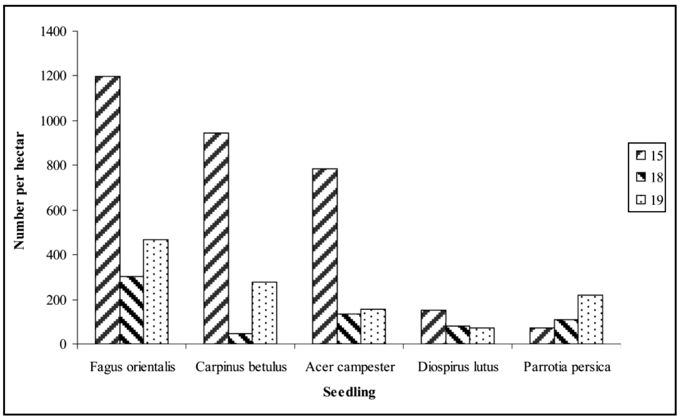

Figure 6. Number of tree species seedling within treefall gaps.

ANOVA showed no significant difference between regenerations in parcels 18 and 19, but there were significant differences in regenerations in parcel 15 versus the other two parcels (F=33.156, P<0.0001). The results of Duncan test is summarized in Table 4.

Table 4. Comparison of regeneration among three studied parcels.

Parcel	*Mean ± Standard error*
15	588.61±258.21^{a}
18	140.92±65.26^{b}
19	242.14±134.85^{b}

Regeneration and gap size classification

The Spearman rank correlation showed direct relation between gap size and regeneration (S_{CC}=0.87 & P=0.001) and when gap size increased, the number of seedlings increased as well (Figure 7).

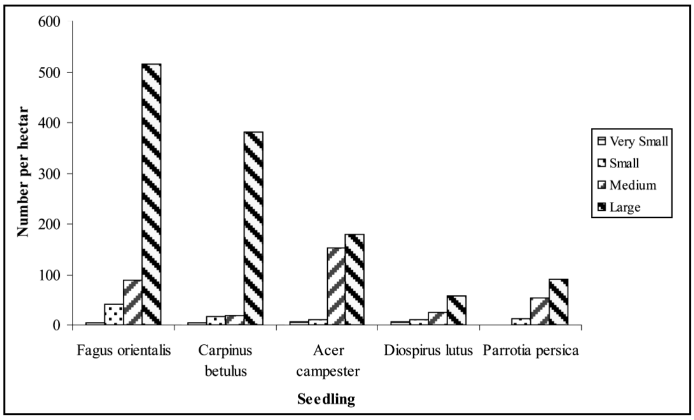

Figure 7. Relationship between seedling and gap size.

Discussion

According to field observation, most natural disturbances that created gap in the study area were storms and natural mortality of trees. Around 13.72 (7.4%) ha of the total studied area were opened due to natural disturbances. Maximum numbers of gaps were in parcel 15; however gap classes often were small and medium size in this parcel (Figure 3 and Table 2). Although average slope and the dominant aspect of three parcels were equal, nonetheless major large gap sizes (1000-2000 m^2) with average 909.92 m^2 of opened surface were observed in parcel 19, with a significant difference between gaps sizes compared to parcel 15 and 18 (Tables 3 and 4). The three studied parcels were the same in terms of soil texture, soil depth, slope and aspect (Table 1), but parcel 19 was prune to dominant wind direction, hence the mean gap size in this parcel was greater than the other two parcels (Table 4). Previous studies reported that most gaps were caused by the death of two trees (rather than single trees) and mean gap size was from 50 to 550 m^2 across different forest areas. Table 5, compares gap size in previous studies with our findings.

Results of the spatial pattern analysis (equation 1 and Figure 4) showed uniform pattern for treefall gaps in the study area. One reason to justify this event may be uniform slope in the study area. It seems that slope, aspect, soil (depth and texture) and windstorms were the main reasons for gap formation in the study area and they were uniform with respect to these features; however other phenomena like tree illness, harvesting operation and forest roads disturbance were different in the studied parcels.

Table 5. Results of some similar studies compared with our findings.

