The effect of shelterwood silvicultural method on the plant species diversity in a beech (*Fagus orientalis* Lipsky) forest in the north of Iran

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ABSTRACT: To clarify the effect of shelterwood silvicultural method on the diversity of plant species in a beech (*Fagus orientalis*) forest in the north of Iran, we compared the plant species diversity in three compartments (treatments) where regeneration cuttings were performed with that in a primary compartment. The sampling procedure was a systematic random method and the tree, tree regeneration, shrub and herbaceous species were identified and measured within sampling plots. Results indicated that the mean tree richness in compartment No. 1 (only with one seed cutting) was higher than in the other compartments. The mean richness of understorey species in compartment No. 4 (with all regeneration cuttings) was higher than in the other compartments. The mean evenness (E_{Var}) of tree species in compartment No. 4 was higher than in the other compartments. The mean evenness of understorey species in compartment No. 1 was higher than in the other compartments. The mean tree diversities (i.e. 1-D, N_2, H' and N_1) in compartment No. 1 were higher than in the other compartments. In addition, the mean diversities of understorey species in compartment No. 1 were higher than in the other compartments.

Keywords: beech forest; shelterwood method; plant diversity; systematic random method

Since the United Nations Conference on Environment and Development Process (UNCED) of Rio de Janeiro (1992) and the Ministerial Conference on the Protection of Forests in Europe of Helsinki (1993), biodiversity has become one of the main topics of forest management (Schmidt 2005). Species diversity is considered to be one of the key parameters characterizing ecosystems and a key component of ecosystem functioning. Site disturbance in managed and unmanaged European forests provides the driving force for forest dynamics and regeneration through structural change, initiation of succession and creation of habitat diversity (Schmidt 2005). Baseline data from reference conditions (virgin forest) provide essential arguments in favour of sustainable forestry, including the protection and maintenance of biodiversity. In the past the scientific and public discussion was often determined by the opinion that forest management reduces species diversity of forests while the virgin forest *per se* has the highest species richness. Since most silvicultural studies have stressed the effectiveness of regeneration or changes in stand structure after logging, ecological knowledge that can be applied to management practices for conserving plant species diversity is still limited (Reader 1987; Taylor, Qin 1989; Gilliam et al. 1995; Hannerz, Hånell 1997; Deal 2001; Kariuki et al. 2006; Müller et al. 2006). Furthermore, the discussion of species diversity and richness after forest management has aroused controversy (e.g. Duffy, Meier 1992; Elliott, Loftis 1993; Selmants, Knight 2003; Atlegrim, Sjöberg 2004). Therefore, more data on the effects of various silvicultural systems on species diversity and richness is required. Logging methods also need to be evaluated from the perspective of their effect on regeneration and on successive tree populations, and from their influence on species diversity.

The beech forests in the north of Iran are an example of a commercially important forest type where biodiversity will need to be maintained in the framework of active timber management. The northern forests of Iran cover an area of 1.8 million hectares. The beech forests extend in the north of Iran, covering 30% of the area of these forests and the typical forests are found from 700 to 1,800 m above sea level and form a beech community (*Fagetum-orientalea*). Scientific management of beech forests was started using a shelterwood method in 1959, and the aim was to achieve even-aged and regular forest stands. After a long time, this aim was not obtained for numerous reasons. The understorey vegetation accounts for the vast majority of plant species in these forests. The relative merits of silvicultural techniques in regard to yield and tree regeneration have been well documented, but their impact on plant diversity is unknown.

The objectives of this study are: (a) to quantify current patterns in overstorey and understorey species diversity with taxonomic and statistical rigor, (b) to study the effects of shelterwood method on plant diversity.

The presented results should also be used to test the following hypotheses:

(a) The shelterwood silvicultural method affects plant species diversity.
(b) Plant species richness increases with performed silvicultural practices.

