BIODIVERSITAS
Volume 16, Number 1, April 2015
Pages: 1-9

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d160101

Effects of timber harvest on structural diversity and species composition in hardwood forests

FARZAM TAVANKAR[1,♥], AMIR ESLAM BONYAD[2]
[1]Department of Forestry, Khalkhal Branch, Islamic Azad University, Khalkhal, Iran. P.O. Box 56817-31367, Tel.: +98 4532451220-2, Fax: +98 42549050452, ♥email: farzam_tavankar@yahoo.com
[2]Department of Forestry, Faculty of Natural Resources, University of Guilan, Somehsara, Iran.

Manuscript received: 13 August 2014. Revision accepted: 10 September 2014.

Abstract. *Tavankar F, Bonyad AE. 2015. Effects of timber harvest on structural diversity and species composition in hardwood forests. Biodiversitas 16: 1-9.* Forest management leads to changes in structure and species composition of stands. In this research vertical and horizontal structure and species composition were compared in two harvested and protected stands in the Caspian forest of Iran. The results indicated the tree and seedling density, total basal area and stand volume was significantly (P < 0.01) higher in the protected stand. The *Fagus orientalis* L. had the most density and basal area in the both stands. Species importance value (SIV) of *Fagus orientalis* in the protected stand (92.5) was higher than in the harvested stand (88.5). While, the SIV of shade-intolerant tree species such as *Acer insigne, Acer cappadocicum* and *Alnus subcordata* was higher in the harvested stand. The density of trees and seedling of rare tree species, such as *Ulmus glabra, Tilia begonifolia, Zelkova carpinifolia* and *Fraxinus coriarifolia,* was also higher in the protected stand. The Shannon-Wiener diversity index in the protected stand (0.84) was significantly higher (P < 0.01) than in the harvested stand (0.72). The highest diversity value in the harvested stand was observed in DBH of 10-40 cm class, while DBH of 40-70 cm had the highest diversity value in the protected stand.

Key words: Beech stands, Shannon-Wiener index, stand structure, uneven aged management.

INTRODUCTION

One main principle of biodiversity protection in multiple management of national forest is the protection of stands structure composition (Eyre et al. 2010; Sohrabi et al. 2011). In forest science, stand structure refers to the within-stand distribution of trees and other plants characteristics such as size, age, vertical and horizontal arrangement, or species composition (Powelson and Martin 2001). Structural diversity is a straightforward indicator of potential biodiversity in forest landscapes because a diverse stand structure provides better habitat for forest-dwelling organisms. Broadly accepted, a structurally diverse stand provides living space for a number of organisms. Increasing and maintaining structural diversity in forest stands, also has become an important forest management strategy for adapting climate change. Conservation of forests biodiversity is one of important objective in sustainable forest management (Burton et al. 1992; Brockerhoff et al. 2008). It is common opinion in forest ecology that different management practices are a major determinant of forest diversity and that a more complex forest structure is linked to a high diversity of plant and animal species (Pretzsch 1997; Boncina 2000; Shimatani 2001). Forest management leads to changes in horizontal and vertical structure (Kuuluvainen et al. 1996; North et al. 1999) and in the species composition (Nagaike Hayashi 2004; Uuttera et al. 1997). The idea that biodiversity can be maintained by managing the structural diversity of stands is a common argument among researchers (Buongiorno et al. 1994; Lindenmayer and Franklin 1997; Sullivan et al. 2001; Franklin et al. 2002; Kant 2002; Varga et al. 2005). Some silvicultural practices can enhance biological diversity in managed forests, such as retaining old trees (Seymour and Hunter 1999), maintaining adequate levels of dead wood (Sturtevant 1997), establishing mixed stands (Palik and Engstrom 1999) or extending rotation lengths (Ferris et al. 2000).

The Caspian natural forests of Iran also called Hyrcanian forests, are located on the southern border of the Caspian Sea and cover an area of 2 million hectares. The stands in this area are the most valuable and economical. The main benefits of these forests are essentially two-fold: on the one hand there is its wood production while on the other hand there are various physical and social effects frequently termed as forest influence. In many instances, the latter transcends is the significance of forests as producers of wood (Bonyad et al. 2012). The current forest harvesting method in these forests is mainly selective cutting. The main goal of selection cutting management is uneven aged and mixed stands that are close to nature. Selection cutting is the silvicultural practice of harvesting a proportion of the trees in a stand (Pourmajidian and Rahmani 2009). In selective cutting, each tree must be individually assessed to decide whether it should be cut or left. In reality, this method is the practice of removing mature timber or thinning to improve the timber stand. Selection cutting improves the health of the stand and releases space for young trees to grow. In the *selection* system, *regeneration*, tending, and harvesting all take place concurrently (Marvie Mohadjer 2006). Selection cutting may include opening up areas to allow tree species that require greater light intensity to grow but that are not large enough to meet the legal definition of a clear cut (Nyland 1998; Anderson et al. 2000; Webster and Lorimer 2002; Pourmajidian and Rahmani 2009). Selection cutting is appropriate for forests composed of trees of different sizes and ages. Selection cutting does not have a visual impact on landscapes because only some of trees are removed, a factor that is much appreciated by forest users. Uneven-aged management is one alternative that could generate sustainable harvests while maintaining continuous forest cover and protecting stands diversity (Guldin 1996).

A planned program of silvicultural treatments ensures the conservation and maintenance of biological diversity and richness for sustainable forestry (Torras and Saura 2008; Schumann et al. 2003; Battles and Fahey 2000; Simila et al. 2006). The uneven-aged management can be economically viable while preserving forest stand diversity (Buongiorno et al. 1994, Schulte and Buongiorno 1998, Volin and Buongiorno 1996).

Beech (*Fagus orientalis* Lipsky) is the most industrial commercial tree species among more than 80 broad-leaved trees and shrubs. Many studies have been carried out on plant biodiversity in Beech stands in Iran and around the world (Sohrabi et al. 2011; Pourmajidian et al. 2009; Brunet et al. 2010; Sefidi et al. 2011; Pourbabaei et al. 2013). The study of forest structure especially in virgin forests is very important and gives us comprehensive information about the condition in forest for programming. The selection cutting, such as other forestry practices, can leads to changes in stand structure and tree compositions. The stand structural diversity can be characterized horizontally, i.e. the spatial distribution of trees, and vertically in their height differentiation (Zenner and Hibbs 2000). In this research, stand volume and structure, tree and seedling density, and species composition were compared in the harvested and protected Beech dominated stands. The objective of this study was effects of timber harvesting on structural diversity and species composition in oriental Beech stands in the Iranian Caspian forests.

