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Effects of anthropogenic disturbance on plant composition, plant diversity and soil properties in oak forests, Iran

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Abstract

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Three sites including "less disturbed", "moderately disturbed" and "severely disturbed" were selected in Zagros forests in Kurdistan province (Iran). Three forest stands with similar physiographic conditions of each site were selected and three 400 m^2 plots were assessed in each stand to record the floristic information and soil sample (0–30 cm). Different diversity indices were calculated for each sample. Cluster analysis and to collect soil samples detrended correspondence analysis were applied to categorize and investigate the vegetation trend. Indicator species analysis was used to determine the characteristic species. Tukey test was used to compare the variables amongst sites. The results showed that 47, 25, 15 species were exclusively observed in less disturbed, moderately disturbed and severely disturbed sites, respectively. Furthermore, cluster analysis illustrated the distinction amongst sites and detrended correspondence analysis result showed that the vegetation of the regions was ordinated by disturbance gradient. 21, 5, 7 characteristic species were respectively indicated in less disturbed, moderately disturbed and severely disturbed sites. In general, plant composition, plant diversity and soil quality were decreased dramatically along the disturbance gradient.

Keywords: *Quercus brantii*; richness; understory species; Zagros forests; canopy cover

Politic and scientific sensitivities on the biodiversity issue have increased since the remarkable enhancement of the extinction rate of species because of human activities (Ehrlich, Wilson 1991) and ecologists and natural resources managers have shown great attention to the relationship between anthropogenic disturbance and species diversity (Robert, Gilliam 1995). The exact understating of the relationship between biotic and abiotic sections of forest ecosystems and human influences on plants' biodiversity is crucial for forest managerial and protective activities. Scott et al. (1998) emphasized the impact of improper use and land use change on decline of species diversity and ecosystem destruction. Also, Ruprecht et al. (2009) stated that structure and biodiversity of the forest ecosystem were directly affected by human activities. In this context, Bell et al. (2016) stated that the effects of silvicultural disturbances on species richness in northern temperate and boreal forests were independent of climate and soil properties. The effect of anthropogenic disturbance on plant composition and plant diversity was investigated in many studies all over the world. Moreover, Mishra et al. (2004) studied the influence of human based disturbance on three subtropical mountainous forest stands and showed that the more the disturbance intensity increased the more the species richness and diversity of trees and shrubs decreased. Mligo (2011) illustrated that pole cutting and fuel wood cutting had significant influences on decreasing the biomass, plant diversity and changing the species distribution pattern. Blanko and Pereira (2015) evaluated the anthropogenic disturbance on natural vegetation in fragmented forests and showed that protection of woodland habitats were necessary for conservation of plant richness in the remaining stands. Shaheen et al. (2001) investigated the effects of human exploitation on structural diversity and community composition in the subtropical forests of India and demonstrated that density, basal area and the number of species were less than those in similar undisturbed stands. Furthermore, they mentioned that this destruction caused much pressure on *Quercus ilex* Linnaeus, *Quercus dilatata* Lindley ex de Candolle, *Pinus wallichiana* A.B. Jackson, and *Pinus roxburghii* Sargent species. Despite abovementioned studies, Linares et al. (2011) stated that the species diversity of those stands that experienced low human intervention was five times more than species diversity in protected areas. Moreover Shrestha et al. (2012) evaluated the effects of human-made disturbance on the vascular plant diversity in oak forests in Nepal and illustrated that all diversity indices were enhanced where forest disturbance was at intermediate level. On the other hand, the soil properties of forest can be affected by human activities (Gömöryová et al. 2008). In the forest ecosystems tree and herb species could influence soil properties and also there is an interaction between trees and soil, in other words, growth and production of trees depend on the soil fertility. In addition, the amount of mineralization and nitrification of organic matter in soil is associated with species richness (Augusto et al. 2002). Moreno et al. (2007) stated that harvesting of trees resulted in reduction of organic matter and soil quality; therefore, disturbance caused by human activities could change the composition, quality and quantity situation of tree species and as a result affect the soil properties in forest ecosystems. Latty et al. (2004) evaluated the influences of land-use history on soil characteristics and nutrient dynamics in northern hardwood forests of the Adirondack Mountains. The results showed that anthropogenic disturbance decreased the soil carbon and nitrogen pools compared to old-growth. Also, Borrelli et al. (2017) demonstrated that 45.3% of soil loss is caused by water erosion in the logged forests in Italy.