MATERIALS AND METHODS

Study area

The study area covers approximately 200 ha of the beech forests, belongs to district No. 6 (latitude from 36°55'48" to 37°1'20"N, longitude from 49°45'0" to 49°59'30"E) of Shenrood (Watershed No. 25), in the northern forests of Iran (Fig. 1). Altitude ranges from 900 to 1,250 m a.s.l. and general aspect of this area is northeastern. Climatically, mean annual rainfall and temperature are 1,362 mm and 11.3°C,

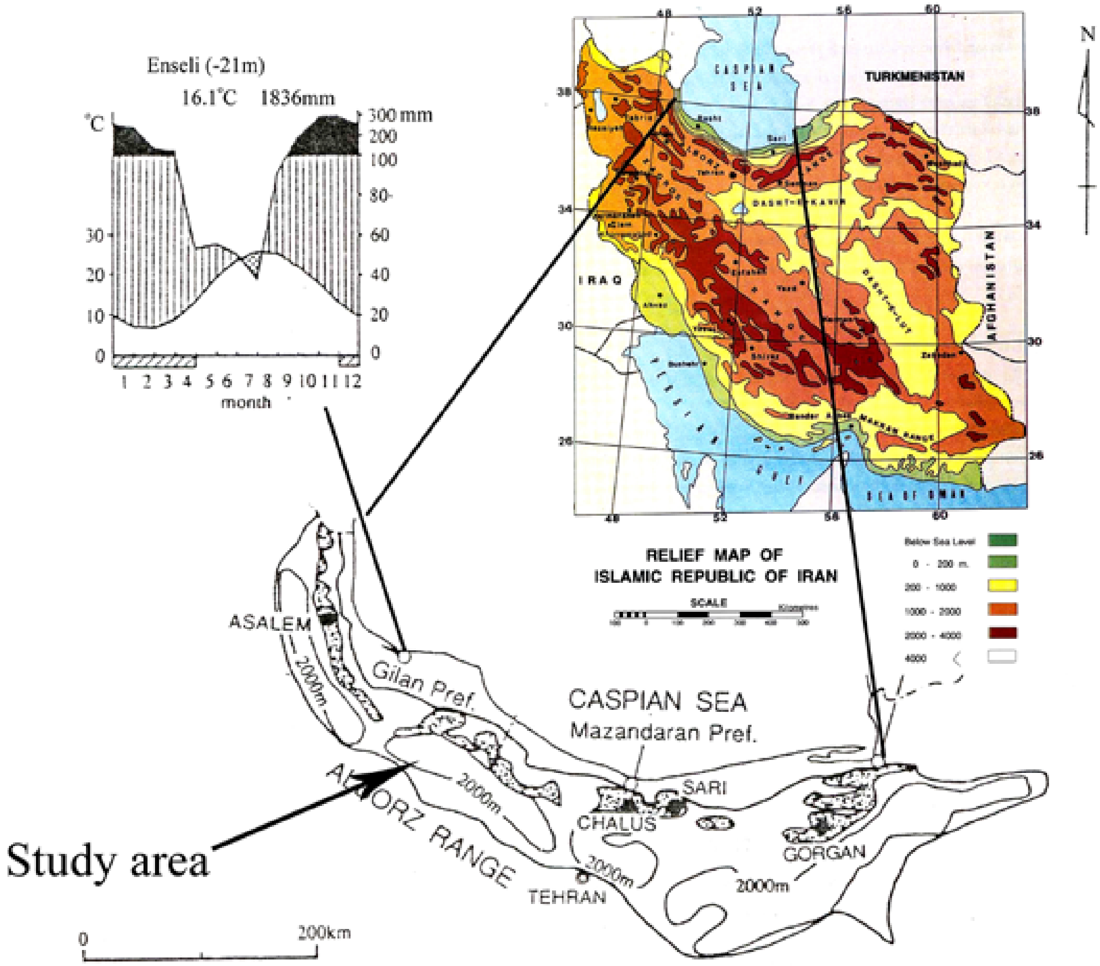

Fig. 1. Study area in Guilan province in the north of Iran

Table 1. The number of sampling plots allocated into each compartment

Compartment	Number of sampling plots	
	understorey	overstorey
1	16	16
2	75	52
3	33	8
4	48	13
Total	172	89

respectively (altitude is 1,150 m a.s.l. in Cheshmeh – Sar, Shenrood).

