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Impact of logging intensity on stem density, basal area and biodiversity indices five years after logging in a Caspian hardwood forest

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Abstract

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The aim of the present study was to analyse the impacts of different logging intensities after five years from logging including non-logged, low (3.4 felled stems per hectare), medium (5.2 felled stems per hectare) and high (7.1 felled stems per hectare) treatments on stem density, basal area, canopy cover, and forest biodiversity indices. The study area was located in northern Iran. Data was collected on a set of 120 circular plots with 5 m radius from both non-logged and logging areas. Stem density, basal area, and percentage of canopy cover were measured. Biodiversity study was done by measuring two diversity indices including Simpson's and Shannon-Wiener's, two richness indices including Margalef's and Menhinick's and two evenness indices including Pielou's and Hill's indices. The results indicated that the treatment with the medium logging intensity was found to cause the highest amount of positive effects on stem density, basal area, and biodiversity indices. It is concluded that harvesting intensity should be limited to a medium level (approximately 5 felled trees per hectare) during each logging operation to improve forest biodiversity indices.

Keywords: harvesting intensity; forest biodiversity; northern Iran

Caspian forests are important for environmental reasons such as biodiversity, protection of plants and animals and as a carbon sink (Erikson et al. 2012). These forests belong to the rich and biologically diverse ecosystems in Iran with valuable variety of endemic species. It is proved that the ecosystems with high species diversity are more stable and resilient to human disturbances compared with those having low species diversity (Hegetschweiler et al. 2009; Tynsong, Tiwari 2010). Biological diversity is now recognized increasingly as a vital parameter to assess global and local environmental changes and sustainability of developmental activities (Saha et al. 2011). Selective logging has been denoted as the practice of harvesting the most important timber species in natural forests, allowing the remaining forest to naturally regenerate over time (Bawa, Seidler 1998). Selective logging, the harvest of valuable timber trees above a threshold stem diameter with prescriptions designed to maintain the forest cover, is considered to be a better practice compared with clear-cutting and it is increasingly embraced as an approach to protect forest integrity while allowing an appropriate use of resources (Deckker, De Graaf 2003; Rametsteiner, Simula 2003). In recent decades, many tropical forest nations have adopted the mechanized selective logging regimes for timber production (Gascon et al. 1998; De Wasseige, Defourny 2004; Drigo et al. 2009). Biodiversity maintenance is a key management objective and a requisite for sustainable forestry and it is necessary to understand the dynamics and heterogeneity of natural forests to provide guidelines for management (Spies, Turner 1999; Lindenmayer et al. 2000). Despite the weak scientific evidences, selective logging is considered as a "sustainable forest management" practice and it is increasingly embraced as an approach to protect forest integrity while allowing an appropriate use of resources.

Undisturbed tropical forests have become extremely rare (Gardner et al. 2009). Thus, forest management should focus on maximizing the conservation values of human-modified forest (Gardner et al. 2009). In this context, selective logging was proposed as a management option to maintain conservation values, in terms of carbon stocks and biodiversity, as well as the economic value of a once-logged forest (Putz et al. 2012).

In this context, forest logging activity can be understood as disturbances that may have a large influence on the biodiversity of the forest. Logging activities can cause extensive damage to soil, ground vegetation, shrubs and trees (Behjou, Mollabashi 2013).

In recent years, research on biodiversity in managed landscapes has been motivated by species declines and habitat loss (Halpern, Spies 1995) and the use of management practices to emulate natural disturbances and dynamics has been explored in several studies (Hansen et al. 1991; Niemela 1999). The compatibility of logging activities and biodiversity conservation in forests is a critical challenge (Behjou, Mollabashi 2013), not only because of societal demands but also because human-managed ecosystems are critical for maintaining biodiversity (Pimentel et al. 1992). Our study aims to assess the effects of logging intensity on some forest site parameters and forest biodiversity indices in the Caspian forest. Specifically, the aim of this study is to analyse the effects of logging intensity on biodiversity indicators of tree species diversity, richness and evenness. Little information is available about the impact of logging intensity on some forest site parameters and biodiversity indices. The Caspian forests in the north of Iran, as an important ecological area, are considered to belong to the areas of Iran with the richest biodiversity.

The impact of forest logging on population characteristics is well documented but little is known about the impact on biodiversity, so the main objectives of the present study are: (*i*) comparing indicators of biodiversity between non-logged and logged areas, (*ii*) evaluating the effects of different logging intensities on stem density, basal area and biodiversity indices.

