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Are disturbances altering the species composition of Iranian oak woodland?

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Abstract

The species composition of plant communities is influenced by the interaction of disturbances and environmental factors. This study examined the effect of environmental factors and disturbance (grazing and fire) on plant species composition of oak (*Quercus brantii* Lindl.) woodlands in western Iran. Vegetation and soil and other environmental variables were measured in 77 sample plots distributed among in various disturbance classes. Canonical correspondence analysis, combined with forward selection was used for data analysis. For each variable, the gross and net effect on plant species composition was calculated. Numerical index were applied to assess plant diversity of vegetation units. Disturbance and environmental variables explained 24.9% of the total variation in species data. Most variation in species data was explained by disturbance, followed by soil, light and topography. Our results showed that disturbances in the oak woodlands of the study were an important factor to change the species composition in oak woodlands and altered the plant species composition in predictable ways.

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Introduction

Disturbance is usually defined as "any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resource pools, substrate availability, or the physical environment" (Pickett & White 1985). The effect of disturbance on species composition have been studied for decades (Connell 1978; Huston 1979; Grime 1977; **Sousa** 1984; Hobbs & Huenneke 1992; Davis 2000; Davis *et al.* 2005a; Zida *et al.* 2007), it is also known that spatial distributions of species can be influenced by environmental gradients. The effect of environmental factors on species distribution and species diversity have been studied to determine the most important environmental variables affecting plants composition in communities (Whittaker 1975; Heydari and Mahdavi 2009; Arekhi *et al.,* 2010; Pinke *et al.* 2010; Grantham and Hann 1994; Lososová *et al.,* 2004). It seems changes in vegetation are associated with a complex gradient of environmental factors and disturbance (Davis *et al.,* 2005b). Previous researches have been done on the effect of environmental factors and disturbance on changes in plant composition separately, regardless of their contribution in these variations. Our objective in this study was to determine the relative effects of environmental gradients and disturbances on understory species composition in an Iranian oak woodland with emphasis on the contribution of each of them and also introduced the indicator species in these disturbances, in order to predicting how management practices may potentially affect species composition and diversity in Iran's oak woodlands. Since grazing and fire are two types of disturbances known to substantially influence plant species composition (Hamilton and Hamilton, 2006), in this study we examined the effects of these disturbances on change in plant composition.

Materials and methods

Study site

The investigation was conducted in the Daalaab Park, located in west of Iran, approximately 25 km north-west of Ilam between 33°40´- 33°45´ N latitude and 46°20´- 46°30´ E longitude (Fig. 1). Three sampling areas, each with a distinctive history (grazed, burned, disturbance free) were selected within a 2000 ha of oak woodland at Daalaab Park (A high woodland). The disturbance-free site has been protected for 25 years by the Forest and Range Organization of Iran. The climate at the study site is Mediterranean, with cool moist winters and hot dry summers; mean annual precipitation is 571 mm, most of which falls during the winter and spring. Elevations range from 1300 to 2200 m in the areas sampled. Mean annual temperature is 16 °C. The dominant tree species is Brant's oak (*Quercus brantii* Lindl.), a winter-deciduous oak.

Fig.1. Location of the Study area in west of Iran.

Vegetation sampling

The data set was carefully stratified to control for environmental disturbance heterogeneity. Minimum surface area of sample plots (relevés) was determined based on minimal area, using helical technique and curve of area-species (Cain and Castro 1959). Vegetation was sampled in seventy seven 16×16 m plots. We compiled a data set of 77 sample plots. These plots were taken by random method in various environment variables and disturbances classes (grazing, fire and protected sites). Geographical coordinates of plots location were recorded using GPS **(**Garmin 60). Abundance values measured in Braun-Blanquet scale for each species (Mueller- Dombois and Ellenberg 2002). **The nomenclature of vascular plants followed the Flora of Iran (**Rechinger, 1963-2006), **Flora of** Turkey (Davis, 1965-1985) and Flora of Ilam (Mozaffarian, 2009**).**