MATERIALS AND METHODS

Study area

The study area is Iranian Caspian forests. These forests are suitable habitats for a variety of hardwood species and include various forest types. Approximately 60% of these forests are used for commercial purposes and the rest of them are more or less degraded (Marvie Mohadjer 2006). This study was conducted in Nav forests (latitude 37° 38' 34" to 37° 42' 21" N, longitude 48° 48' 44" to 48° 52' 30" E) in Guilan province, north of Iran. Two adjacent compartments of 123 (protected) and 112 (harvested) with areas of 43 and 63 ha were selected for collection of data. The physiographical characteristics of these compartments are almost similar. The elevation of these compartments ranges from 850 m to 1,100 m asl. The climate is temperate on based Demarton climate classification, with a mean annual temperature of 9.1°C and mean annual precipitation of 950 mm for along with the 1990 to 2008 years. Vegetation period maintains for 7 months in average. The original vegetation of this area is an uneven-aged mixed forest dominated by *Fagus orientalis* and *Carpinus betulus*, with the companion species *Alnus subcordata*, *Acer platanoides*, *Acer cappadocicum*, *Ulmus glabra* and *Tilia rubra*. The soil type is forest brown soil and the soil texture varies between sandy clay loam to clay loam. This study was carried out in two areas, harvested and protected compartments in the Nav forest area of Iran (Nav Forest Management Plan 1998).

Data collection

Data were collected by circular sample plots with an area of 0.1 hectare. The sample plots were located on the study area through systematic grid (100 m × 100 m) with a random start point. Diameter at breast height (DBH) of all trees (DBH ≥ 7.5 cm) was measured by diameter tape. Individuals of trees with DBH < 7.5 cm were counted by species as seedling. Height was measured to the nearest m using Suunto clinometer.

Data analysis

Species importance value (SIV) for each specious was calculated by (Ganesh et al. 1996; Krebs 1999; Pourbabaei et al. 2013; Rezaei Taleshi 2014): SIV= Relative density (RD) + relative frequency (RF) + relative dominance (RD). Basal area was considered for dominancy and relative dominance (RD) calculated by: RD = (basal area of a species × 100) / total basal area of all species. The species diversity index was computed using the Shannon-Wiener information function (Krebs 1999; Sharma et al. 2009; Abedi and Pourbabaei 2010; Pourbabaei et al. 2012) as: $H' = -\Sigma n_i/n \log_2 n_i/n$, where: n_i = denote to the SIV of a species and n= denote to the sum of total SIV of all species. The species evenness index was computed using the Pielou's evenness index (J) as: J = H' / ln S, where ln is Natural logarithm, S is the total species number in each plot. Also species richness (S) was number of species per plot. After checking for normality (Kolmogorov-Smirnov test) and homogeneity of variance (Levene's test), the means of stand characteristics (tree and seedling density, basal area, stand volume) in two compartments (harvested and protected) were compared using independent samples t test. The means of biodiversity indices (diversity, evenness and richness) in two compartments were also compared using independent samples t test. The means of biodiversity indices in DBH classes compared using a one-way ANOVA. Multiple comparisons were made by Tukey's test (significance at $\alpha < 0.05$). Regression analysis was applied to test the relations between DBH and stand volume, tree density and tree height. SPSS 19.0 software was used for statistical analysis; also the results of the analysis were presented using descriptive statistics.