MATERIAL AND METHODS

Material. The study was performed in the Hyrcanian forest region of Iran (north of Iran). Conditions in the region have favoured great vegetation diversity and a number of endemic species. In the region, some parts of the forest have been impacted by logging activities for decades and a small amount of non-logged forests remains. The dominant forest tree species in the region are hornbeam (*Carpinus betulus* Linnaeus), beech (*Fagus orientalis* Linnaeus) and maple (*Acer velutinum* Boissier). The study was done 5 years after logging.

Methods. Sampling plots are located according to a systematic sampling design in the intersections of the 50 × 50 m grid that fall inside forests, with an average sampling intensity of four plots per hectare of land. Plots were circular and concentric, with a fixed size, with a plot radius of 5 m (approximately 78.5 m^2). The total number of sampling plots that were analysed was 120 in the logged forest. Generally, in studied parts 2 areas including impacted areas (3 different logging intensities) and one non-logged area were studied by sampling. Sixty plots are located in a control area (non-logged area) and sixty are located in logging areas (impacted area) (totally 120 plots). The logging area was divided into three categories including low intensity (20 plots), medium intensity (20 plots), and high intensity (20 plots).

Biodiversity study was done by measuring two diversity indices including Simpson's and Shannon-Wiener diversity index, two richness indices including Margalef's and Menhinick's diversity index and two evenness indices including Pielou's and Hill's diversity index.

ANOVA was used to examine the impact of different logging intensities on the number of individual trees, basal area and the amount of canopy cover. To test for significant effects of different logging intensities (low, medium, and high), the mean values for the biodiversity indicators on the plots were contrasted with those corresponding to the control plots.

RESULTS AND DISCUSSION

Descriptive statistics for the number of individuals per hectare, basal area per hectare and canopy cover per hectare are given for each area in Table 1. Summary statistics are given for estimates of each variable and for each area (protected and logged areas with different logging intensities) (Table 1). The

Table 1. Descriptive statistics of the variables in the plots in four treatments*

Variable	Treatment		Number	Mean	SD
Stem density (No. of stems per ha)	non-logged		60	142	7.40
	logged*	low	20	148.1	5.20
		medium	20	151.3	6.10
		high	20	134.1	6.20
Basal area ($m^2 \cdot ha^{-1}$)	non-logged		60	23.1	4.9
	logged*	low	20	24.7	5.4
		medium	20	25.3	4.2
		high	20	21.7	5.3
Canopy cover (%)	non-logged		60	81.13	5.64
	logged*	low	20	77.32	9.97
		medium	20	73.15	11.22
		high	20	68.66	12.09

*including non-logged, low, medium and high logging intensity; SD – standard deviation

Table 2. The diversity indices of control and disturbed areas

Treatment logging intensity		Index					
		diversity		richness		evenness	
		Simpson	Shannon-Wiener	Margalef	Menhinick	Pielou	Hill
Non-logged		0.53 (0.02)	0.88 (0.06)	0.81 (0.04)	0.85 (0.07)	0.83 (0.04)	0.83 (0.02)
Logged	low	0.66 (0.08)	1.22 (0.15)	1.29 (0.12)	0.91 (0.06)	0.88 (0.03)	0.86 (0.09)
	medium	0.68 (0.05)	1.26 (0.09)	1.30 (0.10)	0.90 (0.08)	0.91 (0.11)	0.89 (0.05)
	high	0.61 (0.03)	0.90 (0.05)	0.87 (0.15)	0.82 (0.03)	0.85 (0.04)	0.81 (0.01)

the values of standard errors are shown in parentheses

results of one-way ANOVA indicate that logged stands had significantly lower stem density ($F_{3,119}$ = 45.43, P = 0.000), basal area ($F_{3,119}$ = 31.36, P = 0.000), canopy cover ($F_{3,119}$ = 109.56, P = 0.000), diversity ($F_{3,119}$ = 109.56, P = 0.000), richness ($F_{3,119}$ = 109.56, P = 0.000), and evenness ($F_{3,119}$ = 109.56, P = 0.000) than non-logged areas (Tables 2 and 3). The results of Duncan's test indicate that the stem density in high logging intensity was significantly smaller than in the other three treatments (Fig. 1a). The lower stem density in the non-logged area indicated that logging activities tended to increase density with the increasing intensity of logging. In the non-logged area basal area was significantly higher than in the logging areas accepted for areas with high logging intensity (Fig. 1b). Higher basal area in the logging area indicated that logging activities tended to increase the basal area. Also, according to Fig. 1c the percentage of canopy cover in the non-logged area was significantly higher than in logged areas (low, medium, and high logging intensities). The lower percentage of canopy cover in the logging area indicated that logging activities tended to decrease the canopy area. Also the results of Duncan's test for a comparison of diversity, richness, and evenness indices between non-logged and logging areas indicate that plant biodiversity indices tended to increase, so that this increase will be reached to the highest point in medium logging intensity (Figs 2a–c).