Life forms of species were determined based on the definition Raunkiaer **(**Raunkiaer, 1934)**.**

Explanatory variables

Environmental attribute data were collected for each plot. These attributes can be broadly grouped as describing a plot's (1) disturbance history; (2) topography; (3) soil (0-10 cm depth); (4) light. The disturbance history variables included, the year of the last fire, grazing intensity (light, moderate and heavy grazing) and land use history (protected or non-protected area). Stocking rate (sheep ha^{-1} $year^{-1}$) (Throne and Stevenson, 2007; Shakeri, 2012) and density of livestock feces in each plot (Kenneth *et al.,* 2003) were used as indicator of grazing pressure. Topographic variables included slope inclination (%), elevation (m a.s.l.), and slope aspect that were recorded using GPS and Vertex IV Transponder T3. Soil variable included soil texture (i.e. sand, silt and clay proportions), pH, bulk density, organic carbon, total nitrogen, available phosphorus and potassium, saturation percent, porosity, T.N.V%, bare soil percent, litter, compaction (trampling), volumetric moisture. The air-dried, < 2 mm soil was used for the analyses in laboratory as follow. Soil texture was determined using hydrometer method. Soil pH was measured with a combination electrode in 1:2.5 water suspension, total organic carbon (Walkey-Black method), available phosphorus (Olsen method) and total nitrogen (kjeldahl method). Exchangeable potassium was measured by ammonium acetate method using spectrophotometer, and T.N.V% was measured by titration. Bulk density was determined by soil bulk density sampler. Soil compaction and soil volumetric moisture were recorded using penetrometere and time domain reflectometry, respectively. Light variable included percentage of overstory canopy as a measure of the amount of light reaching the forest floor (Rodríguez-Calcerrada, 2008). Geographic coordinates of each sampling plot were recorded using GPS (model: Garmin 60). Of course, spatial components included 9 variables related to geographical coordinates plots were used in all subsequent analyses to account for spatial autocorrelation (Borcard *et al.,* 1992).

Analysis

Prior to data analysis, spatial autocorrelation of plots was performed using Mantel test (Mantel, 1967) by PC- ORD 4.17 programme (McCune and Mefford, 1999). In order to assess vegetation unit, Two-Way Indicator Species Analysis **(**TWINSPAN**) was used** by PC- ORD 4.17 programme (McCune and Mefford, 1999). Each vegetation unit reflects specific environmental factors and biological interactions among diagnostic species. The third cut- level was chosen for stopping point of the formation of clusters (Mac Nab *et al.,* 1999). We constructed trait groups by study of disturbance regimes in each of plots in these groups. Indicator species were determined by their indicator value index ($p < 0.01$) by the Monte Carlo test of significance of observed maximum indicator values with 9999 permutation. The indicator value (IndValij) was expressed as the product of the mean abundance of species i in the plots of group j compared to all groups (Aij) and the relative frequency of that species in the plots of group j (Bij) (Dufrêne and Legendre, 1997) (equation 1).

$$IndVal_{ij} = A_{ij} \times B_{ij} \times 100 \qquad \text{(eqn 1)}$$

Data set were analyzed using a direct ordination method to describe the appropriate pattern in species composition and to relate it to explanatory variables. Canonical correspondence analysis is a method that can help us to unravel how a multitude of species simultaneously respond to external factors, such as environmental variables, pollutants and management regime, using data either from observational studies or from designed experiments, and of assessing to what extent this variation can be explained by associated environmental variation, it can analysis the effect of particular environmental variables by partialling out nuisance variation (partial CCA) (ter Braak and Smilauer, 2002). An absence of covariation may thus signal that multiple factors are at play in determining the response of variability to disturbance

(Fraterrigo and Rusak, 2008). To reduce and determine variables that affect the composition of the vegetation, forward selection method was used.