Geologically, this region emerged in the Jurassic and cretaceous periods of the Mesozoic era. The parent materials are mainly calcareous and they are accompanied with argillic siltstone, sandstone and basalt in some places. Edaphically due to mountainous conditions of the area, relatively high – very high slope and homogeneous parent materials, the soil texture does not show important variability. The soil is usually acidic, neutral in some parts, and it is mostly the mature soil with profile A – (B) – C until A–B–C. The soil texture in the most part is heavy with poor or moderate drainage and the topsoil contains gravel (Forests and Rangelands Organization of Iran 1994). Major constraints of the area are relatively high slope, heavy and gravel soil in the top horizontal.

Sampling methods

This study was conducted in four compartments (treatments) where in compartment No. 1 only seed cutting was performed and in compartments No. 3 and 4 all regeneration cuttings were performed and compartment No. 2 was a reference compartment. Compartments and sampling plots were assigned as treatment and replication, respectively. The number of sampling plots varied in dependence on the compartment area (Table 1). In some sampling plots in the overstorey, only one species (i.e. beech tree) was found, and therefore diversity measures could not be calculated. This is the reason for a lower number of sampling plots in overstorey (89) compared to understorey (172).

For data collection, the systematic random method with dimension of 80 × 80 m was used. The sampling plot area was determined using nested plot sampling and the species/area curve was also plotted (Fig. 2). The plot area was 20 × 20 m. Primarily, characteristics of each sampling plot (i.e. elevation, aspect and slope) were recorded. All four compartments (treatments) had approximately similar ecological conditions in terms of altitude, aspect, slope and edaphic properties (Forests and Rangelands Organization of Iran 1994). Variations of elevation, aspect and slope were found 900–1,000 m a.s.l., northeastern and western and 30–50%, respectively in the majority of the sampling plots. Thus, topographical conditions were relatively homogeneous amongst the compartments.

In the overstorey, the diameter at breast height (dbh, 1.3 m above the ground) of all trees ≥ 10 cm was measured and identified. dbh was used to calculate the basal area for each tree. In the understorey, shrub, tree seedling and herbaceous species were identified and abundance-dominance for each species was estimated on the basis of the Braun-Blanquet scale (Mueller-Dombois, Ellenberg 1974; Bredenkamp 1986; Kooij et al. 1990; Fuls et al. 1993) in the given layers. Sampling plots were taken from May to July 2002.

Data analysis

Data analysis was conducted separately in the overstorey and understorey. In the overstorey, dbh of trees were converted to basal area (m^2) data and substituted for the number of individuals in the calculations (Brockway 1998). In the understorey, dominance-abundance data of shrub, tree seedling and herbaceous species were transformed into cover percentages per each species and substituted for the number of individuals in the calculations (Wild et al. 2004). In order to calculate species diversity in each storey, Simpson's (1-D), Shannon- Wiener's (H´) diversity indices, Hill's (N_2) and McArthur's (N_1) were used (Ludwig, Reynolds 1988; Krebs 1999; Magurran 2004). Since diversity is composed of

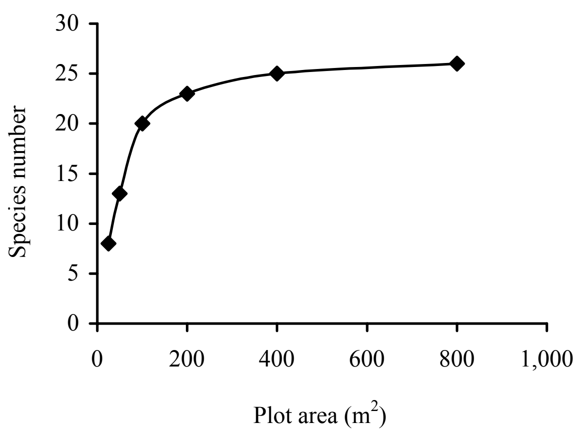

Fig. 2. The species/area curve in compartment No. 2 (reference treatment)

two components: richness and evenness, the number of species (S) was considered as richness. The evenness indicates how individuals are distributed among species. In this study, Smith and Wilson's evenness index (E_{Var}) was used as follows (Krebs 1999):

$$E_{Var} = 1 - \left[\frac{2}{\pi \arctan\left\{ \sum_{i=1}^{S} (Log_e\,(n_i) - \sum_{j=1}^{S} Log_e\,(n_j)/S)^2/S \right\}} \right]$$

where:

arctangent – measured as an angle in radians,

n_i – basal area for overstorey species and is coverage for the understorey of the i^{th} species in the sampling plot,

n_j – basal area for overstorey species and is coverage for the understorey of the j^{th} species in the sampling plot,

S – total number of species in the entire sample.