Authors	*Country*	*Maximum gap size (m^2)*	*Mean gap size (m^2)*
Sefidi *et al.* (2011)	Iran	1250	206
Mataji *et al.* (2008)	Iran	-	210
Delfan-Abazari *et al.* (2004)	Iran	-	550
This study	Iran	1827	658
Hart and Grissino-Mayer (2009)	USA	125	213
Gognon *et al.* (2004)	USA	1161	420
Weiskettel and Hix (2003)	USA	1105	386
Mihók *et al.* (2007)	Hungry	378	61
Zeibig *et al.* (2005)	Slovenia	833	137
Yamamoto and Nishimora (1999)	Japan	583	113

Tree competition and mature tree existence can affect regeneration and determine regeneration number. These results are supported with Gognon *et al.* (2004). Also maximum number of regenerations belonged to *Fagus orientalis lipsky* (Oriental Beech), then to *Carpinus betulus* (Hornbeam) that are dominant species in the study area (Table 1).

Figure 7 showes that number of regeneration inside gaps increased when gap size increased. Some studies identified average light intensity was 3% higher in small gaps and 8% higher in large gaps compared to the understory of the surrounding closed canopy (Mihók *et al.,* 2007). Hence, larger gaps allow more sun light in forest floor and increase litter decomposition, which leads to regeneration increase (Gagnon *et al.,* 2003). These results are in line with previous studies (Clinton *et al.,* 1994; Goldblum, 1997; Bolton and D'Amato, 2011). Although larger gaps increase seedling, but maximum number of seedling was seen in parcel 15. It seems that the number of gaps is more effective than gap size.

Existence of mature tree, trees competition and gap size are three important reasons in mountainous forests in northern Iran that affect tree regeneration (Mataji *et al.,* 2008, sefidi *et al.,* 2011). Gap size is recognized as an important control over the density of tree seedlings and saplings within forest systems (Brokaw and Busing 2000). According to Iranian forests organization instruction, forest management must use singe selection method to manage these forests. The results of this study provide information about tree-fall gap size, pattern and regeneration for forest managements in a virgin forest. Ecological forestry tends to emphasize silvicultural approaches that more closely resemble natural processes (Franklin, 1989). We believe that forest management can use ecological forestry principles in single selection system in order to approach near to natural silvicultural method. Forest management can consider the natural spatial pattern of tree-fall gaps, mature trees and regeneration conditions in forests, as they embark on marketing and cutting tree in harvesting operation in northern Iran. Approaches based on natural disturbance patterns provide significant opportunities to harvest wood products, while also achieving biodiversity-related goals (Bolton and D'Amato, 2011). In addition, ecological forestry and near to nature method can also be applied to manipulating forest composition for other purposes, such as improving habitat for certain species of wildlife or desirable plants, or enhancing recreational or aesthetic values. Finally, we suggest that, according to obtained results in this study and dominant species in northern Iran (e.g. *Fagus orientalis lipsky* & *Carpinus betulus*) and ecological and morphological characteristics of these species, the amount of opened area in these mountainous forests should be between 5-10 ha in each parcel (about 1.06 gaps per hectare). Also, the spatial pattern of these opened areas should be kept uniform and their dominant average size should be between 200 to 1000 m^2.

Conclusion

Windstorms and natural mortality of trees cause gaps which are the dominant source for regeneration in natural forests in northern Iran. Most gap sizes ranged from 500 to 900 m^2 in the study area and they showed an irregular shape while their spatial patterns were uniform. There was a positive correlation between gap size and regeneration such that number of regeneration inside gaps increased when gap size increased. Tree-fall gap size, mature tree and tree competition are three important factors among others in mountainous natural forests in northern Iran that effect trees regeneration.

Acknowledgements

Funding was provided by the Gorgan University of Agricultural Sciences and Natural Resources through M.Sc. thesis grants. We would like to thank Dr. Kiomars Sefidi (Mohaghegh Ardebili University) for his help with the manuscript and our special thanks goes to Dr. Jennifer Gognon (University of Florida) for her valuable suggestions.

References

Administration of natural resources of Golestan province in Iran. 1995. The booklet of forestry plan of district number two of Shastkalateh Forest. Golestan province. 550p (In Persian).