Some differences in stem density, basal area and canopy cover were recorded in logged area compared to non-logged area. Some researchers have reported similar results (Cakir et al. 2010). Also, the present study shows that logging activities affected the tree diversity indices. The low values of biodiversity indices were obtained in high logging intensity, which precludes the existence of forests in advanced or decadent stages of devel-

Table 3. ANOVA of the effect of logging intensity on stem density, basal area, canopy cover, diversity, richness and evenness

Variable	$F_{3,119}$	P
Stem density	45.43	0.000**
Basal area	31.36	0.000**
Canopy cover	109.56	0.000**
Diversity	49.66	0.000**
Richness	43.87	0.000**
Evenness	54.26	0.000**

**P < 0.01

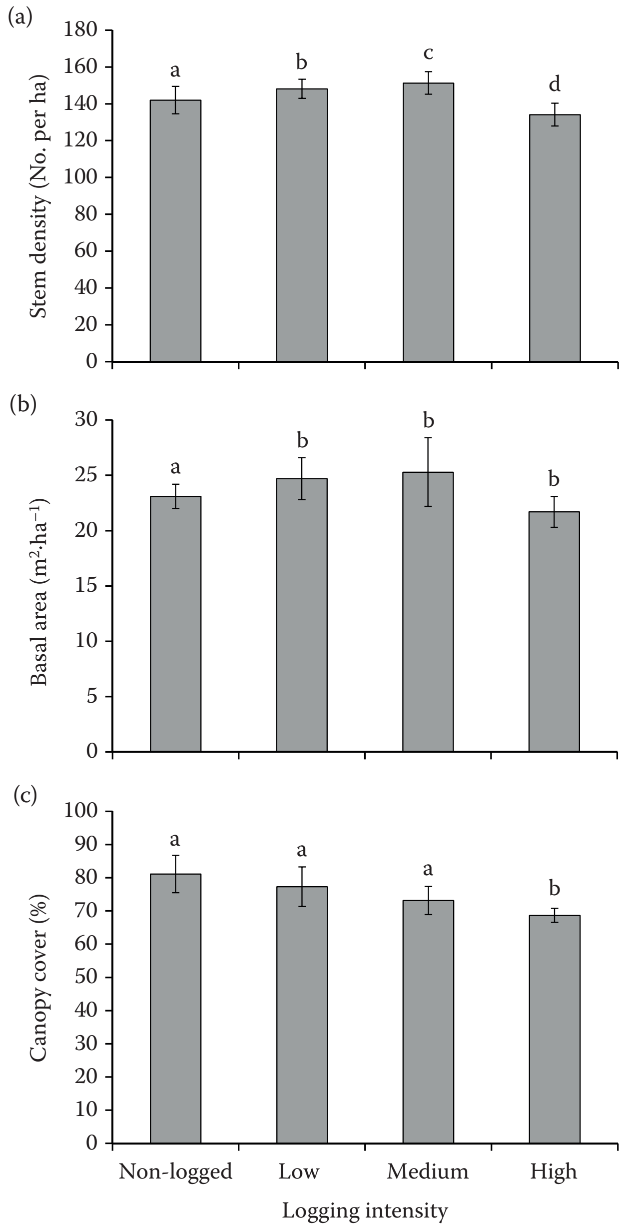

Fig. 1. Stem density (a), basal area (b), percentage of canopy cover (c) in non-logged and logged areas