This is the best available index of evenness, because it is independent of species richness and is sensitive to both rare and common species in the community (Krebs 1999). All diversity calculations were conducted using Ecological Methodology Software (Krebs 1999). Statistical analyses were conducted by ANOVA and Kruskal-Wallis tests (SPSS10.0, Kinnear, Gray 2001). In order to conduct these analyses, various compartments and sampling plots were considered as treatment and replication, respectively. Before doing data analyses for diversity measures, data of elevation, aspect and slope were analyzed and there were not any significant differences between them ($P > 0.05$).

RESULTS

Overstorey layer

There were 12 tree species in this layer which belong to 11 and 8 genera and families, respectively (Tables 2 and 3). The diversity measures and their standard deviation in the studied compartments are shown in Table 4. The richness and evenness measures and their standard deviation are also shown in Table 6. The ANOVA test indicated that there were significant differences among mean diversity measures in the four compartments ($P < 0.05$). Tukey's test showed that there was a significant difference between the mean diversity of compartment No. 1 and the other compartments. In addition, there were no significant differences among mean evenness measures in the four compartments. Finally, the Kruskal-Wallis test indicated that there were significant differences among mean richness measures in the studied compartments and also Tukey's test showed that there was a significant difference between the mean richness of compartment No. 1 and that of the other compartments.

Understorey layer

There were 11 shrub species, 53 dicotyledons and 25 monocotyledons of herbaceous species and 15 mosses and ferns species which belong to 8, 29 and 7 families, respectively in this layer (Table 3).

The diversity measures and their standard deviations are shown in the studied compartments in Table 5. In addition, the richness and evenness measures and their standard deviation are also shown in Table 6. The ANOVA test indicated that there were no significant differences among mean diversity measures in the four compartments. In addition, there were significant differences among mean evenness measures in the four compartments. Meanwhile, Tukey's test showed that there was a significant difference between the mean evenness measure of compartment No. 1 and others. Finally, the Kruskal-Wallis test indicated that there were no significant differences among mean richness measures in the studied compartments.

Table 2. Plant coenological characteristics according to treatments

Treatment	Coverage range of species (%)			
	E3	E2	E1	E0
1	1–75	0.5–3	0.5–37.5	0.5–1
2	1–100	0.5–3	0.5–87.5	0.5–3
3	0.5–100	0.5–47.5	0.5–37.5	0.5–1
4	0.5–75	0.5–37.5	0.5–37.5	0.5–1

E3: tree, E2: shrub, E1: herb (all herbs, grass, herbaceous ferns and juvenile woody species), and E0: moss layer