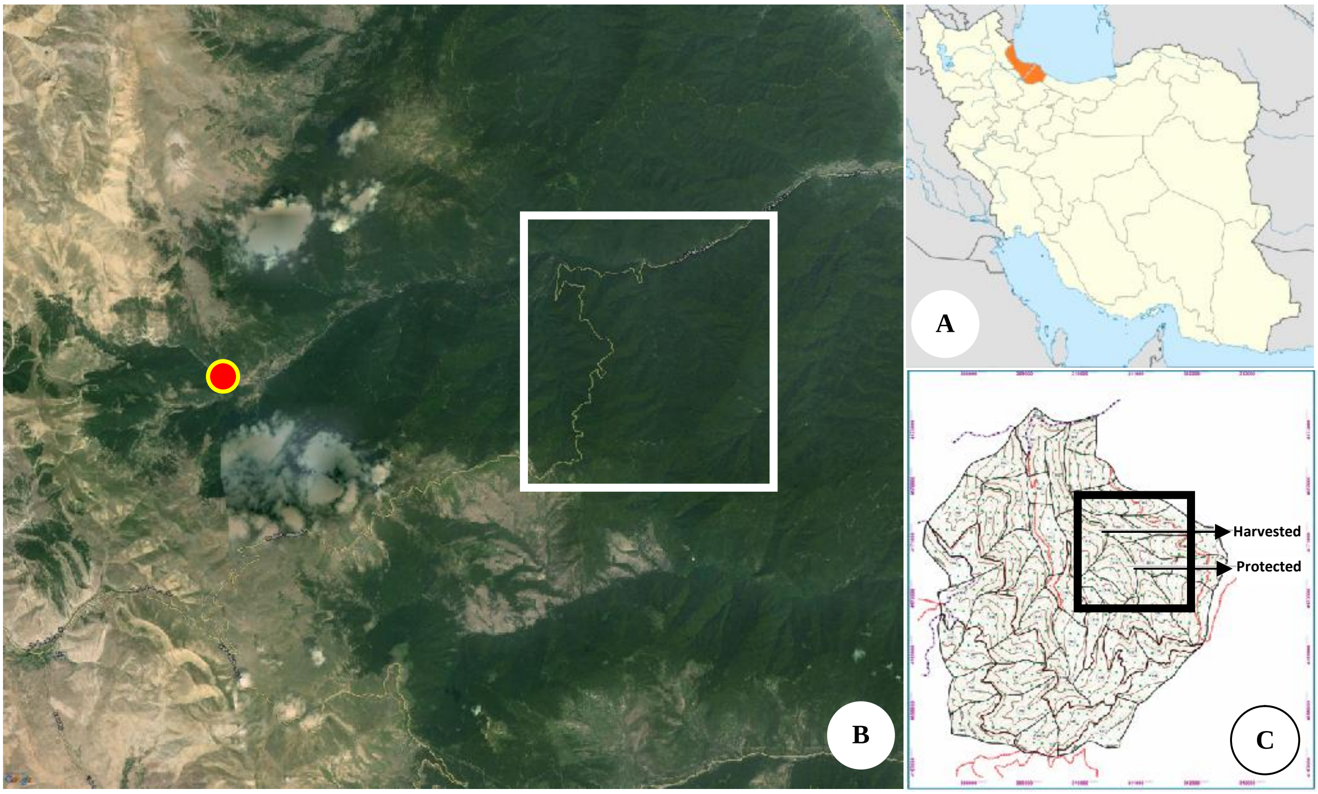

Figure 3. Study site map of Nav-forest, northern Iran. A. Guilan Province, Iran, B. Nav-forest within study site, near Nav (●), Asalem, Talesh, Guilan, Iran, C. Detailed site of forest sampling.

RESULTS AND DISCUSSION

Results

The stand parameters in two studied compartments are shown in table 1. The results indicated the tree and seedling density in the protected stand was significantly higher ($P < 0.01$) than the harvested stand. The total basal area and stand volume in the protected stand was also significantly higher ($P < 0.01$) than the harvested stand (Table 1).

A total of 16 tree species from 8 families were observed in the sample plots (Table 2). The *Fagus orientalis* had the most density and basal area in the both stands. Density of Beech trees in the harvested stand was 66.8 stem.ha^{-1} (28.7%), while in the protected stand was 89.1 stem.ha^{-1} (25.9%). Basal area of Beech trees in the harvested stand was 5.1 m^2.ha^{-1} (29.3%), while in the protected stand was 7.9 m^2.ha^{-1} (31.7%). Indeed, the density percentage of Oriental Beech trees was higher in the harvested stand, while the basal area percentage of Oriental Beech trees was higher in the protected stand. After the Oriental Beech trees, *Carpinus betulus* had the most density in the harvested (32.6 stem.ha^{-1} or 14%) and in the protected (54.7 stem.ha^{-1} or 15.9%) stands. In addition, the density percentage of *Carpinus betulus* was higher in the protected stand, but the basal area percentage of *Carpinus betulus* was higher in the harvested stand (16.1% vs. 13.6%). The family of Aceraceae had three species (*A. insigne*, *A. cappadocicum* and *A. platanoides*) in these stands. The density of Aceraceae species in harvested stand was 77.3 stem.ha^{-1} or 33.2%, while in the protected stand was 99 stem.ha^{-1} or 29%. Also the basal area of Aceraceae species in the harvested stand was 4.8 m^2.ha^{-1} or 27.6%, while in the protected stand was 6.3 m^2.ha^{-1} or 25.3%. However, the family of Rosaceae had the most number of tree species, but these trees had the minimum density and basal area in two stands. The Rosaceae species include *Mespilus germanica, Cerasus avium, Pyrus communis, Prunus divaricata* and *Sorbus torminalis.*

Species Importance Value (SIV) of different tree species in the harvested and protected stands is shown in Figure 1. The SIV of *Fagus orientalis* in the protected stand (92.5) was higher than the harvested stand (88.5). While, the SIV of *Carpinus betulus*, *Acer insigne*, *Acer cappadocicum* and *Alnus subcordata* in the harvested stand was higher than in the protected stand. Also, the SIV of *Acer platanoides*, *Quercus castaneifolia*, *Tilia begonifolia*, *Ulmus glabra* and *Zelkova carpinifolia* in the protected stand was the higher than the harvested stand. The SIV of other tree species (*Fraxinus coriarifolia, Mespilus germanica, Cerasus avium, Pyrus communis, Prunus divaricata* and *Sorbus torminalis* was almost equal in the harvested and protected stands (Figure 1). Volume of different tree species in the harvested and protected stands is shown in Figure 2. The volume of all tree species in the protected stand was higher than in the harvested stand. The volume of *Fagus orientalis* in harvested and protected stands was 51.5 and 74.5 m^3.ha^{-1}. Seedling of different tree species in harvested and protected stands are shown in Figure 3. The seedling density of all tree species, except of *Carpinus betulus*, in the protected stand was higher than in the harvested stand. The multiple regression analyses applied to test the relations between DBH and tree height in the harvested and protected stands that were statistically significant (P < 0.001) and the result are shown in Figure 4. The regression analysis between DBH and tree density in the harvested and protected stands was also statistically significant (P < 0.001) and the results are shown in Figure 5. The regression analyses applied to test the relations between DBH and stand volume in the harvested and protected stands that were statistically significant (P < 0.001) and the result are shown in Figure 6.

Biodiversity indices in harvested and protected stands are shown in table 3. The value of diversity index in the protected stand (0.84) was significantly higher (P < 0.01) than harvested stand (0.72). The value of evenness and richness indices in the protected stand were also higher (P < 0.01) than in the harvested stand. ANOVA tests showed the DBH classes had significantly affect (P < 0.01) on the means of biodiversity indices in the harvested and protected stands (Table 4). The highest diversity value in the harvested stand was observed in DBH of 10-40 cm class, while DBH of 40-70 cm had the highest diversity value in the protected stand. The highest evenness value in the harvested stand was observed in DBH of 70-100 cm, while DBH of > 100 cm had the highest evenness value in the protected stand. The highest richness value was observed in DBH of 10-40 cm in the both of harvested and protected stands.

The results of t test showed were not significant difference between the values of diversity index in two stands in the DBH class of 10-40 cm (Table 5). While, the values of diversity index in the DBH classes of 40-70, 70-100 and > 100 cm in the protected stand were significantly higher than harvested stand (Table 5). The value of evenness index was significantly higher in the protected stand than the harvested stand only in the DBH class of > 100 cm (Table 5). The values of richness index in the all of DBH classes in the protected stand were significantly higher than the harvested stand (Table 5).

Table 1. Stand parameters (mean ± standard deviation) in the study sites.

Parameter	Harvested	Protected	T-Value
Tree density (stem.ha^{-1})	232.7 ± 57.7	344.1 ± 41.3	11.14**
Basal area (m^2.ha^{-1})	17.4 ± 2.3	24.9 ± 5.2	8.59**
Volume (m^3.ha^{-1})	154.3 ± 14.2	257.3 ± 17.3	31.05**
Seedling density (stem.ha^{-1})	350.4 ± 18.1	486.8 ± 68.5	10.87**

Note: **: P < 0.01.