Zagros forest is the largest forest land in Iran in which oak genus is the main woody species. These forests are divided into northern and southern parts based on oak species occurrence. The northern part is the specific habitat of *Quercus infectoria* Olivier, but in some regions it is combined with *Quercus libani* Olivier and *Quercus brantii* Lindley, while the southern part is just covered by *Q. brantii* (Fattahi 1995). From the past to present, these forests have been inhabited by residents and nomads who have caused deforestation in some parts and severe damages in others. In these forests, people follow a classical form of managing the forest in which forage for feeding their animals and wood for fuel were collected (Ghazanfari 2004). Unfortunately, due to social problems and lack of proper and comprehensive management, these forests have been heavily disturbed and have lost their productivity potential which endangers the future of the forests (Fattahi 1995). According to the increasing destruction of oak forests in Zagros forest in Iran, it is necessary to investigate the influence of human disturbance with various intensities on species diversity and soil properties. Oak stands in Zagros forests are loaded with a complex of disturbance regimes including fuel wood cutting, local people use and livestock grazing. The local people use and fuel wood cutting and livestock grazing may have distinct effects on the herbaceous plant diversity. This study, however, does not distinguish the disturbance types but only their intensity levels. The spatial extent and frequency of disturbances in the region show that these disturbances impact on all areas simultaneously but with different intensity. Therefore, the current study aims to compare the woody and herbaceous species diversity and soil properties in less disturbed (LD), moderately disturbed (MD) and severely disturbed (SD) areas of oak forests in Zagros forests.

MATERIAL AND METHODS

Study area. The research area is located in the Kurdistan province (Iran), latitude 35°45' to 36°15'N and longitude 45°30'E to 46°15'E. Nine patches of oak forests (*Q. brantii*) were selected which were situated on north-facing sites with similar slope and altitude conditions. The altitude is 1,550 m and the percentage of slope is between 15 and 23°. The mean annual temperature is 13.8°C and the mean annual rainfall is 658 mm. The soil type is belongs to the Entisol order developed on calcareous substrate (Pourbabaei, Navgran 2011).

Sampling methods. We observed a complex of disturbance regimes including livestock grazing, local people use and fuel wood cutting in the region. The frequency and spatial extent of disturbances in the studied region showed that many areas would be impacted by these disturbances at the same time but with different intensity which resulted in different canopy openness. We categorized the disturbance intensity by specifying the canopy openness classes and defining the livestock grazing and traditional wood cutting levels. At first, from the oak forests of the region, three different sites were selected. The first one was the LD area with more than 50% canopy cover (maximum canopy cover was 70%), little impact from livestock and other forms of traditional utilization. The second one was the MD area with 10 to 50% canopy coverage and some impact of livestock grazing and traditional wood cutting. The last one was the SD area with less than 10% canopy of trees, permanent livestock grazing and extensive pole and fuel wood cutting (Mishra et al. 2004). Three forest stands with similar physiographic conditions of each site were selected and in each stand, three 400 m^2 plots were assessed at 0, 100 and 200 m on transect, for recording the floristic information (nine plots per a site). The names of the herbaceous species were recorded and their abundance was counted on 5 subplots with dimensions 1.5 × 1.5 m (Fu et al. 2004; Eshaghi Rad et al. 2009). Tree's DBH and crown cover (large and small crown diameter) were measured for calculating the basal area and canopy cover within the plots. In total, there were 45 plots for each site. Also, a soil sample was assessed from 0–30 cm of mineral soil in each plot (nine soil samples for each site). The humus layer was not considered in this study because this layer was very thin and it could not be distinguished. Before the laboratory analysis, the soil samples were air-dried and sieved with a 2 mm. Sand, silt and clay percentages were determined to the hydrometric method. Soil pH (in H_2O) was determined by a pH meter. Total N was analysed using the Kjeldahl method. Available P by colorimetry according to Bray-II method and organic carbon by the Walkley and Black method were determined. Organic matter was obtained by multiplying C values by 1.72. Exchangeable potassium was extracted with ammonium acetate 1 N and was analysed by using flame photometer device. Also, the C/N ratio (as an indicator of mineralization of organic matter) was calculated.

Biodiversity indices. For measuring plant diversity for each sample, species richness (SR) was calculated as the number of species inventoried in the plot. We applied the Shannon diversity index (H') and evenness index (E), they were calculated as follows (Eqs 1 and 2):

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

where:

s – number of species,

p_i – relative cover of i^{th} species.

$$E = \frac{H'}{H'_{max}} \tag{2}$$

where:

H'_{max} = ln(SR).

In addition, rarefaction method was used to estimate the richness of herbaceous species in different sites. Rarefaction curve shows standardized comparison of species richness for three individual-based rarefaction curves (Magurran 2004). The original data was used for calculating the diversity indices.

Statistical analysis. Tukey Test was applied for comparing the means of species diversity indices and soil properties amongst different sites using SPSS software (Version 18, 2010).