Table 3. Plant species list based on growth layers

Layer	Species
E3	*Acer cappadocicum* Geld., *Acer velutinum* Boiss., *Alnus subcordata* C. A. Mey., *Carpinus betulus* L., *Cerasus avium* (L.) Moench., *Diospyros lotus* L., *Fagus orientalis* Lipsky, *Juglans regia* L., *Pterocarya fraxinifolia* (Lam.) Spach., *Tilia begonifolia* Stev., *Quercus castaneaefolia* C. A. Mey., *Ulmus glabra* Huds.
E2	*Crataegus microphylla* C. Koch., *Danae racemosa* (L.) Monch., *Euonymus latifolia* (L.) Mill., *Frangula alnus* Miller., *Hedera pastuchovii* Woron. ex Grossh., *Ilex spinigera* Loes., *Laurocerasus officinalis* (L.) Roemer., *Mespilus germanica* L., *Prunus divaricata* Ledeb., *Ruscus hyrcanus* Woron., *Vaccinium arctostaphylos* L.
E1	*Allium paradoxicum* L., *Arum maculatum* L., *Asperula odorata* L., *Asplenium adiantum-nigrum* L., *Asplenium trichomanes* L., *Athyrium filix-femina* (L.) Roth, *Atropa belladonna* L., *Blechnum spicant* (L.) Roth, *Brachypodium sylvatica* Hudson. P. Beauv., *Calystegia sylvesteris* (Wild) Roem & Schult., *Campanula rotundifolia* (Wild) Roem & Schult., *Cardamine bulbifera* (L.) Crantz., *Cardamine impatienies* L., *Carex digitata* L., *Carex distance* L., *Centaurea hyrcanica* Bornm., *Circaea lutetiana* L., *Clinopodium vulgare* L., *Corydalis hyrcana* (Pall) Press., *Corydalis verticillaris* (Pall) Press., *Cyclamen coum* Miller., *Dryopteris filix-mas* (L.) Schott, *Epimedium pinnatum* Fisch., *Equisetum ramosissimum* Desf., *Euphorbia amygdaloides* L., *Fragaria vesca* L., *Galium odoratum* L., *Geranium robertianum* L., *Geum urbanum* L., *Carex divulsa* L., *Carex pendula* Hudson., *Carex sylvatica* L., *Cephalanthera rubra* (L.) L. C. Rich., *Dactylis glomerata* (L.), *Erythronium caucasicum* Woron., *Festuca drymeia* Mert. & Koch., *Juncus effusus* L., *Henrardia persica* (Boiss.) C. E. Hubb., *Hypericum androsaemum* L., *Hypericum perforatum* L., *Iranecio oligolepis* (Boiss.) B. Nord., *Lamium album* L., *Lamium galeobdolon* L., *Lathraea squamaria* L., *Lathyrus laevigatus* (Desf.) O., *Lathyrus laxiflorus* (Desf.), *Listera ovata* (L.) R. Br., *Luzula forsteri* Smith., *Mentha aquatica* L., *Mercurialis perennis* L., *Neottia nidus-avis* (L.) L. C. Rich., *Oplismenus undulatifolius* (Ard.). Beauv., *Petasites officinalis* Moench & Meth., *Phyllitis scolopendrium* (L.) Newm., *Platanthera bifolia* (L.) L. C. Rich., *Poa nemoralis* L., *Polygonum polygonatum* (M. B.) A. Dietrich., *Polypodium vulgare* L., *Polystichum aculeatum* (L.) Roth, *Polystichum woronowii* Fomin., *Primula heterochroma* Staff., *Prunella vulgaris* L., *Pteridium aquilinum* (L.) Kuhn., *Pteris cretica* L., *Ranunculus aucheri* Boiss., *Rhynchocorys elephas* (L.) Griseb., *Rubus caesius* L., *Rubus hyrcanus* Jus., *Rumex sanguineus* L., *Salvia glutinosa* L., *Sambucus ebulus* L., *Sanicula europaea* L., *Saxifraga cymbalaria* L., *Sedum stoloniferum* S. G. Gmel., *Scilla sibirica* Haw., *Scrophularia vernalis* L., *Scutellaria tournefortti* Benth., *Silen schafta* Gmel., *Solanum kieseritzckii* C. A. Mey., *Solidago virga-aurea* L., *Stellaria media* (L.) Cyr., *Tamus communis* L., *Urtica dioica* L., *Veronica persica* Poir., *Vincetoxicum scandens* Sommier., *Viola odorata* L., *Viola shieheana* W. Becker., *Viscum album* L.
E0	*Funaria* sp., *Mnium undulatum* (Hedw)., *Palamocladium euchloron* (Comull.)

DISCUSSION

Diversity is only one complex feature describing the structure of the community. Searching for diversity of community changes should be based on analyses of changes in the species composition. Tree species are directly affected by forest management practice. Mean richness of tree species per sampling plot in compartment No. 1 was higher than in the other compartments, since in this compartment only seed cutting was performed. There were 9 tree species in compartment No. 1, the species including: *Fagus orientalis*, *Carpinus betulus*, *Alnus glutinosa*, *Acer insigne*, *A. cappadocicum*, *Quercus castaneifolia*, *Diospyros lotus* (common species), *Tilia begonifolia* and *Cerasus avium* (rare species). There were 8 tree species in compartment No. 2 (unmanaged forest), the species including: *Fagus orientalis*, *Carpinus betulus*, *Alnus glutinosa*, *Acer insigne*, *A. cappadocicum*, *Juglans regia* (rare species), *Pterocarya fraxinifolia* and *Diospyros lotus*. In addition, there were 5 and 4 tree species in compartment No. 3 and 4, respectively. The tree species of *Fagus orientalis*, *Carpinus betulus*, *Alnus glutinosa*, *A. cappadocicum* and *Quercus castaneifolia* were found in compartment No. 3 and *Fagus orientalis*, *Carpinus betulus*, *Alnus glutinosa* and *Acer insigne* were in compartment No. 4. Previous research indicated that the response to forest management or changing forest structure after logging varied from species to species. It was stated that common species were less susceptible to the effects of harvesting operations than rare species (Nagaike et al. 1999).