Table 2. Frequency and basal area of tree species in the study sites.

Tree species	Family	Density (stem.ha^{-1})		Basal area (m^2.ha^{-1})	
		Harvested	Protected	Harvested	Protected
Fagus orientalis Lipsky	Fagaceae	66.8	89.1	5.1	7.9
Carpinus betulus L.	Corylaceae	32.6	54.7	2.8	3.4
Acer insigne Boiss.	Aceraceae	28.1	38.0	2.3	2.6
Acer cappadocicum Gled.	Aceraceae	26.5	32.6	1.8	2.3
Alnus subcordata C.A.M.	Betulaceae	25.0	30.1	1.1	1.7
Acer platanoides L.	Aceraceae	23.3	28.4	0.7	1.4
Quercus castaneifolia Gled.	Fagaceae	9.6	20.5	0.9	1.6
Tilia begonifolia Stev.	Tiliaceae	5.2	20.3	0.7	1.8
Ulmus glabra Huds.	Ulmaceae	3.3	10.8	0.6	1.4
Zelkova carpinifolia Diopp	Ulmaceae	2.8	8.5	0.5	1.0
Fraxinus coriarifolia Scheel	Oleaceae	2.2	4.1	0.3	0.6
Mespilus germanica L.	Rosaceae	2.0	2.4	0.1	0.2
Cerasus avium L.	Rosaceae	1.7	2.0	0.1	0.2
Pyrus communis L.	Rosaceae	1.2	1.8	0.1	0.1
Prunus divaricata Ledeb.	Rosaceae	1.0	1.5	0.1	0.1
Sorbus torminalis L.	Rosaceae	0.5	0.8	0.1	0.1

Table 3. Biodiversity indices (mean ± standard deviation) in DBH classes.

DBH (cm)	Diversity*		Evenness		Richness	
	Harvested	Protected	Harvested	Protected	Harvested	Protected
10-40	0.78 ± 0.18a	0.70 ± 0.13b	0.51 ± 0.14b	0.46 ± 0.18b	4.96 ± 1.50a	6.80 ± 1.54b
40-70	0.55 ± 0.16b	0.91 ± 0.19a	0.60 ± 0.17a	0.53 ± 0.12b	4.51 ± 1.45ab	6.21 ± 1.53ab
70-100	0.44 ± 0.15c	0.81 ± 0.20a	0.66 ± 0.15a	0.71 ± 0.16a	3.88 ± 1.38b	5.65 ± 1.58a
> 100	0.40 ± 0.10c	0.55 ± 0.13c	0.53 ± 0.14b	0.76 ± 0.19a	3.20 ± 1.25c	4.31 ± 1.62a
All trees	0.72 ± 0.15	0.84 ± 0.09	0.61 ± 0.08	0.70 ± 0.07	3.77 ± 1.09	4.79 ± 1.08

Note: *: Different letters in each column indicated significant difference at α = 0.05.

Table 4. ANOVA results for means of biodiversity indices in DBH class.

Indices	Sites	SS	df	MS	F	P-Value
Diversity	Harvested	3.307	3	1.102	182.05	0.000
	Protected	3.839	3	1.279	201.38	0.000
Evenness	Harvested	2.736	3	0.912	112.45	0.000
	Protected	3.263	3	1.088	131.52	0.000
Richness	Harvested	49.293	3	16.431	28.760	0.000
	Protected	64.72	3	21.573	30.536	0.000

Table 5. Results of t test for comparing means of biodiversity indices in harvested and protected stands according DBH class.

DBH (cm)	Diversity	Evenness	Richness
10-40	$1.678^{N.S}$	$1.982^{N.S}$	5.528**
40-70	2.543*	$2.104^{N.S}$	3.371**
70-100	4.659**	$2.001^{N.S}$	4.580**
> 100	2.324*	3.064**	5.051**
All trees	5.032**	6.058**	4.584**

Note: N.S: Not significance, *: P < 0.05, **: P < 0.01

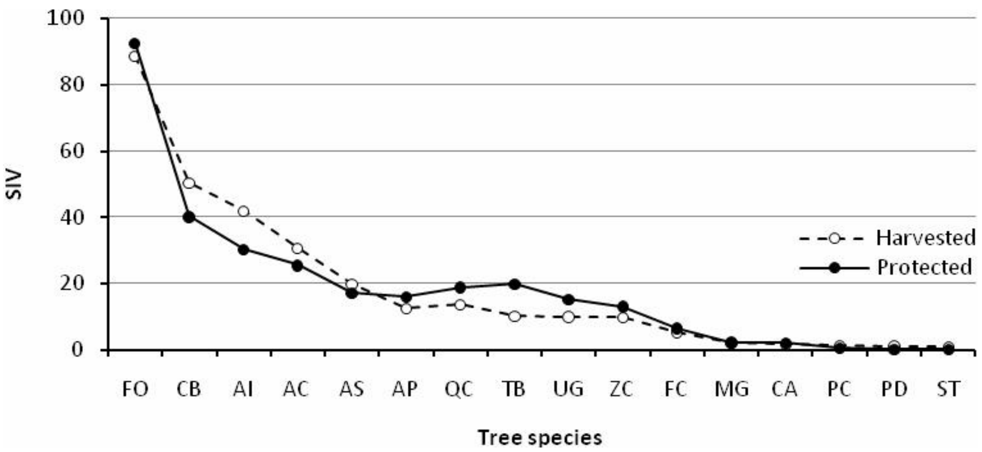

Figure 1. SIV of tree species in the harvested and protected stands.

