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Effect of repeated fire on understory plant species diversity in Saravan forests, northern Iran

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Abstract

Fire usually causes changes in the composition and diversity of herbaceous species. The present paper aimed to study the effect of repeated fire incidents on understory species diversity in the Saravan forests of Guilan Province located in the north of Iran. To do so, three 50-hectare areas with identical physiographical conditions and overstory (hand-planted softwood *Pinus taeda*) were selected. Seven fire incidences occurred for the 10-year period in one of the areas and the other area experienced three fire incidents within the same period. The area with no fire incidents was considered as the control area. All the fire incidents were surface ones. The systematic random method with a sample size 100 × 200 m was used for collecting data. Based on the above, 25 samples were determined in each area. The whole coverage of the understory was taken into consideration using Whittaker's method and the Domain criterion so as to calculate species diversity indices. The results showed that Shannon-Wiener diversity and Menhinick's richness in the regions which experienced 3 and 7 fire incidents were maximum and minimum, respectively, whereas no significant difference was seen between the regions with regard to Smith and Wilson's evenness index.

Key words

repeated fire, understory vegetation, diversity, Guilan Province, northern Iran

Introduction

Disturbances can cause major changes in plant communities depending on their intensity, extent, frequency, seasonality and resilience of component species (Herath et al. 2009). Fire is one of the most important disturbance factors in natural ecosystems throughout the world (Moretti and Barbalat 2004). In post-fire succession studies, many factors have to be taken into account, such as characteristics of vegetation before fire occurrence, the season when it occurs, fire intensity, the concentration of ash nutrients added into soil as well as rain, air and soil temperature and animal populations associated with a habitat. These parameters as a whole determine vegetation response. In wildfires, however, it is very difficult to analyze many of these parameters: only the season is easily recorded. (Calvo et al. 2003).

Fires in the north of Iran normally occur in autumn, when forest floor litter dries as hot-dry winds

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cause a short period of drought. These are mostly surface fires that rarely exceed 10–30 cm in flame height under normal fuel and humidity conditions. They consume the fine and course litter on the forest floor (Banj Shafiei et al. 2010). Forests of Guilan Province are located in the western part of the Hyrcanian forest region in Iran. The dominant species in northern forests of Iran is the beech (*Fagus orientalis* Lipsky). Beech forests are the richest forest community in Iran because they are both economically and environmentally valuable. Forests dominated by the oriental beech (*Fagus orientalis*) cover about 565 000 ha and represent the total area of indigenous forests in Guilan Province (Adel et al. 2012b). Forest plantation was performed using softwood indigenous species such as *Pinus taeda, Pinus pinaster, Pinus pinea, Pinus sylvestris, Picea abies, Larix deciduas, Cryptomerai japonica, Eucalyptus* sp. and *Cupressus sempervirens* var. *horizontalis* in lowland forests of Guilan Province located in the north of Iran, where the destruction rate was high. One of tree species which were planted successfully was *Pinus taeda*. Yousefi Gorji et al. (2007), Pourbabaei and Pourrahmati (2009) and Fadaei (2008) discussed successful growth of this species in their studies. In the region under the study, *Pinus taeda* was planted in 1968. It had a good ecological sustainability in the region. During last few years several medium scale surface fires have occurred in the region, having several effects on its biodiversity.

Plant species diversity in the forest understory has been extensively studied because the understory is the major component of forest ecosystems and plays an important role in many ecological functions and processes (e.g., Yirdaw 2001; Roberts 2002; Nagaike et al. 2006; Pourbabaei and Pourrahmati 2009). Studying and surveying fire effects on forest composition would yield important information on forest vegetation recovery, which is necessary to forecast forest composition and succession (Adel et al. 2012a). The aim of this study was to investigate the impact of repeated natural fires in plantation forests on herbaceous species diversity after fire. We hypothesized that repeated fire has no effects on different measures of plant diversity.

