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Research Paper

Effects of strip and single-tree selection methods on woody species diversity in Caspian forests (Iran)

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Abstract: In this study, variations of woody species diversity were investigated in Beech (*Fagus orientalis)* and Beech-Horn Beam (*Carpinus betulus)* stands of Janbesara district (located in the west of Guilan province, Iran) after harvesting by single selection method and strip methods. Random-systematic sampling method was applied in the first and last year of the 10-year period and 200×150 network dimensions. Woody species (shrubs and trees in different strata) were recorded in circle shape plots with 1000 m^2 for overstory layer and 100 m^2 for understory layer. Species richness, Shannon Wiener and Simpson diversity indices were used to evaluate plant diversity in each sampling plot. The means of different diversity indices were calculated and t Test was used to test all indices means differences in both sampling. The results showed that species richness significantly raised and also evenness and plant diversity indices were a little bit increased (but no significant differences) after performing of the single selection approach. Strip harvesting had a significant effect on the species richness as well as all diversity indices of woody species. Our results suggest that single selection approach can be applied as a relevant silvicultural method in Caspian pristine forests for plant diversity conservation accompanied with wood production. But in the destructive forests of this region, more intensive silvicultural methods such as strip method can be applied to make the forests to move towards to potential situation which are more diverse and stable.

Keywords: Beech, plant diversity, strip method, single selection method, Caspian forests

Introduction

Modern silvicultural practices stress forest management that combines timber harvesting and biodiversity preservation (Mitchell *et al.*, 2002). Traditional even-aged silvicultural approaches usually lead to homogeneous forests (Mitchell *et al.*, 2002), while it is assumed that natural disturbances create heterogeneity, influencing the variety and diversity of forest species (Palik *et al.*,2002). More intensive harvesting resulted in increased richness and diversity, but mostly through the addition of habitat generalists and weedy species. However, partial harvest does not appear to drive vegetation community composition (Burke et al., 2008).

Management that mirrors natural disturbances is being recommended to sustain biodiversity (Harvey *et al.*, 2002). This type of management can increase heterogeneity in forested areas (Klinka *et al.*, 1985), leading to an array of different environmental situations, even in initially homogeneous areas, which in turn will bring changes in vegetation.

The selection system tends to mimic small-scale disturbances and has been recommended as a way of maintaining forest biodiversity while still allowing for timber extraction (Robinson and Robinson, 1999; Schieck and Hobson, 2000; Simon et al., 2000). However, information relating past harvest practices to current understory and overstory conditions in managed forests is scarce (but see Metzger & Schultz, 1984; Halpern and Spies, 1995; Burke et al., 2008). This information is needed in order to predict the effects of future anthropogenic disturbances on biodiversity, stand development, and long-term ecosystem structure and function. The selection system allows for natural regeneration and mimics the opening of small- to medium-size gaps by natural small-scale disturbances, including tree fall. Gap creation affects the species diversity of the forest, and the plant species found in the gaps vary according to the size and quality of the gaps (Abe *et a*l., 1995). At the ecosystem where tree cutting was conducted, diversity of the understory layer was extremely low compared to those of the near-natural ecosystems (Saeki, 2007). Single-tree and group selection harvesting don't affect on the diversity and abundance of spring forest herbs in deciduous forests (Falk *et al*, 2008).

Hyrcanian vegetation zone or Caspian forests is a green belt stretching over the northern slopes of Alborz mountain ranges and covers the southern coasts of Caspian Sea (*Sagheb-Talebi, 2004*). The flora of the Caspian forests is considered to be more diverse than that of Europe. The variation in mountain topography and wide climatic range are broad factors supporting this diversity (Mohajer, 2005). Most of the deciduous forests in this region are governmentally owned and are periodically cut for timber and fuelwood. The grazing of domestic herbivores, firewood and industrial purposes, extraction of litter for fertilizing purposes were examples of the human impacts on low land forests in the region to make the forests to be dominated by undesired tree species such as Ironwood (*Parrotia persica*) and to be less diverse. However in higher parts with steep which were less reachable and well preserved the forests are more diverse with desired quality. Thus during the period, strip method had been done in the low land or destructive forests(100-500m a.s.l) to obtain a situation for natural regeneration of potential desired species and also the selection system had been performed in the upper part or pristine forests (500-900m a.s.l) to maintain or enhance the existence suitable conditions. The logging operations were conducted in the winter in Caspian forests as well as in the study area. It is generally recognized that winter logging generally disturbs the soil surface less than summer logging (Archambault *et al*., 2006).