In order to recognize plant species groups within predefined categories, cluster analysis was used to classify the samples based on abundance data using a Sørensen distance measurement and flexible beta linkage – PC-ORD for Windows (Version 4, 1999).

Detrended correspondence analysis (DCA) was applied to assess the rate and direction of changes on the plant composition in different stands. Indicator species analysis accompanied by Monte Carlo test was used to determine the characteristic species of each site. For an ecological interpretation of the ordination result, scores of plots of the first two ordination axes were correlated with corresponding measurements of environmental variables using Spearman rank correlation – PC-ORD for Windows (Version 4, 1999). Before data analysis, species with less than 5% frequency were deleted from the species matrix and the matrix of soil physical and chemical variables was standardized to a mean of 0 and variance of 1 prior to ordination.

The computer program PC-ORD for Windows (Version 5.0, 2006) was used to calculate all diversity indices and the multivariate analysis (McCune, Grace 2002).

RESULTS

The results showed that there were significant differences in the basal area and canopy cover amongst LD, MD and SD areas (Table 1).

In the study areas (LD, MD and SD) 195 plant taxa were observed which 16 species were woody species

Table 1. Mean and standard error of basal area and canopy cover in less, moderately and severely disturbed areas

	Disturbed area		
	less	moderately	severely
Basal area (m^2)	2.52 (0.006)[a]	0.9 (0.02)[b]	0.1 (0.003)[c]
Canopy cover (m^2)	62.9 (14.2)[a]	35.5 (8.9)[b]	4.3 (1.6)[c]

Different letters indicate the significance differences

including: (*i*) tree species: *Q. brantii*, *Q. infectoria*, *Q. libani*, *Crataegus azarolus* Linnaeus, *Crataegus aronia* (Linnaeus) Bosc ex de Candolle, *Pistacia atlantica* Desfontaines, *Amygdalus communis* Linnaeus, (*ii*) shrub species: *Lonicera nummulariifolia* Jaubert & Spach, *Rosa canina* Linnaeus are the most abundant species. Floristic information and species of trees, shrubs and herbaceous plants are shown in Table 2. Some recorded species were exclusive in 3 sites. For instance some exclusive species were observed in LD area including: *Allium macrochaetum* Boissier & Haussknecht, *Alyssum szowitsianum* Fischer & C.A. Meyer, *Astragalus* (*Adiaspastus*) *michauxianus* Boissier, *Muscari longipes* Boissier, *Rumex acetosella* Linnaeus, *Scorzonera laciniata* Linnaeus.

Some exclusive species in MD area included: *Traginia latyfolia* Linnaeus, *Chardinia orientalis* (Linnaeus) Kuntze, *Lactuca serriola* Linnaeus, *Scorzonera phaeopappa* (Boissier) Boissier, *Carduus arabicus* von Jacquin ex Murray subsp. *arabicus*, *Lathyrus inconspicuus* Linnaeus.

Some exclusive species in SD area are included: *Cousinia inflata* Boissier & Haussknecht ex Boissier, *Sonchus arvensis* Linnaeus, *Vicia narbonensis* Linnaeus, *Scabiosa macrochaete* Boissier & Haussknecht, *Medicago radiata* Linnaeus, *Lolium perenne* Linnaeus.

Moreover, 179 herbaceous species were identified in the studied areas which belonged to 103 genera and 27 families (Table 2). 41 species (21.02%) belonged to Asteraceae or Compositae, 31 species (15.9%) belonged to Fabaceae, 19 species (9.75%)

Table 2. Family, the scientific name of the species and percentage of species frequency in different sites

Family	Scientific name	Frequency (%)		
		LD	MD	SD
Apiaceae	*Apium* spp.	78	22	11
	Bunium coringerum (Boissier & Haussknecht) Drude	56	44	0
	Bunium elegans (Fenzl) Freyn	44	33	0
	Bunium cylindricum (Boissier & Hohenacker) Drude	22	22	0
	Chaerophyllum macropodon Boissier	22	44	0
	Eryngium billardieri F. Delaroche	11	11	33
	Eryngium thyrsoideum Boissier	11	0	44
	Falcaria vulgaris Bernhardi	33	22	11
	Grammosciadium platycarpum Boissier & Haussknecht	44	11	0
	Grammosciadium scabridum Boissier	44	33	0
	Pimpinella tragium Villars	100	22	0
	Prangos ferulacea (Linnaeus) Lindley	56	22	0
	Scandix iberica Marschall von Bieberstein	0	33	33
	Scandix stellata Banks & Solander	11	0	0
	Smyrniopsis aucheri Boissier	33	0	0
	Torilis heterophylla Gussone	0	11	56
	Torilis leptophylla (Linnaeus) Reichenbach f.	0	89	56
	Traginia latyfolia Linnaeus	0	11	0
Araceae	*Arum conophalloides* Kotschy ex Schott	33	0	0
Asteraceae	*Achillea biebersteinii* Afanassiev	22	0	0
	Achillea millefolium Linnaeus ssp. *millefolium*	67	33	11
	Achillea wilhelmsii C. Koch	11	22	0
	Anthemis hyalina de Candolle	0	33	56
	Anthemis haussknechtii Boissier & Reuter var. *haussknechtii*	56	22	11
	Anthemis tinctoria Linnaeus	78	22	11
	Carduus arabicus von Jacquin ex Murray subsp. *arabicus*	0	11	0
	Carduus spp.	0	0	11
	Centaurea aggregata Fischer & C.A. Meyer ex de Candolle subsp. *aggregata*	44	0	0
	Centaurea behen Linnaeus	56	0	0
	Centaurea solstitialis Linnaeus	44	22	33