Bolton, W.N., and D'Amato, W.A. 2011. Regeneration responses to gap size and coarse woody debris within natural disturbance-based silvicultural systems in northeastern Minnesota, USA. Forest Ecology and Management. 262, 1215-1222.

Brockway, D.G., and Outcalt, K.W. 1998. Gap-phase regeneration in longleaf pine wiregrass ecosystems. Forest Ecology and Management. 106, 125-139.

Brokaw, N.V.L. 1996. Treefalls: frequency, timing and consequences. In: Leigh, E.G., Rand, A.S., and Windsor, D.M. (Eds). The ecology of a tropical forest: seasonal rhythms and long-term changes. Smithsonian Institution Press, Washington D.C, pp. 101-108.

Brokaw, N., and Busing, R.T. 2000. Niche versus chance and tree diversity in forest gaps. Trends in Ecology and Evolution. 15, 183-188.

Clinton, B.D., Boring, L.R., and Swank, W.T. 1994. Regeneration patterns in canopy gaps of mixed-oak forests of the Southern Appalachians: influences of topographic position and evergreen understory. The American Midland Naturalist. 132 (2), 308-319.

Cressie, N.A. 1993. Statistics for Spatial Data (revised edition), John Wiley and Sons. pp. 613-617.

Dale, M.R.T. 1999. Spatial Pattern Analysis in Plant Ecology, Cambridge University Press, 340p.

Davis, L.S., Johnson, K.N., Bettinger, P.S., and Howard, T.E. 2001. Forest management, 4th edition. McGraw-Hill Higher Education, 544p.

Delfan-Abazari, B., Sagheb-Talebi, K., and Namiranian, M. 2004. Regeneration gaps and quantitative characteristics of seedlings in different development stages of undisturbed beech stands (Kelardasht, northern Iran). Irananian Journal of Forestry Research. 12, 251-266 (In Persian).

Fortin, M.J., Dale, M.R.T., and Hoef, J.V. 2002. Spatial analysis in ecology. John Wiley and Sons, Ltd, Chichester, pp. 2051-2058.

Foster, D.R., Knight, D.H., and Franklin J.F. 1998. Landscape patterns and legacies resulting from large, infrequent forest disturbances. Ecosystems. 1, 497-510.

Franklin, F.J. 1989. Toward a new forestry. American Foresters. 95, 37-44.

Fries, C., Johansson, O., Pettersson, B., and Simonsson, P. 1997. Silvicultural models to maintain and restore natural stand structures in Swedish boreal forests. Forest Ecology and Management. 94, 89-103.

Gagnon, J.L., Jokela, E.J., Moser, W.K., and Huber, D.A. 2003. Dynamics of artificial regeneration in gaps within a longleaf pine flat woods ecosystem. Forest Ecology and Management. 172, 133-144.

Gagnon, J.L., Eric, J., Jokela, W.K., and Moser, D.A. Huber. 2004. Characteristics of gaps and natural regeneration in mature longleaf pine Flatwoods ecosystems. Forest Ecology and Management. 187, 373-380.

Goldblum, D. 1997. The effects of tree-fall gaps on understory vegetation in New York State. Journal of Vegetation Science. 8, 125-132.

Hart, J.L., and Grissino-Mayer, H.D. 2009. Gap-scale disturbance processes in secondary hardwood stands on the Cumberland Plateau, Tennessee, USA. Plant Ecology. 201, 131-146.

Hubbell, S.P., Foster, R.B., O'Brian, S.T., Harms, K.E., Condit, R., Wechsler, B., Wright, S.J., and Loo-de-Lao, S. 1999. Light gap Ants in Gaps 477 disturbances, recruitment limitation and tree diversity in a neo tropical forest. Science. 283, 554-557.

Hunter, M.L. 1999 Maintaining Biodiversity in Forest Ecosystems. Cambridge University Press, Cambridge, 698p.

Jonikavičius, D., and Mozgeris, G. 2013. Rapid assessment of wind storm-caused forest damage using satellite images and stand-wise forest inventory data. iForest – Biogeosciences and Forestry. 6, 150-155.