Material and methods

Study area

The study area is located in Saravan forest between the cities Rasht and Roudbar in the south of Guilan Province in northern Iran. This region was artificially forested with softwood and indigenous species – *Pinus taeda*. This is a pure even-aged forest. At present, its compression is 250 trees per hectare and the mean breast height diameter of *P. taeda* is 30 centimeters, while its annual wood production exceeds 18 cubic meters per year. So far, the forest has been exploited several times, however, during 10 recent years, it has not been harvested and livestock was prohibited to enter the region. There used to be native broadleaf species such as *Pterocarya fraxinifolia, Parrotia persica, Gleditschia caspica, Prunus divaricata, Alnus glutinosa,* and *Quercus castaneifolia* which had been destructed due to uncontrolled exploitation. The number of surface fires, and sometimes crown fires, has increased in the north of Iran which caused considerable losses in the composition and diversity of plant species. The region is situated at 50 to 250 m a.s.l. The mean slope of the region is 5% and its overall direction is northern. Total annual rainfall is 1374.4 mm and mean annual temperature is 15.9°C. The maximum and minimum rainfalls are observed in October (218.6 mm) and June (39.5 mm),. The maximum and minimum temperatures are in July (20.38) and February (2.34). According to Emberger's climatic index it is a very humid region. Region's soil is made of siltstone and sandstone, has heavy texture with rooting depth from 60 to 70 cm and indicates low pH. Percentages of region's canopy cover and grass cover are 80% and 30%, respectively.

Data collection

To conduct the present research, sampling was performed in three areas of Saravan forests. The areas were all hand-planted with softwood tree species. The selected masses were located close to each other and indicated just about similar conditions in terms of age, plantation distance, slope, orientation, height and so on. Within last 10 years, one of the areas experienced 7 surface fire incidents and the other one – 3 fire incidents. The area with no fire incident was considered as the control. The distances between the three areas were 300 meters. Twenty-five plots were prepared for each area. Totally, 75 plots were prepared. The plots were determined using a 100 × 200 meter network for data acquisition. The Whittaker's method and minimal area were used to determine the size of the plots, which was obtained as 32 m^2 (Adel et al. 2012a). Cover percentage of all the species was measured in each plot using the Domain criterion (Pourbabaei and Pourrahmati 2009).

In each sample plot, after removing the litter, three soil samples were taken from the depth of 0–30 cm. Next a compound sample from each plot was taken to the laboratory for further analyses. Soil moisture was measured by weighing soil, drying overnight at 105°C and then reweighing to calculate moisture loss. Soil carbon (C) was measured by the method of Walkey and Black (Allison 1965) and total nitrogen (N) was determined by the Kjeldahl procedure (Bremner 1996).

Data analysis

To evaluate the effect of fire on different aspects of herbaceous biodiversity we used three indices. Firstly, species diversity was assessed with the Shannon–Wiener index (Magurran 1988):

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

where
P_i – relative frequency of the i^{th} species.

Secondly, species richness was estimated according to the Menhinic index (Ludwig and Reynolds 1988):

$$R_{Mn} = \frac{s}{\sqrt{N}}$$

where
S – the total number of species and N is the total number of individuals.

At last, the Smith–Wilson index (Smith and Wilson, 1996) was used to calculate species evenness:

$$E_{\text{var}} = \frac{2}{\pi \ \arctan\left\{\sum_{i=1}^{s}\left[\log_e(n_i) - \sum_{j=1}^{s}\log_e(n_j)/s)^2\right] \Big/ S\right\}}$$

where
n_i – the number of individuals of the i^{th} species in a plot,
n_j – number of individual of j^{th} species,
S – the total number of species in U and UB areas.

All three indices were computed with Ecological Methodology for Windows software, version 6.0 (Krebs 1989).

Kolmogorov–Smirnov tests were used to test normality of all parameters. Significance of differences between means was analyzed by one-way ANOVA, followed by Duncan's test at 95% confidence level. All statistical analyses were performed with the use of SPSS software (version 18.0).