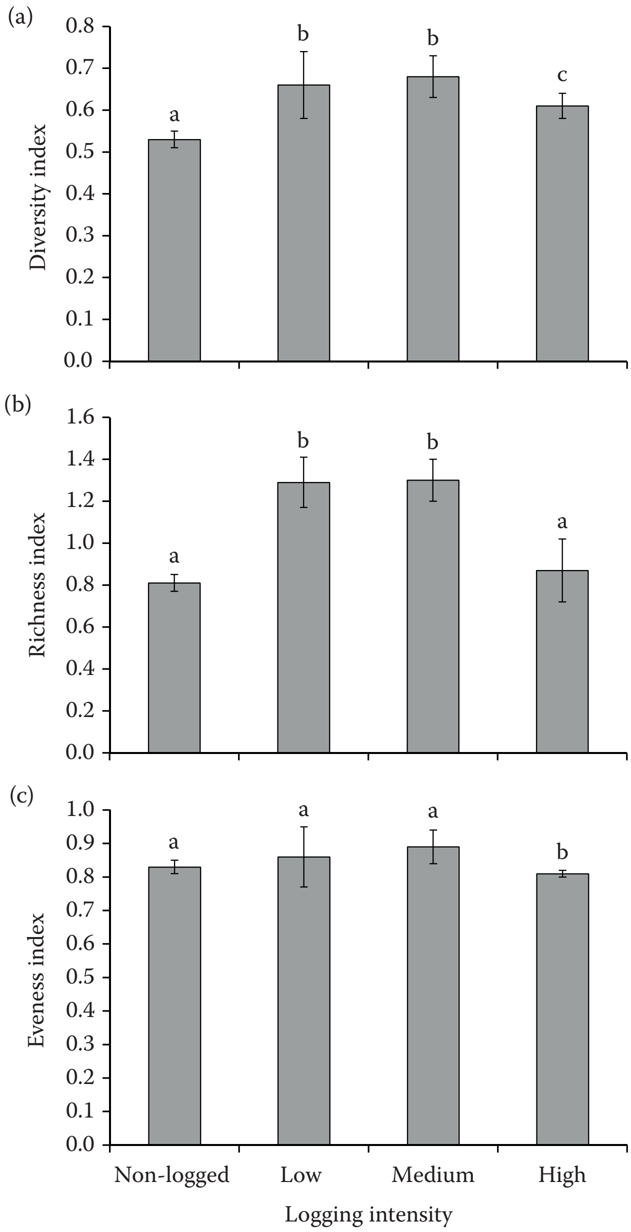

Fig. 2. The values of diversity (a), richness (b), evenness (c) index in non-logged and logged areas

opment and negatively impacts on the abundance of these elements that are considered critical for forest biodiversity, as has been observed by numerous authors (Green, Peterken 1997; Rowland et al. 2005). Hansen et al. (1991) reported similar results for intensively managed forests in the Coastal Northwest of the United States, where they found a higher abundance of large trees and large snags in natural forests than in managed stands. This result was supported in part by other authors (Rowland et al. 2005). Many studies have pointed out that vegetation was affected by logging activities, and they noticed a negative correlation between logging intensity and plant cover, species richness and species diversity (Sarah, Zhevelev 2007; Cakir et al. 2010). Our results complete other studies on changes in plant populations and communities due to logging activities (Nuzzo 1995; Farris 1998; McMillan, Larson 2002; Rusterholz et al. 2004).

CONCLUSIONS

According to the results of the present study, the logging intensity in the studied region should be monitored to improve the quantity and quality of the biodiversity, it is important for developing restoration plans in forest sites affected by intensive logging activities.

The results proved that the stem density in medium logging intensity is at the highest level compared to other treatments.

According to the results the basal area in low and medium logging intensity is at the highest level compared to non-logged and high logging intensity.

The results of the present study showed that the percentage of canopy cover in non-logged areas and low logging intensity is at the highest level compared to other treatments.

The results of the present study indicated that the values of diversity index in low and medium logging intensities are at the highest level compared to other treatments.

The results of the present study proved that the values of richness index in low and medium logging intensities are at the highest level compared to other treatments.

The results of the present study indicated that the values of evenness index in low and medium logging intensities are at the highest level compared to other treatments.

As commercial logging in Caspian forests is applied by natural resources policy makers, it can be concluded that a medium-level logging intensity may be beneficial for moving toward sustainable forest management regarding ecological and economic aspects.

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References

Bawa K.S., Seidler R. (1998): Natural forest management and conservation of biodiversity in tropical forests. Conservation Biology, 12: 46–55.

Behjou F.K., Mollabashi O.G. (2013): A practical sampling strategy for assessing woody debris in Fandoghlou forest, Iran. Journal of Environmental Science, 8: 83–87.

Cakir M., Makineci E., Kumbasli A. (2010): Comparative study on soil properties in a picnic and undisturbed area of Belgrad forest, Istanbul. Journal of Environmental Biology, 31: 125–128.

De Wasseige C., Defourny P. (2004): Remote sensing of selective logging impact for tropical forest management. Forest Ecology and Management, 188: 161–173.