Klenner, W., Arsenault, A., Brockerhoff, E.G., and Vyse, A. 2009. Biodiversity in forest ecosystems and landscapes: a conference to discuss future directions in biodiversity management for sustainable forestry. Forest Ecology and Management. 258, 1-4.

Latty, E.F., Werner, S.M., Mladenoff, D.J., Raffa, K.F., and Sickley T.A. 2006. Response of ground beetle (Carabidae) assemblages to logging history in northern hardwood-hemlock forests. Forest Ecology and Management. 222, 335-347.

Lertzman, K.P., Sutherland, G.D., Inselberg, A., and Saunders, S.C. 1996. Canopy gaps and the landscape mosaic in a coastal temperate rain forest. Ecology. 77, 1254-1270.

Linden, M.D., and McCarthy, M.A. 2002. Congruence between natural and human forest disturbance: a case study from Australian mountain forests. Center for Resource and Environmental Studies, the Australian National University, Canberra, Australia.

Mataji, A., Kafaki, S.B., Safaee, H., and Kiadaliri, H. 2008. Spatial pattern of regeneration gaps in managed and unmanaged stands in natural beech (*Fagus orientalis*) forests. Irananian Journal of Forestry Research. 16, 149-157 (In Persian).

McClure, J.W., and Lee, T.D. 1993. Small-scale disturbance in a northern hardwoods forest: effects on tree species abundance and distribution. Canadian Journal of Forestry Research. 23 (7), 1347-1360.

Mesdaghi, M. 2000. Wildlife Ecology and Management. Second edition. Emam Reza Education, Mashhad, 456p (In Persian).

Mihók, B., Gálhidy, L., Kenderes, K., and Standovár, T. 2007. Gap regeneration patterns in a semi-natural beech forest stand in Hungary. Acta Silvatica Lignaria Hungarica. 3, 31-45.

Mountford, E.P., Savill, P.S., and Bebber, D.P. 2006. Pattern of regeneration and ground vegetation associated with canopy gaps in a managed beech wood in southern England, Forestry. 79 (4), 389-408.

Palik, B.J., and Pederson, N. 1996. Overstory mortality and canopy disturbances in longleaf pine ecosystems. Canadian Journal Forestry Research. 26, 2035-2047.

Patrick, M., Fowler, D., Dunn, R.R., and Sanders, J.N. 2012. Effects of Treefall Gap Disturbances on Ant Assemblages in a Tropical Mountain Cloud Forest. Biography Journal. 44, 472-478.

Pickett, S.T., and White, P.S. 1985. The ecology of natural disturbance and patch dynamics. Academic Press, New York, 472p.

Rahbari Sisakht, S., Majnounian, B., Saravi, M.M., Abdi, E., and Surfleet, C. 2014. Impact of rainfall intensity and cutslope material on sediment concentration from forest roads in northern Iran. iForest – Biogeosciences and Forestry. 7, 48-52.

Schnitzer, S.A., and Carson, W.P. 2001. Tree-fall gaps and the maintenance of species diversity in a tropical forest. Ecology. 82, 913-919.

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

Seymour, R.S., White, A.S., and DeMaynadier, P.G. 2002. Natural disturbance regimes in northeastern North America – evaluating silvicultural systems using natural scales and frequencies. Forest Ecology and Management. 155, 357-367.

Stoyan, D., and Stoyan, H. 1994. Fractals, Random Shapes and Point Fields (Methods of Geometrical Statistics). John Wiley and Sons.

Strong, D.R. 1977. Epiphyte loads, tree falls and perennial forest disruption: a mechanism for maintaining higher tree species richness in the tropics without animals. Biogeography. 4, 215-218.

Upton, J.G., and Fingleton, B. 1987. Spatial Data Analysis by Example (Point Pattern and Quantitative Data), John Wiley & Sons, pp. 114-116.

Weiskettel, A.R., and Hix, D.M. 2003. Canopy gap characteristics of an oak-beech-maple old-growth forest in northwestern Ohio. Ohio Journal of Science. 103, 111-115.

Yamamoto, S., and Nishimura, N. 1999. Canopy gap formation and replacement pattern of major tree species among developmental stages of beech (*Fagus crenata*) stands, Japan. Plant Ecology. 140, 167-176.

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