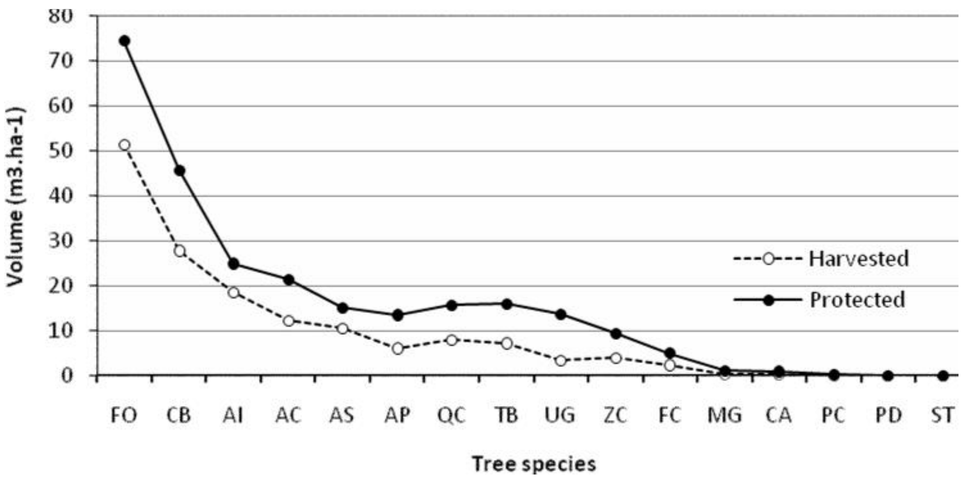

Figure 2. Volume of tree species in the harvested and protected stands.

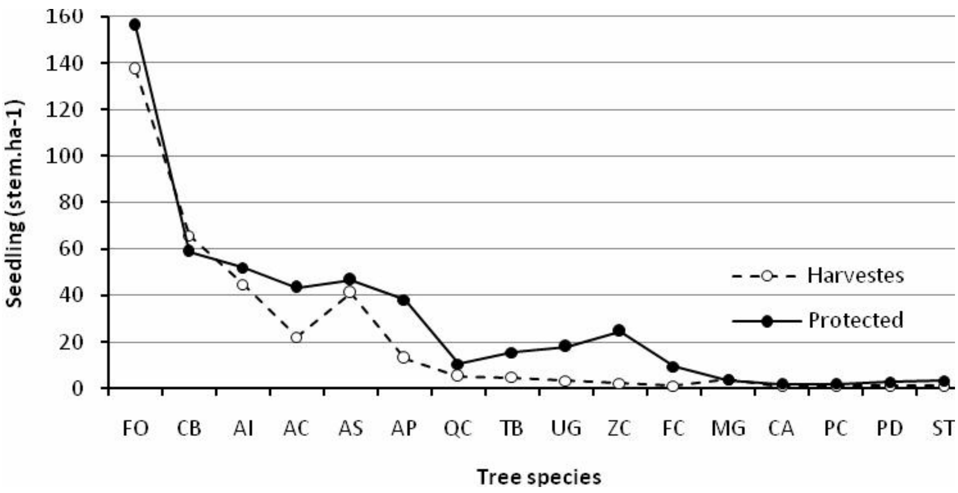

Figure 3. Seedling density of tree species in the harvested and protected stands.

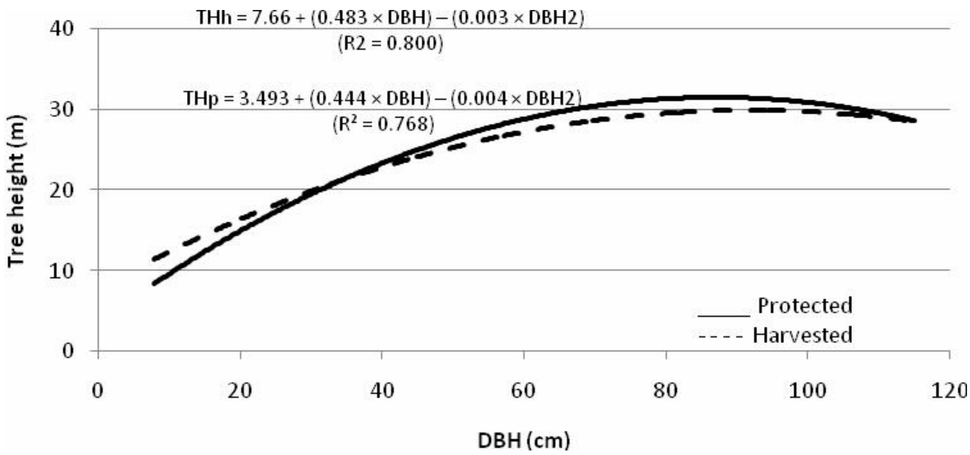

Figure 4. Relation between DBH and tree height in the harvested and protected stands.

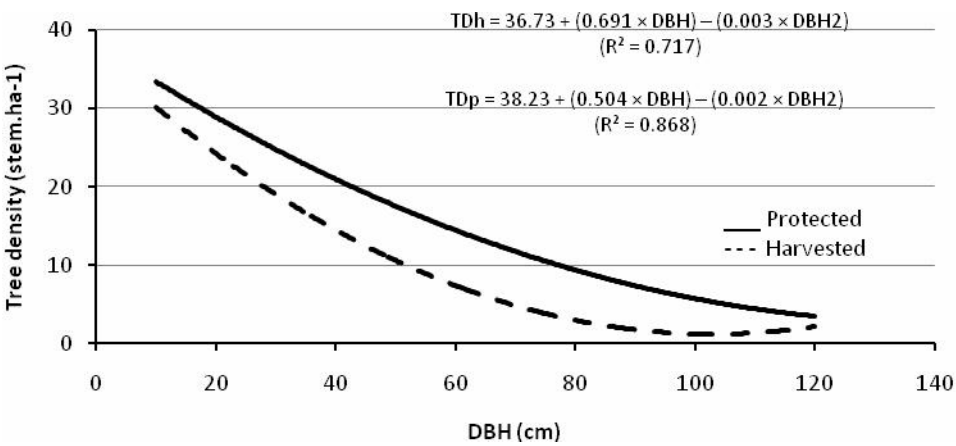

Figure 5. Relation between DBH and tree density in the harvested and protected stands.