Due to the spatial correlation between sample plots (according to the Borcard *et al.,* 1992), geographical coordinates of the sampling plots were considered as a covariate factors, and considering the variables selected as constraining variables in CCA. Subsequently we tested gross and net effects of each set of the selected variables on species composition using partial canonical correspondence analysis (p-CCA) (ter Braak and Smilauer, 2002). The effect both gross and net, of each explanatory variable to species composition was undertaken using Monte-Carlo tests. Separate analyses with single environmental variable were done to assess the gross effects. The net effects (effect of particular variable after partialling out the effect of all other variables) were tested by partial-CCA, where all other environmental variables were used as covariates (Lososová *et al.,* 2004). In all tests the target Type I error rate was set to 5%, the accepted Type II error rate was set to 1% and the maximal number of permutations was 9999. All analyses were taken by the CANOCO 4.99 programme (ter Braak and Smilauer, 2012).

Results

Trait groups

Altogether 147 vascular plant species belonging to 113 genera and 33 families were recognized. Therophytes with 39.6% were the dominant life form and the abundance of hemicryptophytes, geophytes, chamephytes and phanerophytes were 25.7, 15.9, 13.2 and 5.6 %, respectively. From the TWINSPAN analysis of the data clustered the oak woodland vegetation into six plant ecological groups. Fig. 2 shows these disturbance classes.

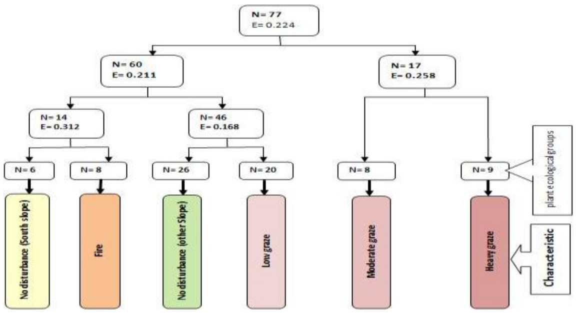

Fig.2. Dendrogram of TWINSPAN for vegetation in the study area. N = Number of plot, E = Eigenvalue.

Species composition

In total, 48 species were identified as significant indicators of different disturbance type. The indicator species of different disturbance classes varied from four to sixteen (Table 1).

Table 1. Indicator species for six disturbance types.

Plant ecological groups	Disturbance	Species	Observed value	(P)*
1	Fire	*Vicia sativa*	26.7	0.0304
		Galium aparine	34.4	0.0044
		Coronilla scorpioides	44.5	0.0014
		Torilis leptophylla	30.1	0.0204
		Onopordon carduchorum	48	0.0002
		Anthemis odontostephana	27.7	0.0212
		Carduus pycnocephalus	36.3	0.0060
		Helianthemum salicifolium	31.2	0.0100
		Geranium tuberosum	29.3	0.0214
		Boissiera squarrosa	35.7	0.0044
		Taeniatherum crinitum	38.8	0.0040
		Eryngium billardieri	32.7	0.0090
		Cirsium spectabile	31.7	0.0060
		Gundelia tournefortii	30.1	0.0004
		Avena fatua	21	0.0432
		Parapholis incurva	23.2	0.0458

Plant ecological groups	Disturbance	Species	Observed value	(P)*
2	Low graze	*Daphne mucronata*	25.2	0.0212
		Asyneuma cichoriforme	26.2	0.0470
		Bromus tomentellus	44.8	0.0004
		Festca ovina	38.1	0.0038
		Smyrniopsis aucheri	25.2	0.0212
3	Moderate graze	*Acer monspesulanum (SD)*	32.4	0.0092
		Rhagadiolus angulosus	50.9	0.0002
		Ceratocephalus falcatus	41.6	0.0020
		Erodium cicotarium	34.5	0.0032
		Valerianella dactylophylla	24.9	0.0336
4	Heavy graze	*Stellaria media*	77.8	0.0002
		Picnomon acarna	32.4	0.0078
		Valerianella vesicaria	41.9	0.0004
		Holesteum umbellatum	64.3	0.0002
		Rochelia disperma	49.4	0.0004
		Ficaria Kochii	56.7	0.0004
		Bromus tectorum	38.5	0.0022
		Turgenia latifolia	41	0.0016
		Euphorbia macroclada	44.6	0.0012
5	Undisturbance (south slope)	*Teucrium polium*	55.6	0.0004
		Aegilops umbellulata	48.9	0.0006
		Centaurea behen	38.5	0.0050
		Centaurea koeieana	35.8	0.0050
6	Undisturbance (Other slope)	*Quercus brantii(SD**)*	32.6	0.0114
		Chaerophyllum macropodum	38.9	0.0004
		Trigonella elliptica	27.3	0.0224
		Bunium luristanicum	42	0.0012
		Cerasus microcarpa	38	0.0002
		Ranunculus oxyspermus	45.6	0.0002
		Lens cyanea	31.3	0.0106
		Bromus sterilis	33.9	0.0126