In the last decades, all forests which had been managed in even-age system by strip and shelterwood silvicultural systems were turning toward uneven-age system by single or group selection system (Mohajer, 2005). However, no study has been conducted to investigate how suitable the silvicaltural methods are for Caspian forests.

The object of the study was to explore the effect of single selection and strip silvicultural system on woody species diversity in the mixed forests of Caspian forests.

Materials and Methods

Study area

This study was being carried out in the Janbesara district in Guilan province (located in northern Iran) with total area ca. 1850 ha between 100 to 900 meters altitude. The average annual rainfall is 1542 mm, the annual mean temperature is 15.7c, the average maximum temperature in the hottest month (July) is 30.3c and the coldest month (January, February) is 2.5c during a year. The soil type of the district consists of brown acidic, brown forest and psoudoglay which have average drain situation. The study area is covered by natural deciduous hardwood forests. These forests had been under single selection and strip methods. 650 ha of the district, located between 500 to 900 meters altitude, had been under single selection (which is named SE afterward). In this zone, *Fagus orientalis* and *Carpinus betulus* are the main species. 1200 ha of the district, located between 100 to 500 meters altitude, had been harvested by strip method (which is named ST afterward). Parts lower than 500 meters altitude consist of *Parrotia persica*, *Carpinus betulus*, *Diospyros lotus* as a main species. Other tree species in this district include *Tilia begonifolia*, *Fraxinus excelsior*, *Acer velutinum*, *Ulmus glabra*, *Alnus glutinosa*, *Quercus castanifolia, Acer cappadisicum, Pronus avium and Albizia Julibrisin, Geliditsia caspica, Celtis australis, Petrocarya fraxinifolia, Sorbus acuparia.*

Data Collection

The study area was sampled by randomized-systematic method with 200×150 network dimensions in the first and last year of the 10-year period. 153 and 314 samples were respectively recorded in the SE and ST part. At each sample, the type and the frequency of shrubs and trees species in the overstory strata were recorded in circle shape plots with 400 m^2 and also all woody species (as regeneration) were recorded in the understory layer in square shape 16 m^2 at the center of the sample.

Data Analysis

Species richness index was estimated as the number of species inventoried in the sample.

We applied the Shannon index (H') as a measure of species abundance and richness to quantify diversity of the plant species. This index takes both species abundance and species richness into account, is sensitive to changes in the importance of the rarest classes (Heuserr, 1998). For any sample it is calculated as:

$$H' = -\sum_{i=1}^{s} p_i \ln p_i \quad (1)$$

Where s equals the number of species and p_i equals the ratio of cover of each species to total cover. In addition, we consider the Simpson index (*D*), a measure of species dominance, and the Shanon-Winer index (*E=Evenness*) , a measure for evenness of spread(Magurran 1988).

The Simpson index is defined as:

$$D=\sum P_i^2 \quad (2)$$

As biodiversity increases, the Simpson index decreases. Therefore, to get a clear picture of species dominance, we used $D' = 1 - D$.

The Shannon-Wiener index (E) is defined as:

$$E = \frac{H'}{H_{\max}} = \frac{-\sum_{i=1}^{s} p_i \ln p_i}{\ln s} \quad (3)$$

Where $H_{\max}$ is the natural logarithm of the total number of species.

All diversity indices were calculated using PC-ORD for windows version 4.14 (McCune and Mefford, 1999). A Tukey test was used to test whether there were significant differences in the species richness, diversity and evenness indices among the different communities. At the species level, changes in the frequency of occurrence (number of plots where the species was detected) were compared from before to after harvest in both harvesting methods using Chi-square for those species present at observed frequency > 5. The Statistical tests were conducted using SPSS 15.0.