Table 2. to be continued

Family	Scientific name	Frequency (%)		
		LD	MD	SD
Asteraceae	*Centaurea virgata* Lamarck subsp. *squarrosa* (von Willdenow) Gugler	44	22	33
	Cephalorrhynchus tuberusum Gray	33	0	0
	Chardinia orientalis (Linnaeus) Kuntze	0	78	0
	Cirsium haussknechtii Boissier	0	0	11
	Cousinia inflata Boissier & Haussknecht ex Boissier	0	0	22
	Crepis pulchra Linnaeus subsp. *pulchra*	0	11	0
	Crupina crupinastrum (Moris) Visiani	0	44	44
	Echinops inermis Boissier & Haussknecht	11	0	0
	Echinops orientalis von Trautvetter	0	11	56
	Echinops haussknechii Boissier	0	22	67
	Gundelia tournefortii Linnaeus	0	56	44
	Hieracium procerum Fries	11	11	0
	Hieracium spp.	11	11	0
	Lactuca serriola Linnaeus	0	22	0
	Lactuca aculeata Boissier & Kotschy	56	67	0
	Picnomon acarna (Linnaeus) de Cassini	11	44	33
	Rhagadiolus angulusus de Jussieu	0	11	0
	Rhagadiolus stellatus (Linnaeus) Gaertner	0	22	0
	Scariola orientalis (Boissier) Soják subsp. *orientalis*	0	22	33
	Scariola spp.	56	11	22
	Scorzonera laciniata Linnaeus	11	11	0
	Scorzonera luristanica Rechinger f.	22	0	11
	Scorzonera mucida Rechinger f.	44	0	0
	Scorzonera phaeopappa (Boissier) Boissier	0	44	0
	Scorzonera calyculata Boissier	44	44	11
	Sonchus arvensis Linnaeus	0	0	11
	Steptorrhamphus tuberosus (von Jacquin) Grossheim	33	0	0
	Tragopogon bornmuelleri M. Ownbey & Rechinger f.	78	11	0
	Tragopogon buphthalmoides (de Candolle) Boissier var. *buphthalmoides*	67	0	0
Boraginaceae	*Anchusa italica* Retzius var. *italica*	33	56	0
	Cerinthe minor Linnaeus	11	0	11
	Echium italicum Linnaeus var. *italicum*	11	0	11
	Onosma microcarpum de Candolle	0	0	11
	Symphytum kurdicum Boissier & Haussknecht	0	0	11
Brassicaceae	*Alyssum Linifolium* Stephani ex von Willdenow	67	0	0
	Alyssum szowitsianum Fischer & C.A. Meyer	11	44	11
	Arabis nova Villars	22	0	0
	Thlaspi perfoliatum Linnaeus	11	0	0
Caryophyllaceae	*Cerastium dichotomum* Linnaeus	11	0	0
	Cerastium glomeratum Thuillier	11	0	0
	Dianthus orientalis Adams	22	11	0
	Minuartia meyeri (Boissier) Bornmüller	0	0	11
	Silene chlorifolia Smith	33	0	0
	Silene conoidea Linnaeus	44	0	0
	Silene latifolia Poiret	22	0	0
	Silene ampullata Boissier	22	0	0
Cistaceae	*Helianthemum ledifolium* (Linnaeus) Miller var. *ledifolium*	0	44	67
Convolvulaceae	*Convolvulus arvensis* Linnaeus	0	0	11
Cucurbitaceae	*Bryonia multiflora* Boissier & von Heldreich	11	0	0
Dipsacaceae	*Cephalaria microcephala* Boissier	11	0	0
	Pterocephalus plumosus (Linnaeus) Coulter	0	11	0
	Scabiosa macrochaete Boissier & Haussknecht	0	0	11
Euphorbiaceae	*Euphorbia macrocarpa* Boissier & Buhse	22	0	0
	Euphorbia macroclada Boissier	33	11	0