Deckker M., De Graaf N.R.R. (2003): Pioneer and climax tree regeneration following selective logging with silviculture in Suriname. Forest Ecology and Management, 172: 183–190.

Drigo R., Lasserre B., Marchetti M. (2009): Tropical land cover change: Patterns, trends and impacts. Plant Biosystems, 143: 311–327.

Erikson L., Annika M., Nordlund A., Olsson O., Westin K. (2012): Recreation in different forest settings: A scene preference study. Forests, 3: 923–943.

Farris M.A. (1998): The effects of rock climbing on the vegetation of three Minnesota cliff systems. Canadian Journal of Botany, 76: 1981–1990.

Gardner T.A., Barlow J., Chazdon R., Ewers R.M., Harvey C.A., Peres C.A. (2009): Prospects for tropical forest biodiversity in a human-modified world. Ecological Letter, 12: 561–582.

Gascon C., Mesquita R., Higuchi N., Cabarle B.J., Hartshorn G.S., Bowles I.A., Rice R.E., Mittermeier R.A., Da Fonseca G.A.B. (1998): Logging on in the rain forests. Science, 281: 14–53.

Green P., Peterken G.F. (1997): Variation in the amount of dead wood in the woodlands of the Lower Wye Valley, UK in relation to the intensity of management. Forest Ecology and Management, 98: 229–238.

Halpern C.B., Spies T.A. (1995): Plant species diversity in natural and managed forests of the Pacific Northwest. Ecological Applications, 5: 913–934.

Hansen A.J., Spies T.A., Swanson F.J., Ohmann J.L. (1991): Conserving biodiversity in managed forests, lessons from natural forests. Bioscience, 41: 382–392.

Hegetschweiler K.T., Loon N.V., Ryser A., Rusterholz H.P., Baur B. (2009): Effects of fireplace use on forest vegetation and amount of woody debris in suburban forests in Northwestern Switzerland. Environmental Management, 43: 299–310.

Lindenmayer D.B., Margules C.R., Botkin D.B. (2000): Indicators of biodiversity for ecologically sustainable forest management. Conservation Biology, 14: 941–950.

McMillan M., Larson D.W. (2002): Effects of rock climbing on the vegetation of the Niagara escarpment in southern Ontario, Canada. Conservation Biology, 16: 389–398.

Niemela J. (1999): Ecology and urban planning. Biodiversity Conservation, 8: 119–131.

Nuzzo V.A. (1995): Effects of rock climbing on cliff goldenrod (*Solidago sciaphila* Steele) in northwest Illinois. American Midland Naturalist, 133: 229–241.

Pimentel D., Stachow U., Takacs D.A., Brubaker H.W., Dumas A.R., Meaney J.J., O'Neil J.A.S., Onsi D.E., Corzilius D.B. (1992): Conserving biological diversity in agricultural/forestry systems. Bioscience, 42: 354–362.

Putz F.E., Zuidema P.A., Synnott T., Pea-Claros M., Pinard M.A., Sheil D. (2012): Sustaining conservation values in selectively logged tropical forests: The attained and the attainable. Conservation Letter, 5: 296–303.

Rametsteiner E., Simula M. (2003): Forest certification – an instrument to promote sustainable forest management. Journal of Environmental Management, 67: 87–98.

Rowland E.L., White A.S., William H.L. (2005): MP754: A Literature Review of the Effects of Intensive Forestry on Forest Structure and Plant Community Composition at the Stand and Landscape Levels. Orono, Miscellaneous Publications: 28.

Rusterholz H.P., Miiller S.W., Baur B. (2004): Effects of rock climbing on plant communities on exposed limestone cliffs in the Swiss Jura Mountains. Applied Vegetation Science, 7: 35–40.

Saha H.K., Sarkar A., Haldar P. (2011): Effects of anthropogenic disturbances on the diversity and composition of the acridid fauna of sites in the dry deciduous forest of West Bengal, India. Journal of Biodiversity and Ecological Sciences, 1: 131–320.

Sarah P., Zhevelev H.M. (2007): Effect of visitors' pressure on soil and vegetation in several different micro-environments in urban parks in Tel Aviv. Landscape Urban Plan, 83: 284–293.

Spies T.A., Turner M.G. (1999): Dynamic forest mosaics. In: Hunter M.L. (ed.): Maintaining Biodiversity in Forest Ecosystems. Cambridge, Cambridge University Press: 335–361.

Tynsong H., Tiwari B.K. (2010): Diversity of plant species in arecanut agroforests of south Mghalaya, north-east India. Journal of Forestry Research, 21: 281–286.

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