Results

As shown in Figure 1, Species Richness (A), Shannon evenness (B), Shannon Diversity(C) and Simpson diversity (D) indices of woody species significantly increased in the ST part after strip method performance. Harvesting had a significant effect on the species richness of woody species (figure1-A) compared to first year of the period. *Diospyros lotus, Tilia begonifolia*, *Ulmus glabra*, *Alnus subcordata*, *Pronus avium, Acer cappadisicum,* were found to increase significantly (P<0.01) in frequency of occurrence following strip harvesting (Figure 2). *Albizia julibrisin, Parrotia persica*, *Fraxinus excelsior*, *Celtis australis, Quercus castanifolia, Sorbus acuparia* and *buxus hyrcanus*, *Geliditsia caspica, Acer velutinum*, *Petrocaraya fraxinifolia*, *Fagus orientalis* and *Carpinus betulus* a little bit increased but not significantly after strip method performance.

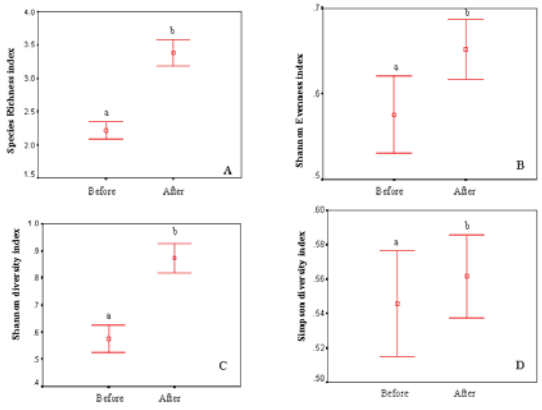

Figure 1. Mean and interval of Species Richness (A), Shannon evenness (B), Shannon Diversity (C) and Simpson diversity (D) indices after strip method performance. Significant differences are depicted by differences letter (P<0.01)

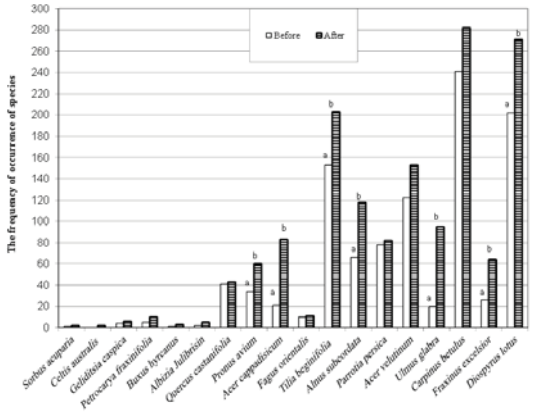

Figure 2. Comparison of woody species frequency of occurrence before and after the tree cutting by strip method in the ST part of the study area (significant differences showed by different letter)

As shown in Figure 3, the mean of Shannon evenness (B), Shannon Diversity(C) and Simpson diversity (D) indices of woody species in the mixed forests of *Fagus orientalis* and *Carpinus betulus* (SE part) a little bit increased after single selection method performance but the differences were not significantly different (P<0.01). However, single selection system had a significant effect on the species richness of woody species (figure 3-A) compared to the first of the period. *Diospyros lotus, Tilia begonifolia*, *Ulmus glabra*, *Alnus subcordata*, *Quercus castanifolia, Acer cappadisicum,* were found to increase significantly (P<0.01) in frequency of occurrence following strip harvesting (Figure 4). However *Albizia julibrisin, Parrotia persica*, *Fraxinus excelsior*, *Pronus avium,* and *buxus hyrcanus*, *Geliditsia caspica, Acer velutinum*, *Fagus orientalis* and *Carpinus betulus* increased but not significantly in this regard. *Sorbus acuparia*, *Celtis australis* and *Petrocaraya fraxinifolia* were not recorded both before and after harvesting in the SE part of the study area.

Discussion

Our results indicate that disturbance associated with single tree selection harvesting does significantly increase the woody species richness after logging. This is consistent with the results of other studies that found increased species richness and diversity associated with single-tree selection harvesting in deciduous forests immediately following harvest (Gotmark et al., 2005; Falk *et al*, 2008), or a tendency for higher species richness in harvested gaps 1–2 years (Galhidy et al., 2006) and 5 years (Schumann et al., 2003) post harvest.

Strip harvesting had a significant effect on the species richness as well as all diversity indices of woody species. *Celtis australis, Sorbus acuparia* and *buxus hyrcanus* were just observed after strip harvesting. Local increases in species richness are likely due to increases in environmental heterogeneity (Vellend et al., 2000) creating niches that favour the establishment of species not present priorto harvest. Changes in

microclimate conditions (increases in light and release of nutrients) may stimulate regeneration of species that form persistent soil seed banks (Mladenoff, 1990; Pykala, 2004; Gotmark et al., 2005).