Results

In total, 17 families and 23 species were identified. Rosaceae and Asteraceae families, each with 4 species, had the maximum number of species. Liliaceae and Poaceae families were represented by two species, while other families – by one species. There occur 6 species in all three areas. *Urtica dioica, Coix lacryma-jobi L* and *Polygonum hyrcanicum* were only available in the control area. *Oxalis acetocella*, *Asplenium adianthum-nigrom* L, *Fragaria vesca*, *Inula helenium*, *Erigeron hyrcanicus*, *Artemisia annua*, *Hypericum perforatum*, and *Potentilla anserine* species were available only in the area which experienced 3 fire incidents. Out of 23 species, only 6 species are in the area which experienced 7 fire incidents. The species include *Carex* sp., *Viola odorata*, *Crataegus microphylla*, S*ambucus ebulus*, *Smilax excels* and *Rubus fruticosus* L.

Oplismenus undulatifolius, Pteridium aquilinum (L.) Kuhn, *Carex* sp., *Viola odorata*, *Smilax excels* and *Pteris dentate Forssk* sp. showed a significant increase in the area which experienced 3 fire incidents when compared with the control area. Species *Pteris dentate Forssk, Viola odorata, Crataegus microphylla* and *Smilax excels* indicated a significant decrease in the area which experienced 7 fire incidents when compared with the control area. The maximum and minimum cover percentages belonged to *Rubus fruticosus* (L.) in the area which experienced 7 fire incidents and the control area, respectively (tab. 1).

Statistical analyses showed that there was a significant difference between mean values of Menhin-

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Tab. 1. Understory plant species in the study areas

Species	Family	7 times burned	3 times burned	unburned
Oplismenus undulatifolius	Poaceae	–	7.5[a]	4.25[b]
Pteridium aquilinum [L.] Kuhn	Hypolepidaceae	–	3.5[a]	0.5[b]
Carex sp.	Cyperaceae	32.5[c]	68.63[a]	47.71[b]
Viola odorata	Violaceae	5.2[c]	24.5[a]	9.5[b]
Crataegus microphylla	Rosaceae	4.5[c]	15.75[b]	32[a]
Sambucus ebulus	Caprifoliaceae	0.5[a]	1.35[a]	1.5[a]
Ruscus hyrcanus	Liliaceae	–	10.5[b]	15.6[a]
Smilax excelsa	Liliaceae	3.65[b]	3.9[b]	6.7[a]
Rubus fruticosus L.	Rosaceae	42.78[a]	21.43[b]	8.5[c]
Pteris dentate Forssk.	Pteridaceae	–	7.2[a]	3.6[b]
Urtica dioica	Urticaseae	–	–	4.9
Calystegia sylvestris	Convolvulaceae	–	7.25[a]	5.1[a]
Polygonum hyrcanicum	Polygonaceae	–	–	4.5
Oxalis acetocella	Oxalidaceae	–	8.5	–
Asplenium adianthum–nigrom L.	Aspleniaceae	–	5.6	–
Coix lacryma–jobi L.	Poaceae	–	–	2.77
Fragaria vesca	Rosaceae	–	7.5	–
Inula helenium	Asteraceae	–	3.2	–
Erigeron hyrcanicus	Asteraceae	–	6.71	–
Artemisia annua	Asteraceae	–	5.2	–
Hypericum perforatum	Hypericaceae	–	7.5	–
Potentilla anserina	Rosaceae	–	3.75	–
Helianthus annus	Asteraceae	–	2.25[a]	3.5[a]

ick's richness and Shannon-Wiener diversity indices in the three areas at confidence level 95%. The numerical value of all the indices in the area which experienced 3 fire incidents was greater than that in the control area and in the area which experienced 7 fire incidents. No significant differences were seen between the three areas for Smith and Wilson's evenness index (fig. 1, 2, and 3).