The mean richness of tree species per plot was higher in compartment No. 2 than in compartments No. 3 and 4, but there was no significant difference between them. Therefore, the shelterwood silvicultural system did not affect tree richness. Nagaike et al. (1999) also reported this result in Japan's beech (*Fagus crenata*) forests. In addition, Deal (2001) found no significant differences in species richness between the uncut and partially cut plots in the forest plant communities of western hemlock – Sitka spruce stands in southeast Alaska. The mean diversity of

Table 4. Mean diversity indices and their standard deviations in the tree layer. All *F*-test values calculated with 3 and 85 degrees of freedom are statistically significant (α < 5%), *P* is probability. The same letters by means indicate that there is not a significant difference among means

Treatment	Repetition (*n*)	1-D	N_2	H´	N_1
1	16	0.540^a ± 0.211	2.529^a ± 0.910	1.356^a ± 0.569	2.732^a ± 0.942
2	52	0.355^b ± 0.166	1.666^b ± 0.500	0.825^b ± 0.391	1.840^b ± 0.544
3	8	0.323^b ± 0.174	1.583^b ± 0.487	0.740^b ± 0.363	1.720^b ± 0.472
4	13	0.342^b ± 0.104	1.558^b ± 0.254	0.751^b ± 0.172	1.693^b ± 0.198
F (*P*)		5.703 (0.001)	11.064 (0.001)	8.368 (0.001)	10.862 (0.001)

Table 5. Mean diversity indices and their standard deviations in the understorey layer. The *F*-test values calculated with 3 and 168 degrees of freedom; *P* is probability

Treatment	Repetition (*n*)	1-D	N_2	H´	N_1
1	16	0.866^a ± 0.087	10.460^a± 5.777	3.776^a ± 0.598	14.749^a
2	75	0.858^a ± 0.081	8.950^a ± 4.507	3.701^a ± 0.578	13.984^a
3	33	0.857^a ± 0.062	8.176^a ± 3.193	3.641^a ± 0.524	13.276^a
4	48	0.857^a ± 0.063	8.583^a± 4.240	3.683^a ± 0.529	13.693^a
F (*P*)		0.069 (0.976)	1.070 (0.364)	0.224 (0.880)	0.349 (0.790)

tree species was higher in compartment No. 1 than in the other compartments, because tree richness had the highest value in compartment No. 1. In addition, the mean diversity of tree species in compartment No. 2 was also higher than in compartments No. 3 and 4, with no significant differences. Thus, this silvicultural system did not have a considerable effect on tree species diversity. This silvicultural system did not significantly influence tree diversity after it was performed for 10 years in beech forests of Shafarood in Guilan (Poorbabaei, Ranjaver 2008). The results from Japan's beech forests confirmed this trend (Nagaike et al. 1999). Furthermore, this silvicultural method increased the evenness of tree species (i.e. the relative abundance of tree species increased), while the evenness value was highest in compartment No. 4 and lowest in compartment No. 2. In Japan's beech forests, although the diversity and richness of both forest floor plant and tree species in primary and managed stands were not significantly different, the relationship between the number and the frequency of occurrence of each species varied in the two stand types (Nagaike et al. 1999). It was indicated that species diversity in managed stands was primarily maintained by a remarkable increase in the frequency of occurrence of managed stand

Table 6. Mean evenness and richness and their standard deviations in the over- and understoreys