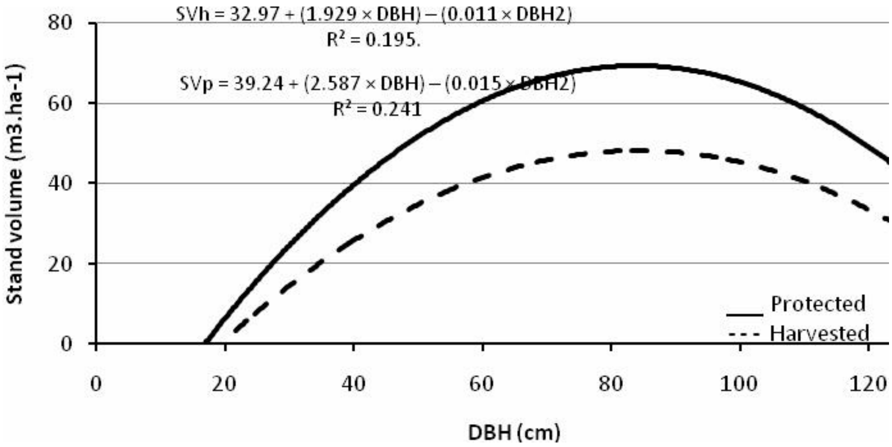

Figure 6. Relation between DBH and stand volume in the harvested and protected stands.

Discussion

Understanding the effects of forest management practices on plant species diversity is important for achieving ecologically sustainable forest management (Banda et al. 2006; Nagaike et al. 2006; Liang et al. 2007; Sefidi et al. 2011). The results of this study indicated the tree and seedling density, total basal area and stand volume in the protected stand was higher than in the harvested stand. Managing the forest for periodic income from the sale of trees as raw material for forest products depends on being able to regenerate the forest successfully. Forests are the most species rich of all terrestrial ecosystems and provide essential benefits to society. Forest management plan should describe both short and long term management goals and how to maintain forest productivity. Qiu et al. (2006) investigated effects of selection cutting on the forest structure and species diversity of evergreen broad-leaved forest in northern Fujian, China. They reported selection cutting of low and medium intensities caused to little variation in the stand structure, while high intensity of selection cutting caused to significantly changing in the stand structure. Sohrabi et al. (2011) studied structural diversity of Beech stands in northern Iran and reported the most diversity of trees is in low height and diameter classes.

The results of this study indicated the density of trees and seedling of rare tree species, for example, *Ulmus glabra, Tilia begonifolia, Zelkova carpinifolia* and *Fraxinus coriarifolia,* in the protected stand was higher than in the harvested stand. It is widely demonstrated that more species contribute to greater ecosystem stability. Nowadays, forest management practices increasingly promote conservation and enhancement of biodiversity. Forest management typically has a marked affect on plant species diversity, which is an important ecological indicator (Lindenmayer et al. 2000). Poor forest management practices contribute to decline or loss of biodiversity. The conservation of biodiversity has become a major concern for resource managers and conservationists worldwide and it is one of the foundation principles of ecologically sustainable forestry (Carey and Curtis 1996; Hunter 1999).

Our results indicated the species importance value (SIV) of shade-intolerant species such as *Acer insigne, Acer cappadocicum* and *Alnus subcordata* in the harvested stand were higher than protected stand. The diversity of a forest stand may not be sufficiently described by tree species diversity alone. Forest ecologically management include forest ecosystem, wood production and non timber values (Lindenmayer et al. 2000; Pourbabaei and Pourrahmati 2009). The forest biodiversity guidelines focus on how best to conserve and enhance biodiversity in forests, through appropriate planning, conservation and management. Tavankar et al. (2011) investigated effects of selection cutting on species diversity of trees and regeneration at a 10 years period in the Caspian forests. Their results indicated species diversity of tree and regeneration were slightly increased after 10 years from cutting since. Also the researchers reported the species importance value (SIV) of Beech and Hornbeam trees were decreased, but SIV of Maple and Alder trees were increased at the end of period.

The structural attributes of forest stands are increasingly recognized as being of theoretical and practical importance in the understanding and management of forest ecosystems (Franklin et al. 2002). The structural diversity can be characterized by diameter variation of trees in a forest stand. The regression analysis of relation between DBH and tree height showed the height of trees with DBH of > 30 cm in protected stand were higher than in the harvested stand. Pourmajidian and Rahmani (2009) compared stand structure after 12 years in a Beech stand. They reported the stand volume was not significantly changed, but density and basal area of trees significantly increased after 12 years. Structural diversity is an important property of forest stands. Diameter diversity is the most straightforward way for quantifying vertical structure (canopy layering) of a forest stand because diameter is strongly associated with tree height and crown width (Neumann and Starlinger 2001). The regression analysis of relation between DBH and tree density showed the density of trees in the protected stand were higher than in the harvested stand in the all DBH classes. Villela et al. (2006) studied effect of selective logging on stand structure in Brazil forests and reported did not differ in stem density and total basal area in logged and unlogged stands, but unlogged stand had more density of large diameter trees and greater mean of canopy height.

Forest managers have been seeking a feasible way to integrate biodiversity issues into management plans. To control forest stand structure may be the most practical way to manage biodiversity in forest ecosystems. The regression analysis of relation between DBH and stand volume showed the trees with DBH of almost 80 cm have the most stand volume in the both harvested and protected stands. Kia-Daliri et al. (2011) investigated how to marking of trees that will be harvested during selection cutting and its impact on stand structure in a mixed Beech stand in Caspian forest. They reported the most marked and harvested trees were large diameter (DBH > 60 cm), high quality and Beech specimen.

It is now widely accepted that forests should be managed in an ecologically sustainable fashion (Kohm and Franklin 1997; Lindenmayer et al. 2000). Biodiversity is an essential case for life continuance, economical affairs and ecosystems function and resistance (Singh 2002). Biodiversity measurement is recognized as guidance for conservation plans in local scale. The knowledge of the floristic composition of an area is a perquisite for any ecological and phyto-geographical studies and conservation management activities (Jafari and Akhani 2008).

Forests are among the most diverse and complex ecosystems in the world, providing a habitat for a multitude of flora and fauna. The results of this study indicated the value of biodiversity indices (diversity, evenness and richness) in the protected stand were significantly higher than in the harvested stand. It has been well documented that species composition and diversity can be used as indicators of past management practices in forested areas (Hunter 1999; Kneeshaw et al. 2000). Species richness and diversity are useful indicators of the effects of forest management practices (Nagaike et al. 2006). Species diversity is an important index in community ecology (Myers and Harms 2009). Ecologically sustainable forestry is the practice of land stewardship that integrates growing and harvesting of trees while protecting soil, water, biodiversity and landscape.