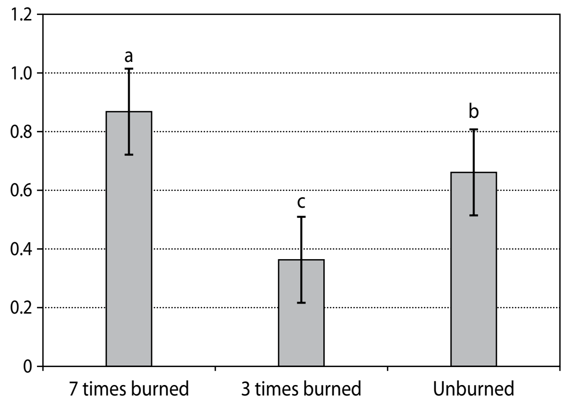

Fig. 1. Shannon–Wiener diversity index

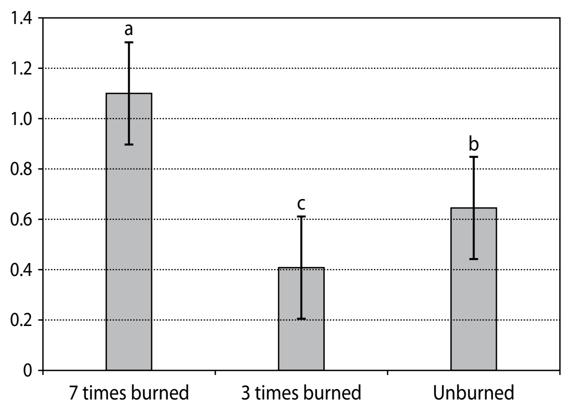

Fig. 2. Menhinick's richness index

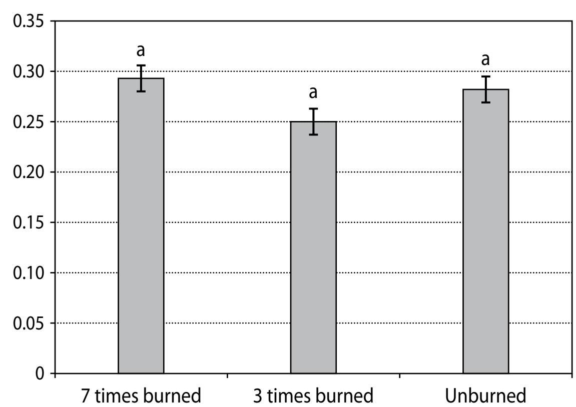

Fig. 3. Smith-Wilson's evenness index

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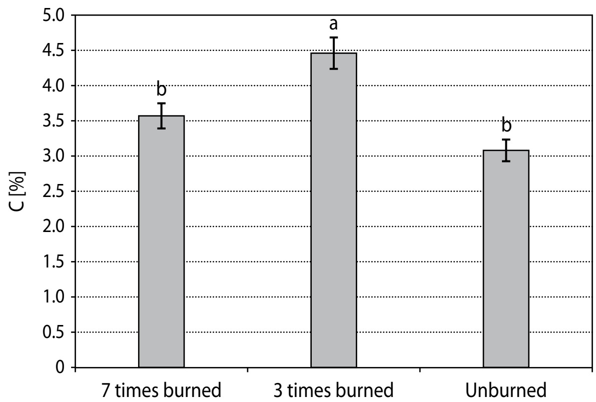