*P, probability (from a Monte Carlo permutation test, 1000 random permutations)

** SD, seedling

Table 1 show the large number of species adapted to establishment in space opening that created by fire. Most important species associated with fire are (*Onopordon carduchorum*, *Coronilla scorpioides*, *Taeniatherum crinitum*, *Carduus pycnocephalus*). Species associated with heavy graze are *Stellaria media, Holesteum umbellatum, Ficaria Kochii, Rochelia disperma, Euphorbia macroclada, Valerianella vesicaria, Turgenia latifolia, Bromus tectorum*. Depending on intensity and frequency of tree species seedlings in these disturbance classes, fire and livestock can lower tree regeneration (Laris and Wardell, 2006). Seedling of *Quercus brantii, Ranunculus oxyspermus, Bunium luristanicum, Chaerophyllum macropodum, Cerasus microcarpa, Bromus sterilis and Lens cyanea* are indicator species of undisturbance classes in north-facing slopes and *Teucrium polium, Aegilops umbellulata, Centaurea behen, Centaurea koeieana* are indicator species of undisturbance classes in south-facing slopes.

The effects of environmental factors and disturbance

15 explanatory variables of 37 primary variables were chosen by forward selection analysis in CCA. The selected variables were summarized in five sets of variables, i.e., Disturbance (D), Soil (S), Light (L), Topography (T) and a spatial component (SP) (Table 2).

Table 2. Significant variables retained after forward selection procedure in CANOCO.

Groups	Variables selected	explained variance %	F*	P*
D	Light grazing	3.3	3.1	0.002
	Moderate grazing	1.6	1.6	0.002
	Heavy grazing	1.6	1.6	0.012
	No disturbance (South- facing slopes)	4.4	4	0.002
	No disturbance (Other slopes)	3.7	3.5	0.002
	Fire	6.2	5.3	0.002
S	Litter %	1.3	1.4	0.049
	Volumetric moisture	2	2	0.002
	Bare Soil %	9.2	7.5	0.002
	Total N %	1.4	1.4	0.002
	T.N.V %	1.7	1.8	0.002
L	Canopies cover of overstory % (amount of light reached the forest floor)	2.2	2.2	0.002
T	Altitude	2.3	2.2	0.002
	Slope%	1.4	1.4	0.03
SP	Latitude	1.7	1.7	0.006

*F, F-ratio for the test of significance of the first three axes.

*P, corresponding probability value obtained by Monte-Carlo-permutation test for the first three canonical axes.

Disturbance's categories including undisturbed (control: south and other slops), grazing (light, moderate and intense), fire; Soil's factors including bare soil%, litter%, volumetric humidity%, total nitrogen%, amount of calcite%; topographic factors including altitude, slope; overstory covering% (i.e. amount of light reached the forest floor) were the most important of environmental factors. All the variables selected were considered as the constraining variable and considering the spatial correlation as a covariate, these variables together explained 24.9% of the total variation in species composition (Table 3).

Table 3. Result of selected partial CCA analyses.