In this research effects of timber harvesting on structural diversity and species composition in mixed Beech (*Fagus orientalis* L.) stands were studied in the Caspian forests of Iran. They are suitable habitats for a variety of hardwood species such as Beech, Hornbeam, oak, maple and Alder. The silvicultural method is single selection cutting and commercial logging is accomplished within the legal framework of forestry management plan in the Caspian forests of Iran. These forests are the most valuable forests in Iran. These forests are known as one of the most basic resources for wood production and have a big share in supplying wood to the related industries. Our suggestion for biodiversity conservation is to leave the tree species that are less dense in these stands, such as *Ulmus glabra*, *Zelkova carpinifolia*, *Fraxinus coriarifolia* and *Cerasus avium* and logging operation focus on the tree species that are high density. Diversity of species is correlated to the diversity of their habitats. Marking for trees selection should not be only for harvesting of the wood, but also it should consider the uneven aged structure, keeping the seed trees and their regeneration and the diversity of wood species. The conservation of biological diversity is one of the goals of ecologically sustainable forestry (Lindenmayer et al. 2000). Fully protected areas are often assumed to be the best way to conserve plant diversity and maintain intact forest composition and structure (Banda et al. 2006). Forest protection should aim at ensuring that forests continue to perform all their productive, socio-economic and environmental functions in the future. Forest structure is the important feature in management of forest ecosystems (Zenner and Hibbs 2000; Tavankar 2013).

REFERENCES

Abedi R, Pourbabaei H. 2010. Plant diversity in natural forest of Guilan Rural Heritage Museum in Iran. Biodiversitas 11 (4): 182-186.

Anderson SC, Kupfer JA, Wilson RR, Cooper RJ. 2000. Estimating forest crown area removed by selection cutting: a linked regression GIS approach based on stump diameters. For Ecol Manag 137 (1-3): 171-177.

Banda T, Schwartz MW, Caro T. 2006. Woody vegetation structure and composition along a protection gradient in a miombo ecosystem of western Tanzania. For Ecol Manag 230: 179-185.

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

Boncina A. 2000. Comparison of structure and biodiversity in the Rajhenav virgin forest remnant and managed in the Dinaric region of Slovenia. Global Ecol Biogeogr 9: 201-211.

Bonyad AE, Sima A, Bakhshandh B, Dadras H. 2012. Evaluation of non-destructive Meyer method for determination the bark volume of Beech (*Fagus oriantalis* Lipsky) in different geographical aspects. Caspian J Environ Sci 10 (1): 67-73.

Brockerhoff EG, Jactel H, Parrotta JA, Quine CP, Sayer J. 2008. Plantation forests and biodiversity: Oxymoron or opportunity? Biodiv Conserv 17: 925-951.

Brunet J, Fritz Ö, Gustav Richnau G. 2010. Biodiversity in European beech forests-a review with recommendations for sustainable forest management. Ecol Bull 53: 77-94

Buongiorno J, Dahir S, Lu HC, Lin CR. 1994. Tree size diversity and economic returns in uneven-aged forest stands. For Sci 40 (1): 83-103.

Burton PJ, Balisky AC, Coward LP, Cumming SG, Kneeshaw DD. 1992. The value of managing for biodiversity. For Chron 68 (2): 225-237.

Carey AB, Curtis RO. 1996. Conservation of biodiversity: a useful paradigm for forest ecosystem management. Wildlife Soc Bull 24 (4), 610-620.

Eyre TJ, Butler DW, Kelly AL, Wang J. 2010. Effects of forest management on structural features important for biodiversity in mixed-age hardwood forests in Australia's subtropics. For Ecol Manag 259: 534-546.

Ferris R, Peace AJ, Humphrey JW, Broome AC. 2000. Relationships between vegetation, site type and stand structure in coniferous plantations in Britain, For Ecol Manag 136: 35-51.

Franklin JF, Spies TA, Van Pelt R, Carey AB, Thornburgh DA, Berg DR, Lindenmayer DB, Harmon ME, Eeton WSK, Shaw DC, Bible K, Chen J. 2002. Disturbances and structural development of natural forest ecosystems with silvicultural implications, using Douglas-fir forests as an example. For Ecol Manag 155 (1-3): 399-423.

Ganesh T, Ganesan R, Soubadra Devy M, Davidar P, Bawa K. 1996. Assessment of Plant biodiversity at a mid elevation evergreen forest of Kalakad-Mundanthurai Tiger Reserve, Western Ghats, India. Curr Sci 71: 379-392.

Guldin JM. 1996. The role of uneven-aged silviculture in the context of ecosystem management. Wes J App For 11 (1): 4-12.

Hunter ML. 1999. Maintaining biodiversity in forest ecosystems. Cambridge University Press, Cambridge, UK..

Jafari SM, Akhani H. 2008. Plants of jahan nama protected area, Golestan province, N. Iran. Pak J Bot 40 (4): 15331554.

Kant S. 2002. The marginal cost of structural diversity of mixed uneven-aged hard maple forests. Can J For Res 32 (4): 616-628.

Kia-Daliri H, Akhavan R, Anisi I. 2011. Timber marking and its impact on forest stand (Case study: Shourab district of Golband region). Iran J For 3 (1): 49-59.

Kneeshaw DD, Leduc A, Drapeau P, Gauthier S, Pare D, Carigan R, Doucet R, Bouthillier L, Messier C. 2000. Development of integrated ecological standards of sustainable forest management at an operational scale. For Chron 76: 481-493.

Kohm K, Franklin JF. 1997. Forestry in 21st century, Island press, Covelo California.

Krebs CJ. 1999. Ecological Methodology. Harper and Row, New York.

Kuuluvainen T, Penttinen A, Leinonen K, Nygren M. 1996. Statistical opportunities for comparing stand structural heterogeneity in managed and primeval forests: An example from boreal spruce forest in southern Finland. Silva Fennica 30: 315-328.

Liang J, Buongiorno J, Monserud RA, Kruger EL, Zhou M. 2007. Effects of diversity of tree species and size on forest basal area growth, recruitment and mortality. For Ecol Manag 243, 116-127.

Lindenmayer D, Franklin J. 1997. Managing stand structure as part of ecologically sustainable forest management in Australian mountain ash forests. Conserv Biol 11 (5): 1053-1068.

Lindenmayer DB, Margules CR, Botkin DB. 2000. Indicator of biodiversity for ecologically sustainable forest management. Conserv Biol 14 (4): 941-950.

Marvie-Mohadjer M. 2006. Silviculture in Iran. Tehran University Press.