Treatment	E_{Var}		*S*	
	overstorey[a]	understorey[b]	overstorey[c]	understorey[d]
1	0.668^a ± 0.297	0.509^a ± 0.080	3.250^a ± 0.856	26.813^a ± 4.475
2	0.649^a ± 0.265	0.452^b ± 0.078	2.346^b ± 0.711	28.733^a ± 5.871
3	0.652^a ± 0.247	0.431^b± 0.080	2.130^b ± 0.354	29.545^a ± 5.668
4	0.744^a ± 0.182	0.445^b ± 0.083	2.000^b ± 0.000	29.750^a ± 6.204

a: *F* = 0.472; *P*-value = 0.702 (α = 5%); b: *F* = 3.428; *P*-value = 0.018; c: χ^2 (3) = 27.893 for Kruskal-Wallis test; *P*-value = 0.001; d: χ^2 (3) = 4.180 for Kruskal-Wallis test; *P*-value = 0.243

species. Thus, in our study, species diversity after logging seemed to be affected mostly by changes in the frequency of occurrence of species rather than by increasing numbers of newly occurred species. Also, Deal (2001) pointed out that the plant community structure appears resilient to partial cutting within a moderate range of cutting intensity.

Regarding that forest management might decrease plant diversity, most recent studies in temperate forests that measured management effects on understory species diversity report either no reductions, short-lived reductions, or increase in species richness following silvicultural practices (Battles et al. 2001). The mean richness of understory species per plot was higher in compartment No. 4 than in the others, the underlying reasoning is a decrease in canopy cover and an increase in light to the forest floor. Regarding that there was no significant difference in species richness among compartments, therefore this silvicultural method had no remarkable effects on plant species richness in the understory. In addition, the mean diversity had the highest value in compartment No. 1 since the evenness value was higher in this compartment, but there was no significant difference in species diversity among the compartments. In contrast, diversity measures of understory were significantly higher in the logged forest than in the unlogged forest after it was performed for 10 years in beech forests of Shafarood in Guilan (Poorbabaei, Ranjaver 2008). Overall, partial cutting maintains diverse and abundant plant understoreys comparable to the plant communities typically found in old-growth stands (Deal 2001). The mentioned method did not have any remarkable effects on plant diversity in the understorey.

In conclusion, the shelterwood system seems to be an option for maintaining plant species diversity after logging.

References

ATLEGRIM O., SJOBERG K., 2004. Selective felling as a potential tool for maintaining biodiversity in managed forests. Conservation Biology, *13*: 1123–1133.

BATTLES J.J., SHLISKY A.J., BARRETT R.H., HEALD R.C., ALLEN-DIAZ B.H., 2001. The effects of forest management on plant species diversity in a Sierran conifer forest. Forest Ecology and Management, *146*: 211–222.

BREDENKAMP G.J., 1986. Ecological profiles of potential bush encroacher species in the Manyeleti Game Reserve, South Africa. Journal of Botany, *52*: 53–59.

BROCKWAY D.G., 1998. Forest plant diversity at local and landscape scales in the Cascade Mountains of southwestern Washington. Forest Ecology and Management, *109*: 323–341.

DEAL L.R., 2001. The effects of partial cutting on forest plant communities of western hemlock – Sitka spruce stands in southeast Alaska. Canadian Journal of Forest Research, *31*: 2067–2079.

DUFFY D.C., MEIER A.J., 1992. Do Appalachian herbaceous understories ever recover from clearcutting? Biological Conservation, *6*: 196–201.

ELLIOTT K.J., LOFTIS D.L., 1993. Vegetation diversity after logging in the southern Appalachians. Biological Conservation, *7*: 220–221.

FORESTS AND RANGELANDS ORGANIZATION OF IRAN, 1994. Forestry plan of district No. 6 of Shenrood. Natural Resources Department: 80. (In Persian)

FULS E.R., BREDENKAMP G.J., VAN R., THERON G.K., 1993. The physical environment and major plant communities of the Heilborn-Lindley-Earden-Villiers area, northern Orange Free State, South Africa. Journal of Botany, *59*: 345–359.

GILLIAM F.S., TURRILL N.L., ADAMS M.B., 1995. Herbaceous-layer and overstory species in clear-cut and mature central Appalachian hardwood forests. Ecological Applications, *5*: 947–955.

HANNERZ M., HÅNELL B., 1997. Effects on the flora in Norway spruce forests following clearcutting and shelterwood cutting. Forest Ecology and Management, *90*: 29–49.

KARIUKI M., KOOYMAN R.M., SMITH R.G.B., JOHNSON G.W., VANCLAY J.K., 2006. Regeneration changes in tree species abundance, diversity and structure in logged and unlogged subtropical rainforest over a 36-year period. Forest Ecology and Management, *236*: 162–176.