Fig. 4. C percent in the study areas

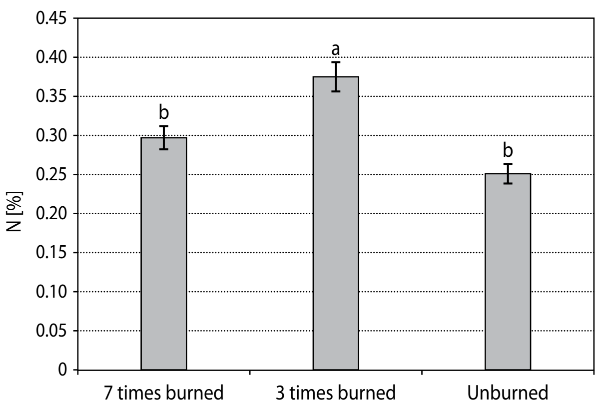

Fig. 5. N percent in the study areas

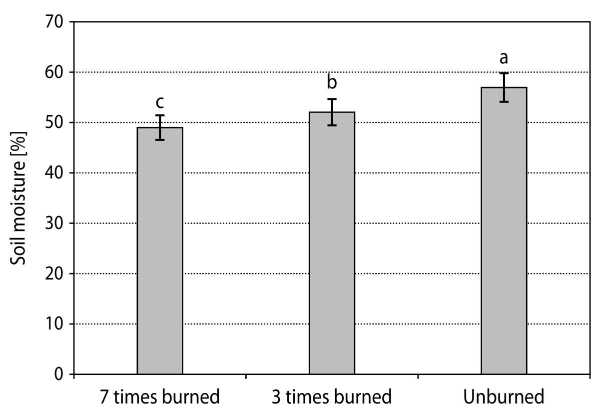

Fig. 6. Soil moisture percent in the study areas

There was a significant difference between the three areas in terms of humidity, carbon and nitrogen as humidity percentage in the control area was greater than that in the area which experienced 3 fire incidents. Humidity percentage in the latter area was greater than that in the area which experienced 7 fire incidents. Carbon and nitrogen rates in the area which experienced 3 fire incidents was significantly greater than those observed in the other two areas (fig. 4, 5, and 6).

Discussion

The results obtained from the present research showed that the maximum and minimum of Shannon-Wiener as well as Menhinick's richness diversity indices were related to the areas, which experienced 7 and 3 fire incidents, respectively. No significant difference was specified on Smith and Wilson's evenness index among the three areas investigated. In fact, fire increased richness and diversity. Richness of species increased after surface fire. Marozas et al. (2007) stated that surface fire leads to richness of land vegetation cover and preliminary substitute species generally help further richness. The authors believe that most pioneer species appear in burnt regions within 1–3 years after a fire incident, which might be due to changing competition conditions and increasing nutrient contents. Metlen and Fiedler (2005) observed that fire has no effect on evenness. The reason of obtaining these results can be stated like this, "Initially, diversity and richness decrease due to fire; however, they increase due to suitable conditions, access to space, and nutrients resources". After fire, diversity of species was at first significantly less than in the control area; however, it increased gradually. Fattahi and Tahmasebi (2010), Certini (2005) and Cassie et al. (2009) observed that diversity of species reduced in the early years after a fire incident, but an increase was observed during the study. In a study in Missouri Ozarks forests in North America, Hartmann and Heumann (2003) observed that fire led to an increase of understory species diversity. In their studies in Ohio, USA, Hutchinson et al. (2005a) stated that fire led to an increase of herbaceous species diversity. Taft (2003), in his studies conducted in Southern Illinois, USA, stated that richness and diversity of understory species increased after fire.

The results obtained in this study showed that there were only 6 species out of the total number of species in the area which experienced 7 fire incidents. However, 4 out of the 6 species indicated a considerable decrease in abundance. In fact, as there were repeated fires in the region that experienced 7 fire incidents and the lack of time for forest to reconstruct, there were observed minimum amounts of richness and diversity. The species did not have a chance for reconstructing and increasing their percentage cover. Massad et al. (2012) concluded that repeated fire incidents decreased the number and diversity of species and caused important changes in the structure and composition of plant communities. Cochrane and Schulze (1999) and Barlow and Peres (2008) achieved similar results in their studies. Malkisnon et al. (2011) observed that repeated fires dramatically changed the type of Mediterranean vegetation cover. Frequent firing may remove vegetation species that rely on seed production for their persistence (Benson 1985; Fox and Fox 1986). Changes in habitat structure as a consequence of frequent burning are likely to disadvantage many native species (Whelan 1995). Peterson et al. (2007) and Peterson and Reich (2008) observed in their studies that repeated fires reduced biological diversity and stated that further repetition of fires might have eradicated species. According to our study, fire can increase richness and diversity of species, however, such an increase is different with respect to repetition and number of fire incidents. Burton et al. (2011) found that species overall diversity, coverage and richness in oak forests could significantly increase from zero to five by repetition of fire incidence during a decade.