Table 2. to be continued

Family	Scientific name	Frequency (%)		
		LD	MD	SD
Euphorbiaceae	*Euphorbia szovitsii* Fischer & C.A. Meyer	22	22	0
Fabaceae (Fabiodae)	*Astragalus* (*Adiaspastus*) *michauxianus* Boissier	22	22	0
	Astragalus (*Anthylloidei*) *tortuosus* de Candolle	22	11	11
	Astragalus (*Hymenostegis*) *persicus* (de Candolle) Fischer & C.A. Meyer	0	44	67
	Astragalus (*Incani*) *curvirostris* Boissier	78	0	0
	Astragalus (*Platonychium*) *verus* Olivier	11	0	0
	Astragalus nervestipulus Boissier	22	33	11
	Cicer oxyodon Boissier & Hohenacker	22	0	0
	Lathyrus inconspicuus Linnaeus var. *inconspicuus*	0	44	0
	Lathyrus boissieri Širjaev	0	11	0
	Lens orientalis (Boissier) Handel-Mazzetti	0	22	0
	Lotus gebelia Ventenat var. *gebelia*	22	22	0
	Medicago radiata Linnaeus	0	22	0
	Medicago rigidula (Linnaeus) Allioni var. *rigidula*	0	0	22
	Medicago sativa Linnaeus	0	22	0
	Oxytropis kotschyana Boissier & Hohenacker	11	0	0
	Pisum sativum Linnaeus subsp. *sativum*	0	11	0
	Trifolium arvense Linnaeus var. *arvense*	0	11	11
	Trifolium campestre von Schreber	0	44	22
	Trifolium grandiflorum von Schreber	11	0	0
	Trifolium pilulare Boissier	0	56	56
	Trifolium pratense Linnaeus var. *pratense*	44	22	0
	Trifolium purpureum Loisel	11	56	44
	Trifolium repens Linnaeus	22	44	0
	Trifolium spumusum Linnaeus	0	33	0
	Trigonella monantha C.A. Meyer subsp. *monantha*	0	11	0
	Vicia assyriaca Boissier	11	0	0
	Vicia ervilia (Linnaeus) von Willdenow	0	11	0
	Vicia michauxii Sprengel var. *michauxii*	0	11	0
	Vicia sericocarpa Fenzl	11	0	0
	Vicia narbonensis Linnaeus	0	0	11
	Vicia variabilis Freyn & Sintenis	89	11	0
Geraniaceae	*Geranium tuberosum* Linnaeus subsp. *micranthum* Schönbeck-Temesy	67	44	0
Hypericaceae	*Hypericum asperulum* Jaubert & Spach	0	0	11
	Hypericum perforatum Linnaeus	22	33	0
	Hypericum scabrum Linnaeus	22	33	0
	Hypericum hirtellum Boissier	0	22	0
Iridaceae	*Gynandris sisyrinchium* (Linnaeus) Parlatore	11	0	0
Lamiaceae	*Lallemantia peltata* (Linnaeus) Fischer & C.A. Meyer	11	0	0
	Lamium album Linnaeus subsp. *album*	67	11	0
	Lamium galeobdolon subsp. *montanum* (Persoon) Hayek	22	0	0
	Phlomis persica Boissier	0	11	00
	Phlomis olivieri Bentham	11	0	11
	Salvia bracteata Banks & Solander	33	11	0
	Salvia syriacasa Linnaues	11	0	0
	Ziziphora capitata Linnaeus subsp. *capitata*	22	78	11
Liliaceae	*Allium atroviolaceum* Boissier	0	11	11
	Allium materculae Bordzilowski	22	0	0
	Allium sarawschanicum Regel	22	0	0
	Allium macrochaetum Boissier & Haussknecht	11	11	0
	Allium stamineum Boissier	11	11	0
	Bellevalia longipes Post	11	11	0
	Muscari longipes Boissier	11	0	0
	Muscari caucasicum (Grisebach) Baker	44	22	0
	Alcea kurdica (von Schlechtendal) Alefeld	67	67	0