KINNEAR P.R., GRAY C.O., 2001. SPSS for Windows made simple release 10 (translated by Akbar Fotouhi Ardakani). London, Psychology Press: 448. (In Persian)

KOOIJ M.S., BREDENKAMP G.J., THERON G.K., 1990. Classification of the vegetation of the Bland type in the North-Western Orange Free State, South Africa. Journal of Botany, *56*: 306–318.

KREBS J.C., 1999. Ecological Methodology. New York, Harper and Row: 432.

LUDWIG J.A., REYNOLDS J.F., 1988. Statistical Ecology. New York, John Wiley and Sons: 337.

MAGURRAN A.E., 2004. Measuring Biological Diversity. London, Blackwell Publishing Company: 256.

MUELLER-DOMBOIS, ELLENBERG H., 1974. Aims and Methods of Vegetation Ecology. New York, John Wiley and Sons: 547.

MÜLLER S.W., RUSTERHOLZ H.P., BAUR B., 2006. Effects of forestry practices on relict plant species on limestone cliffs in the northern Swiss Jura mountains. Forest Ecology and Management, *237*: 227–236.

NAGAIKE T., KAMITANI T., NAKASHIZUKA T., 1999. The effect of shelterwood logging on the diversity of plant species in a beech (*Fagus crenata*) forest in Japan. Forest Ecology and Management, *118*: 161–171.

POORBABAEI H., RANJAVER A., 2008. Effect of shelterwood silvicultural method on plant species diversity in beech (*Fagus orientalis* Lipsky) forests in Shafaroud, Guilan province. Iranian Journal of Forest and Poplar Research, *16*: 61–73. (In Persian)

READER R.J., 1987. Loss of species from deciduous forest understorey immediately following selective tree harvesting. Biological Conservation, *42*: 231–244.

SCHMIDT W., 2005. Herb layer species as indicators of biodiversity of managed and unmanaged beech forests. Forest Snow Landscape Resources, *79*: 111–125.

SELMANTS P.C., KNIGHT D.H., 2003. Understory plant species composition 30–50 years after clearcutting in southeastern Wyoming coniferous forests. Forest Ecology and Management, *185*: 275–289.

TAYLOR A.H., QIN Z., 1989. Structure and composition of selectively cut and uncut *Abies* – *Tsuga* forest in Wolong natural reserve and implications for Panda conservation in China. Biological Conservation, *47*: 83–108.

WILD J., NEUHÄUSLOVÁ Z., SOFRON J., 2004. Changes of plant species composition in the Šumava spruce forests, SW Bohemia, since the 1970s. Forest Ecology and Management, *187*: 117–132.

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Vliv podrostního lesního hospodaření na druhovou diverzitu rostlin v lesích s *Fagus orientalis* v severním Íránu

ABSTRAKT: Srovnávala se druhová diverzita vegetace ve třech různých variantách hospodářských postupů a jedné kontrolní varianty v rámci bukových lesů severního Íránu s *Fagus orientalis*. Cílem bylo zjištění vlivu způsobu hospodaření na druhovou diverzitu. Výběr ploch byl založen na kombinaci systematického a náhodného přístupu. Na každé ploše bylo zaznamenáno: složení stromového patra, zmlazení, složení křovinného a bylinného patra. Výsledky ukazují, že průměrná bohatost stromů ve variantě 1 (tam byla provedena semenná těžba pro zajištění obnovy) byla vyšší než v ostatních variantách. Průměrná druhová bohatost podrostu ve variantě 4 (provedená obnovní těžba) byla vyšší ve srovnání s ostatními variantami. Varianta 2 byla kontrolní. Průměrná vyrovnanost druhů (E_{Var}) stromového patra byla vyšší rovněž ve variantě 4. Vyrovnanost zastoupení druhů v podrostu byla naopak vyšší ve variantě 1. Průměrná druhová diverzita stromového patra hodnocená různými indexy (1-D, N_2, H´ a N_1) byla vyšší ve variantě 1. Totéž se týkalo diverzity v rámci podrostu.

Klíčová slova: lesy s *Fagus orientalis*; podrostní hospodaření; rostlinná diverzita; systematicko-náhodný výběr ploch

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