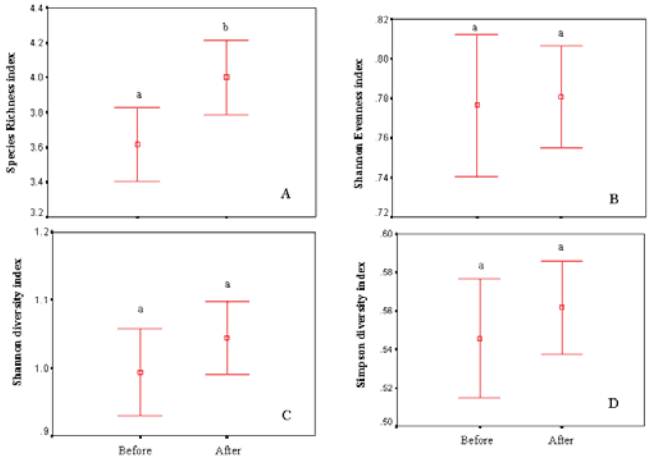

Figure 3. Mean and interval of Species Richness (A), Shannon evenness (B), Shannon Diversity (C) and Simpson diversity (D) indices after single selection method performance. Significant differences are depicted by differences letter (P<0.01)

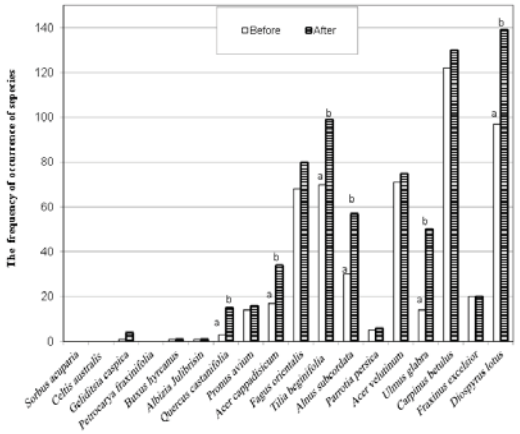

Figure 4. Comparison of woody species frequency of occurrence before and after the tree cutting by single selection method in the SE of the study area (significant differences showed by different letter)

The observed increase in the frequency of the woody species may be attributed to increases in light and nutrients levels caused by harvesting. Canopy opening is likely to have a great effect on species diversity (Ristau et al., 2001). Strip method creates very different light environments than single-tree selection, and that light strongly influences woody species diversity.

In the single-tree selection treatment, increases in richness were paralleled by not changing in evenness resulting in less change in diversity, whereas in strip method plots increases in richness accompanied by increases in evenness, resulting in significant increases in diversity. This suggests that species gained in the strip treatment were generally more abundant than species gained in the single-tree selection treatment (Small and McCarthy, 2002; Falk *et al*, 2008).

The frequency of occurrence of all species in both SE and ST part responded positively to harvesting. Increased light and nutrients were the likely drivers of this positive response to harvest (Falk *et al*, 2008).

In general, species richness and diversity increased with harvesting. However, Inappropriate forest management has caused a destruction of most of the forest stands, and, sometimes, even the destruction of their habitats (Kwiatkowska, 1994). Successive changes in the vegetation following clear cutting have been also reported in many forests (Malik *et a*l., 1997). In the other hand application of adequate silvicultural methods which are appropriate with forests stands conditions, could maintain or enhance the plant diversity. Sebastia *et al*.(2005) showed that the plant diversity in managed forests by selection silvicultural treatment were more diverse than pristine forests. Forest regeneration 50 years following partial cutting in mixedwood ecosystems was not significantly different from that of similar uncut ecosystems (Archambault *et al*., 2009).

The effects of the shelterwood logging system on species diversity are relatively weaker than with other forms of management, such as clear cutting and plantations (Nagaike *et al.,*1999).

In summary, our results suggest that low impact management by single selection system mimicking natural disturbances enhances or preserves plant diversity in the Caspian pristine forests. But in the destructive forests of this region, more intensive silvicultural methods such as strip method can be applied to make the forests to move towards to potential situation which are more diverse and stable.

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