Table 2. to be continued

Family	Scientific name	Frequency (%)		
		LD	MD	SD
Orchidaceae	*Epipactis helleborine* (Linnaeus) von Crantz	22	0	0
Plantaginaceae	*Plantago lanceolata* Linnaeus	11	0	0
	Plantago major Linnaeus	22	0	0
Poaceae	*Lolium perenne* Linnaeus	0	0	22
	Aegilops columnaris Zhukovsky	0	0	11
	Aegilops spp.	0	22	67
	Aegilops triuncialis Linnaeus	0	11	11
	Aegilops umbellulata Zhukovsky	22	11	0
	Agropyron panormitanum Parlatore	44	11	11
	Agropyron elongatiforme Drobov	0	22	0
	Arrhenatherum kotschyi Boissier	11	0	11
	Avena sativa Linnaeus	0	56	11
	Bromus danthoniae von Trinius var. *danthoniae*	100	67	0
	Bromus sterilis Linnaeus	0	56	67
	Bromus tectorum Linnaeus var. *tectorum*	100	11	0
	Dactylis glomerata Linnaeus subsp. *glomerata*	11	44	0
	Eremopoa persica (von Trinius) Roshevitz var. *persica*	0	33	89
	Heteranthelium piliferum (Banks & Solander) Hochstetter	67	67	44
	Hordeum bulbosum Linnaeus	0	0	11
	Milium vernale Marschall von Bieberstein	33	0	0
	Poa bulbosa Linnaeus var. *vivipara* Koeler	89	78	56
	Taeniatherum crinitum (von Schreber) Nevski	0	78	89
Polygonaceae	*Rumex acetosella* Linnaeus	44	11	0
	Rumex tuberusus Linnaeus	56	0	0
Ranunculaceae	*Ceratocephalus testiculatus* (von Crantz) Roth	0	11	0
	Ficaria kochii (von Ledebour) Iranshahr & Rechinger f.	11	0	0
	Ranunculus arvensis Linnaeus	67	44	0
	Ranunculus aucheri Boissier	67	33	11
Rosaceae	*Geum urbanum* Linnaeus	33	0	0
	Sanguisorba minor Scopoli	0	0	11
	Crataegus azarolus Linnaeus	78	11	11
	Crataegus aronia (Linnaeus) Bosc ex de Candolle	33	0	22
	Amygdalus communis Linnaeus	11	0	0
	Pyrus syriaca Boissier	33	0	0
	Pyrus glabra Boissier	33	0	0
	Rosa canina Linnaeus	0	0	0
	Rosa foetida Herrmann	0	0	0
	Cerasus microcarpa C.A. Meyer	0	0	0
	Cotoneaster nummularioides Pojarkova	22	0	0
Anacardiaceae	*Pistacia atlantica* Desfontaines	0	11	0
Caprifoliaceae	*Lonicera nummulariifolia* Jaubert & Spach	0	0	0
Fagaceae	*Quercus brantii* Lindley	100	100	100
	Quercus infectoria Olivier	100	89	11
	Quercus libani Olivier	10	89	0
Rubiaceae	*Galium aparine* Linnaeus	100	44	0
	Galium verum Linnaeus	67	56	0
	Galium tricornutum Dandy	100	33	0
	Callipeltis cucullaris (Linnaeus) de Candolle	0	0	22
	Veronica orientalis Miller	22	0	0
Valerianaceae	*Valerianella tuberculata* Boissier	22	11	0
	Valerianella vesicaria (Linnaeus) Moench	0	0	22
Aceraceae	*Acer cinerascens* Boissier	0	0	0
Thymelaceae	*Daphne mucronata* Royle	0	0	0