Eight species were observed in the area which experienced 3 fire incidents; such species did not exist in the rest of regions. On the other hand, 6 species in the area which experienced 3 fire incidents showed a significant increase in abundance as compared with the control area. In fact, fire helped the growth of these species, since through decreasing competition it created better space conditions and increased availability of resources. In other words, occurrence of these species and the significant increase of other six species after fire were due to a better use of available nutrients and necessary space for establishment.

There were 3 species in the control area which were not observed in the areas after fire. In fact, fire eradicated these species by destroying and/or activating their viability and not allowing them to have a chance to appear. In the area, which experienced 7 fire incidents, 17 other species did not have a chance to appear which was due to repeated fires and the lack of nutrient resources.

There was observed only one species – *Rubus fruticosus* (L.), which indicated a significant increase in the area which experienced 7 fire incidents. *Rubus fruticosus* (L.) is an invasive species. Due to its high compatibility it can be considered as a serious threat for biodiversity of the region. Adel et al. (2012a) and Banj Shafiei et al. (2006) observed a significant increase of this species after fire and proposed that it should be removed from the region through silviculture operation.

One of other reasons that led to reduction of diversity in the area which experienced 7 fire incidents was soil characteristics. There was observed significant reduction of humidity percentage with the increase of fire repetition. Soil moisture plays an important role in dispersion of plant species and it is considered as one of the basic factors in establishment and growth of plants (Shafroth et al. 2000). Graned et al. stated in 2011 that soil humidity decreased 44% after fire. On the other hand, microorganisms need a certain amount of humidity to decompose the litter and perform other processes. In the case when needed humidity is not provided, decomposition processes are disordered and nutrients needed by plants are not supplied. Bruhjell and Tegart (2001) observed in their studies that an increase of organic matter after fire depended on soil humidity. In case soil humidity is supplied, fire increases activity of soil microorganisms, which in turn increases soil organic matter. Brian et al. (2003) obtained similar results in their study. Nitrogen and carbon are the most important nutrient factors required by plants; they participate in most of chemical activities of plants and cause plants to grow. In the region under the study, these two elements showed significant increases in the area which experienced 3 fire incidents. Meanwhile, nitrogen and carbon contents in the area which experienced 7 fire incidents were lower than those in the area which experienced 3 fire incidents. This could be another reason for changing richness and diversity of plant species in the areas studied. Campo et al. (2006) concluded in their studies that repeated fires reduce nutrients elements of soil. In their studies in Hong Kong, Marafa et al. (1999) observed that repeated fires reduced N, NH_4, P, Ca, and Mg in soil. Bastias et al. (2006) in their studies in western Australia observed that fire reduced N and C elements. Aref (2011) and Neff (2005) observed reduction of soil nitrogen after fire. Verma and Jayakumar (2012) expressed that changing nutrients recycle would change ecosystems' products so that more access to nutrients leads to further growth of herbaceous species.

Based on the present research, it can be stated that fire increases diversity and richness of plant species; however, the rate of increase is different with respect to repetition of fire. Another factor that may increase diversity and richness is the effect that fire has on soil. Fire affects the understory cover of forests, diversity and richness. As forest under the study plays environmental and hydrological roles in addition to its economic role and understory species play a crucial role in forest structure, the protection of the forest observed and prevention of repeated fire incidents should be performed by firm and stable management. Such measures should be included at the top of the agenda of region's natural resources authorities.

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