Explanatory variables	Covariates	Eigenvalues	Explained variance %	F*	P**
D, S, L, T	SP	0.372	24.9	3	0.002***
SP	D, S, L, T	0.024	0.9	1.3	0.046
Gross effects					
D	SP	0.237	19.8	4.6	0.002
S	SP	0.176	12.7	3.1	0.002
L	SP	0.037	2.7	3	0.003
T	SP	0.055	3.2	2.2	0.002
Net effects					
D	S, L, T	0.125	11	2.6	0.002
S	D, L, T	0.081	5.2	1.7	0.002
L	D, S, T	0.023	2.2	2.4	0.002
T	D, S, L	0.025	1	1.3	0.02****

*F, F-ratio for the test of significance of all canonical axes (test on the rejection).

** P, corresponding probability value obtained by Monte-Carlo-permutation test.

***= $P< 0.01$ and ****= $P< 0.05$.

Spatial autocorrelation of plots was significant ($r = 0.145$, $p = 0.019$, $z = 0.91$). The gross effects of all variables on species composition were highly significant. Of these, spatial component was used as covariate in all subsequent analyses to account for spatial autocorrelation. Changes in species composition in plant ecological groups had clear response to disturbance and ecological factors. Most variation in species data was explained by disturbance, followed by soil, light and topography, however, there may also be a few other explanatory variables of comparable importance. The net effects of particular explanatory variables on species composition, calculated after removing the effects of other variables from the model, were also significant. The net effects of particular variables were highest for disturbance with 11% and lowest for topographic variables. Environmental factors studied, totaling, explained 8.4% of the variance (soil, light and topography with 5.2, 2.2 and 1%, respectively), regardless shared with each other. Results of selected partial CCAs analyses are shown in Table 3.

The partial CCA ordination diagram showed that the first axis corresponded to disturbance and explained 11.3% of the total variation in species data, while the second axis mainly referred to soil and to a lesser extent slop and elevation that explained additional 7.9% of the total variation (Figs 3 and 4).

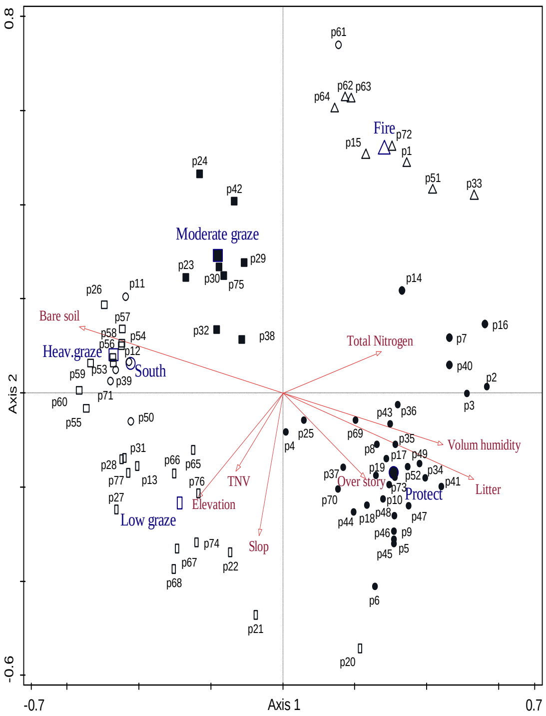

Fig.3. CCA biplot of sample plots and selected variables. Quantitative environmental variables are indicated by arrows and categorical variables are indicated by the types of symbols and labeled. Sample plots are denoted through the following symbols: undisturbance (south-facing slopes), circle; fire, triangle; undisturbance (other slopes), filled circle; Low grazing, diamond; heavy graze, square and moderate graze, filled square.