LD – less disturbed, MD – moderately disturbed, SD – severely disturbed

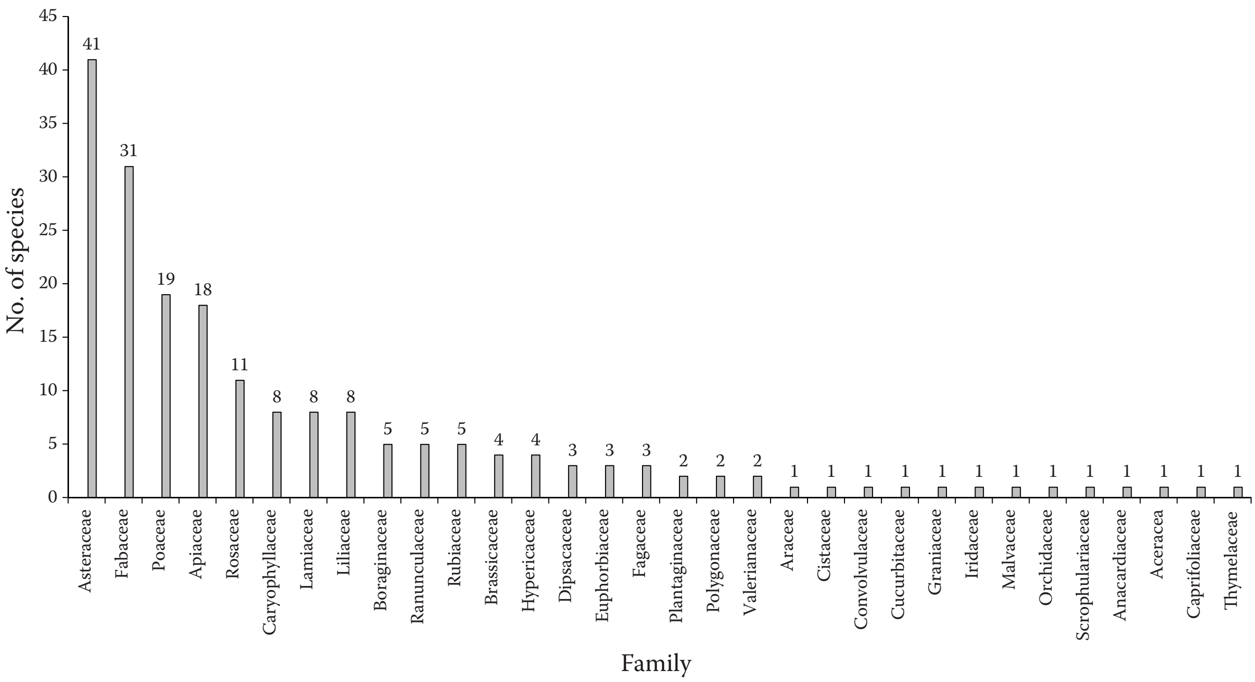

Fig. 1. The number of plant species in each family in the study areas

belonged to Poaceae, and 18 species (9.23%) Apiaceae had the highest amount of plant species (Fig. 1). Furthermore one species was just recorded in the families of Araceae, Cistaceae, Convolvulaceae, Cucurbitaceae, Geraniaceae, Iridaceae, Malvaceae, Orchidaceae, Scrophulariaceae, Anacardiaceae, Aceraceae, Caprifoliaceae, and Thymelaceae.

Investigating biodiversity indices of plant species in the three study areas showed that the highest value was obtained for the LD area and the lowest value was obtained for the severely disturbed area (Table 3). There are significant differences among the levels of disturbance. Rarefaction curve showed that LD forest has the highest number of species and the SD has the lowest number of species (Fig. 2). The curve of MD area is similar to the curve of the LD forest.

The results of the analyses of the soil physical and chemical properties are comprehensively presented in Table 4. The results of Tukey test (Table 4) showed that there is no significant difference in acidity, C/N, exchangeable potassium, and silt among the studied areas (LD, MD, and SD). The organic carbon, total nitrogen, and clay mean differences are significant between the LD area and other areas. The absorbable phosphorus is significantly lowest in the SD area.

The result of the cluster analysis showed that the sample plots are divided into three groups (Fig. 3). The samples taken at the LD area are placed in the

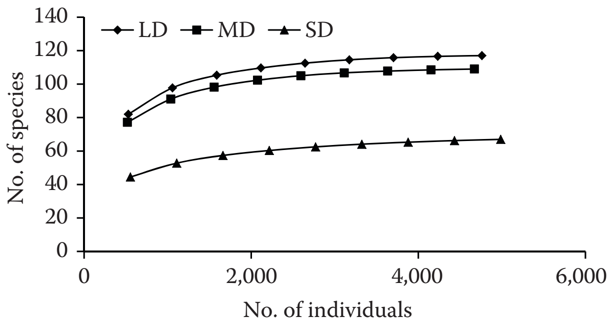

Fig. 2. The rarefaction curve relating to herbaceous plant in three sites

LD – less disturbed area, MD – moderately disturbed area, SD – severely disturbed area

Table 3. Mean and standard error of diversity indices in less, moderately and severely disturbed areas

Diversity index	Disturbed area		
	less	moderately	severely
Species richness	41.5 (2.13)[a]	32.1 (2.13)[b]	18.3 (2.10)[c]
Shannon Wiener evenness	0.88 (0.19)[a]	0.86 (0.18)[a]	0.86 (0.19)[a]
Shannon Wiener species diversity	3.27 (0.99)[a]	2.99 (0.99)[b]	2.4386 (0.99)[c]
Simpson's species diversity	0.94 (0.12)[a]	0.92 (0.12)[a]	0.88 (0.12)[b]

Different letters indicate the significance differences

Table 4. Mean and standard error of soil physical and chemical properties in less, moderately and severely disturbed areas

Soil properties	Disturbed area		
	less	moderately	severely
pH	7.3 (0.050)[a]	7.4 (0.082)[a]	7.5 (0.055)[a]
Organic C (%)	6.17 (1.27)[a]	3.32 (0.29)[b]	2.18 (0.25)[b]
Total N (%)	0.617 (0.125)[a]	0.330 (0.029)[b]	0.217 (0.024)[b]
C/N	9.95 (0.034)[a]	10.07 (0.043)[a]	10.06 (0.034)[a]
Absorbable P ($mg \cdot kg^{-1}$)	34.13(3.106)[a]	4.24 (26.14)[a]	2.24 (14.11)[b]
Exchangeable K ($mg \cdot kg^{-1}$)	273.78 (15.737)[a]	327.89 (71.11)[a]	350.11 (53.11)[a]
Clay (%)	16.4 (1.56)[a]	26.4 (3.50)[b]	29.9 (1.60)[b]
Silt (%)	31.6 (1.12)[a]	32.9 (2.46)[a]	42.2 (5.01)[a]
Sand (%)	52.0 (1.290)[a]	40.7 (5.722)[ab]	27.9 (5.64)[b]