Myers JA, Harms KE. 2009. Seed arrival, ecological filters and plant species richness: a meta-analysis. Ecol Lett 12 (11): 1250-1260.

Nagaike T, Hayashi A. 2004. E□ects of extending rotation period on plant species diversity in *Larix kaempferi* plantations in central Japan. Ann For Sci 61: 197-202.

Nagaike TA, Hayashi A, Kubo M, Abe MN, Arai N. 2006. Plant species diversity in a managed forest landscape composed of *Larix kaempferi* plantations and abandoned coppice forests in Central Japan. For Sci 52 (3): 324-332.

Nav Forest Management Plan. 1998. Asalem Natural Resources Office, Forestry Plan of District 1. Nav, Asalem, Guilan Province, Iran.

Neumann M, Starlinger F. 2001. The significance of different indices for stand structure and diversity in forests. For Ecol Manag 145: 91-106.

North MP, Franklin JF, Carey AB, Forsman ED, Hamer T. 1999. Forest stand structure of the northern spotted owl's foraging habitat. For Sci 45: 520-527.

Nyland D. 1998. Selection system in northern hardwoods. J For 96 (7): 18-21.

Palik B, Engstrom RT. 1999. Species composition, in: Hunter ML (ed.), Maintaining biodiversity in forest ecosystems, Cambridge University Press, Cambridge, UK.

Pourbabaei H, Asgari F, Reif A, Abedi R. 2012. Effect of plantations on plant species diversity in the Darabkola, Mazandaran Province, North of Iran. Biodiversitas 13 (2): 72-78.

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 (2): 89-94.

Pourbabaei H, Pourrahmati G. 2009. Plant species diversity in loblolly pine (*Pinus taeda* L.) and sugi (*Cryptomeria japonica* D. Don.) plantations in the Western Guilan, Iran. Int J Biodiv Conserv 1 (2): 38-44.

Pourmajidian MR, Malakshah NE, Fallah A, Parsakhoo A. 2009. Evaluating the shelterwood harvesting system after 25 years in a beech (*Fagus orientalis* Lipsky) forest in Iran. J For Sci 55 (6): 270-278.

Pourmajidian MR, Rahmani A. 2009. The influence of single-tree selection cutting on silvicultural properties of a northern hardwood forest in Iran. American-Eurasian J Agric Environ Sci 5 (4): 526-532.

Powelson A, Martin P. 2001. Spacing to increase diversity within stands [Internet]. Stand Density Management Diagrams. Available from: http: //www.for.gov.bc.ca/hfp/pubs/standman/Sp_Div.pdf

Pretzsch H. 1997. Analysis and modelling of spatial stand structures: methodological considerations based on mixed beech-larch stands in Lower Saxony. For Ecol Manag 97: 237-253.

Qiu RH, Chen H, Zhuo LX. 2006. Effects of selection cutting on the forest structure and species diversity of evergreen broad-leaved forest in northern Fujian, southern China. For Stud China 8 (1): 16-20.

Rezaei Taleshi SA. 2014. A comparative study on plant diversity in alder (*Alnus subcordata*) stands of natural and plantation areas. Biodiversitas 15 (1): 39-47.

Schulte BJ, Buongiorno J. 1998. Effects of uneven-aged silviculture on the stand structure, species composition, and economic returns of loblolly pine stands. For Ecol Manag 111: 83-101.

Schumann ME, White AS, Witham JW. 2003. The effects of harvest created gaps on plant species diversity, composition, and abundance in a Maine oak-pine forest. For Ecol Manag 176: 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: 1094-1099.

Seymour R, Hunter ML. 1999 Principles of ecological forestry, in: Hunter ML (ed). Maintaining biodiversity in forest ecosystems, Cambridge University Press, Cambridge, UK.

Sharma CM, Suyal S, Gairola S, Ghildiyal SK. 2009. Species richness and diversity along and altitudinal gradient in moist temperate forest of Garhwal Himalaya. J Amer Sci 5 (5): 119-128.

Shimatani K. 2001. On the measurement of species diversity incorporating species differences. Oikos 93: 135-147.

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

Singh JS. 2002. The biodiversity crisis: a multifaceted review. Curr Sci 82: 499-500.

Sohrabi V, Rahmani R, Moayeri MH, Jabbari S. 2011. Assessment of structural diversity of Beech forest stands in north of Iran. Int J Biol 3 (3): 60-65.

Sturtevant BR, Bissonette JA, Long JN, Roberts DW. 1997. Coarse woody debris as a function of age, stand structure, and disturbance in boreal Newfoundland. Ecol Appl 7: 702-712.

Sullivan TP, Sullivan DS, Lindgren PMF. 2001. Influence of variable retention harvests on forest ecosystems. I. Diversity of stand structure. J Ecology 38 (6): 1221-1233.

Tavankar F, Mahmoudi J, Iranparast Bodaghi A. 2011. The effect of single selection method on tree species diversity in the northern forests of Iran (Case study: Asalem-Nav, Gulan province). J Sci Tech in Nat Resour 6 (1): 27-40.

Tavankar F. 2013. Woody species diversity and stand types in relict of Hyrcanian lowland forests, north of Iran. Plant Sci Feed 3 (7): 83-87

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

Uuttera J, Maltamo M, Hotanen JP. 1997. The structure of forest stands in virgin and managed peat lands: a comparison between Finnish and Russian Karelia, For Ecol Manag 96: 125-138.

Varga P, Chen HYH, Klinka K. 2005. Tree-size diversity between single- and mixed-species stands in three forest types in western Canada. Can J For Res 35 (3): 593-601.

Villela DM, Nascimento MT, De Aragao LEOC, Da Gama DM. 2006. Effect of selective logging on forest structure and nutrient cycling in a seasonally dry Brazilian Atlantic forest. J Biogeogr 33: 506-516.

Volin VC, Buongiorno J. 1996. Effects of alternative management regimes on forest stand structure, species composition, and income: a model for the Italian Dolomites. For Ecol Manag 87: 107-125.

Webster CR, Lorimer CG. 2002. Single-tree versus group selection in hemlock-hardwood forests: are smaller openings less productive? Can J For Res 32 (4): 591-604.

Zenner EK, Hibbs DE. 2000. A new method for modeling the heterogeneity of forest structure. For Ecol Manag 129: 75-87.