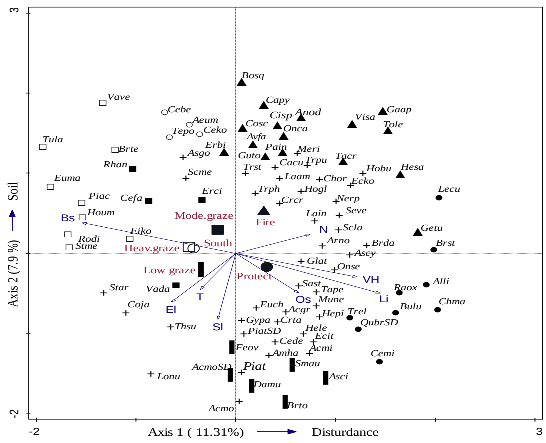

Fig.4. CCA diagram of species with explanatory variables. Quantitative environmental variables are indicated by arrows and categorical variables are indicated by the types of symbols and labeled. Indicator species are denoted through the following symbols according to disturbance types: undisturbance (south-facing slopes), circle; fire, filled triangle; undisturbance (other slopes), filled circle; low graze, filled diamond; heavy graze, square and moderate graze, filled square. Non-indicator species are indicated by cross. Species with low weight are not shown. Bs = Bare soil, Sl = Slope, Li = Litter, VH = Volumetric humidity, N = Total Nitrogen, Os = Overstory, T = T.N.V, El = elevation.

Discussion

Disturbance and species composition

Both livestock grazing and fire disturbances have led to change in species composition including an increase in annuals species in the understory flora of these oak woodlands. The increased light levels and decreased litter percentage at the soil surface following fire likely explains the increased abundance of annual and ruderal species (Chaneton and Facelli, 1991; Keeley *et al.*, 2003), such as *Coronilla scorpioides* (it is light tolerant, according to the CCA diagram of species with explanatory variables), *Onopordon carduchorum, Taeniatherum crinitum, Cirsium spectabile, Eryngium billardieri, Gundelia tournefortii* and *Carduus pycnocephalus* (they are semi-light demanding). Generally, grazing will reduce vascular plants cover and biomass of understory via direct effects (e.g. used of species palatable, especially seedlings) and indirect effects (e.g. soil compaction (trampling)) (Van Uytvanck and Hoffmann, 2009; Wassie *et al.,* 2009; Bouahim *et al.,* 2010). Presence of species such as *Holesteum umbellatum, Bromus tectorum, Euphorbia macroclada, Valerianella vesicaria, Picnomon acarna, Rochelia disperma, Rhagadiolus angulosus* and *Ceratocephalus falcatus* in grazing disturbance are due to their toleration in the high compaction of soil, good seed dispersal (Vavra *et al.,* 2007), non-palatable, low palatability compared to other species or to be used for short periods of phenological stages (Sheley and Petroff, 1999; Augustine and McNaughton, 1998). It seems disturbance led to increase of abundance of ruderal species (sensu Grime, 1977) but we found that grazing and fire do not have similar impacts on species composition in oak woodlands. The presence of seedlings of tree species, especially seedlings of oak in areas that have been free of livestock grazing for 25 years is evidence that these woodlands are regenerating. Although canopy cover in the protected area averaged less than 50%, seedlings growing beneath this canopy likely experienced less water stress than seedlings growing in grazed and recently burned woodland sites, which exhibited less canopy cover (Biaou, 2009; Wassie *et al.,* 2009). Fire along with grazing, are more likely to reduce oak regeneration, at least at the present time. Thus the actual species growth is expected to be locally constrained by the frequency and intensity of disturbances (Huston, 1994 in: Biaou, 2009). There is a clear distinction between indicator species in each disturbance. Helliophyta species dominated at fire plots and, soil-compaction-tolerant species dominated at grazing plots. This demonstrates that different types of disturbance affects on species composition differently.

Factors driving variation in species composition

Our results suggest that disturbances explained more variation in species composition than environmental variables such as soil factors, topography and amount of light reached the forest floor (Table 3). These variables explain 24.9% of variance in data species. Because of the complexity of these natural communities, this degree of explanation is substantial (Leps and Smilauer, 2003; Shakeri, 2012).

High percentage of litter has hidden oak seeds from view of animals and providing moisture for germination and seedling growth (Wassie *et al.,* 2009; Biaou, 2009). Present of seedling of oak at undisturbance class with a high percentage of litter confirms it. Meanwhile, the absence of livestock grazing and abundant cover by the upper tree canopies in these sites is the other reasons for presence of sapling. This relationship can be seen clearly in Fig. 4. So that the vector of the litter is disposed in the right and down of graph, if that, grazing disturbance class is to the left and in front of the undisturbance class. Bare soil is choice as variable influencing on species data by the forward selection in canonical ordination. Previous studies have shown that **there is r**elationship between percent bare soil with soil compaction, soil bulk density and percent porosity in disturbances (Dahlgren *et al.,* 1997; Carcey Hincz and Irma, 2011). Bare soil with soil compaction has an important role in the germination and establishment of plant species (Loris and Wardell, 2006; Wassie *et al.,* 2009). Reduce litter and increase the percentage of bare soil have caused by livestock grazing (Augustine *et al.,* 2012) and fire (Chaneton and Facelli, 1991), generally generate very favorable conditions conductive to the establishment of ruderal, opportunist and helliophyta species (Keeley *et al.,* 2003, 2005). Percentage of canopies cover of overstory as amount of light reaching the forest floor has an important role to alter the species composition. Fire increased resources of light and nutrients and led to the establishment of species that are not found in other classes of disturbance (Tilman, 1982; Keeley *et al.,* 2003), especially shade-intolerant species, that increase richness of understory vegetation in these sites (Hill and French, 2004; Zida *et al.,* 2007). Other factors that influences on changes in species composition are altitude and slope. These variables have little effect on species data. Present of species such as *Daphne mucronata*, *Bromus* *tomentllus*, *Festuca ovina* and *Acer monspesulanum* at higher elevation shows that elevation gradients have an important ecological factors to distribution of plant species in this forest (Jazirehi and Ebrahimie Rostaaghi, 2003; Hamzeh'ee *et al.,* 2008). Elevation and slope have effects on disturbance, with increasing these, grazing pressure was reduced. This relationship can be seen clearly in Fig. 4. So that the vector of the elevation and slop is disposed in the left and down of graph, that low grazing disturbance class is disposed. This is confirmed the reaction between environmental factors and disturbance in diversity pattern (Biaou, 2009).

Based on these results we noted that changing in vegetation and distribution of plant species are due to changes in environmental factors (such as seedbed condition, available resources including light and nutrients, soil compaction, moisture) influence the occurrence of disturbance (Pickett and White, 1985; Turner *et al.,* 1993; Halpern *et al.,* 1995; Fraterrigo and Rusak, 2008). Therefore species composition is more influenced by disturbance than environmental factors.

Disturbances in the oak woodlands of the study alter the plant species composition in predictable ways. Grazing, one of the most important disturbances in oak woodlands has led to a noticeable reduction in palatable species. Increasing grazing intensity will lead to decrease tree regeneration and increase proportion of ruderal plant species. Fire, in addition to reducing tree canopy cover of overstory, has similarly led to an increase opportunistic species in the burned forest. Presence of saplings of oak in without any disturbances class with high canopy cover on overstory and its absence at grazing disturbance, confirms the role of grazing in removal oak seedling, and effect of shadow on generate condition to establishment of oak seedlings and shade tolerant species (e.g. *Bromus sterilis*), through decreased light and increased litter and moisture (Biaou, 2009; Wassie *et al.,* 2009). Thus, if overgrazing and fire continue in these woodlands and natural indicator species are replaced by ruderal and nonnative, the ability of the oak woodlands to regenerate will continue to decline. Therefore, while it is possible that fire may needed in the future to prevent the oak woodlands from being replaced by shade tolerant species, in the near future the woodlands will be best protected by a management plan that tries to minimize fire and control grazing via proper management of livestock (e.g. proportion of livestock with the carrying capacity, observing the grazing season, enforcement of the rotation grazing in order to establish of cultivated plants and natural oak seedling establishment, especially in the seed year of trees).

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