Different letters indicate the significance differences

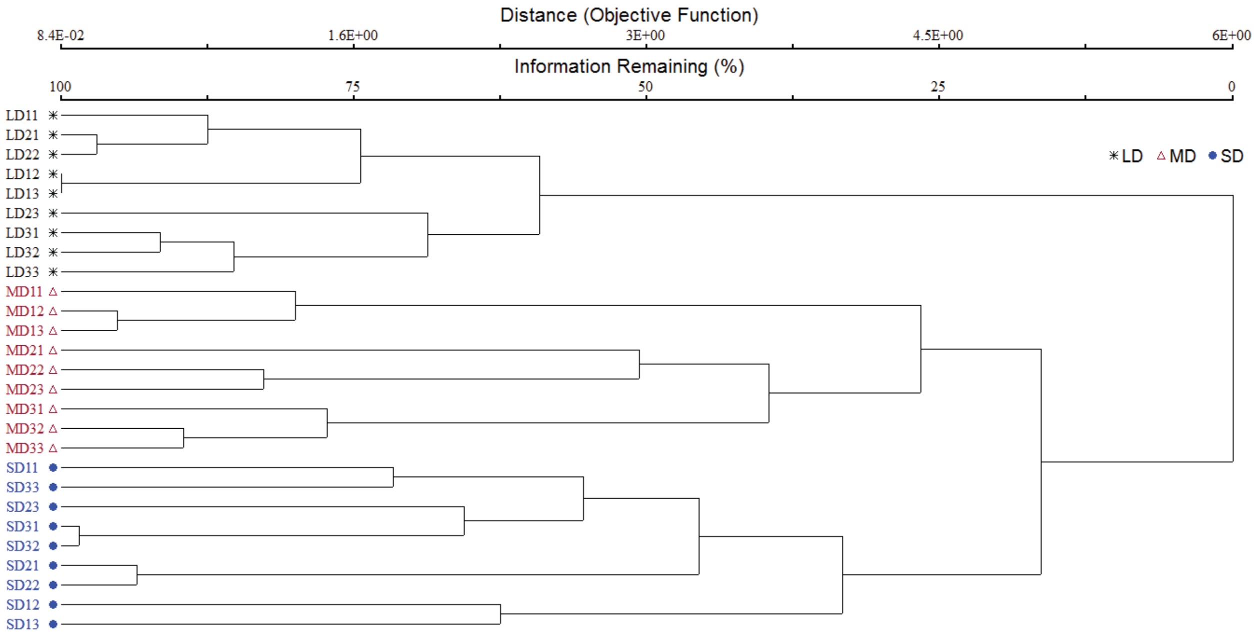

Fig. 3. The cluster analysis result of the sampled plots taken from the investigated areas

LD – less disturbed area, MD – moderately disturbed area, SD – severely disturbed area

first group, sample plots taken at the MD area are placed in the second group and sample plots from the SD area are located in the third group.

Fig. 4 is indicative of the ordination results carried out by DCA for the sample plots taken at the LD, MD and SD stands. The plots of the LD stand are located in the negative part of the first axis and the plots taken at the SD stand are located in the positive part of the first axis. The plots of MD area are placed around the centre coordinate axes and between the two previous sites. Therefore, the first axis can be interpreted as disturbance gradient as the intensity of disturbance is increased from the negative part of the axis towards the positive part. The correlation between soil variables and the axes of this analysis showed that clay, silt percent, and absorbable potassium parameters are positively correlated with the first axis and while the sand percent, total nitrogen, organic carbon percent, and absorbable phosphorus are negatively correlated with the first axis. Other factors such as bulk density, pH, and C/N ratio have no significant correlation with the DCA axes.

Indicator species analysis accompanied by Monte Carlo test introduced different species with high significant indicator values as follows:

(*i*) Indicator species of LD area: *Anthemis tinctoria* Linnaeus, *Apium* spp., *Astragalus* (*Incani*) *curvirostris* Boissier, *Bromus sterilis*, *Centaurea aggregata* Fischer & C.A. Meyer ex de Candolle subsp. *aggregata*, *Centaurea behen* Linnaeus, *Dactylis glomerata* Linnaeus subsp. *glomerata*, *Galium*

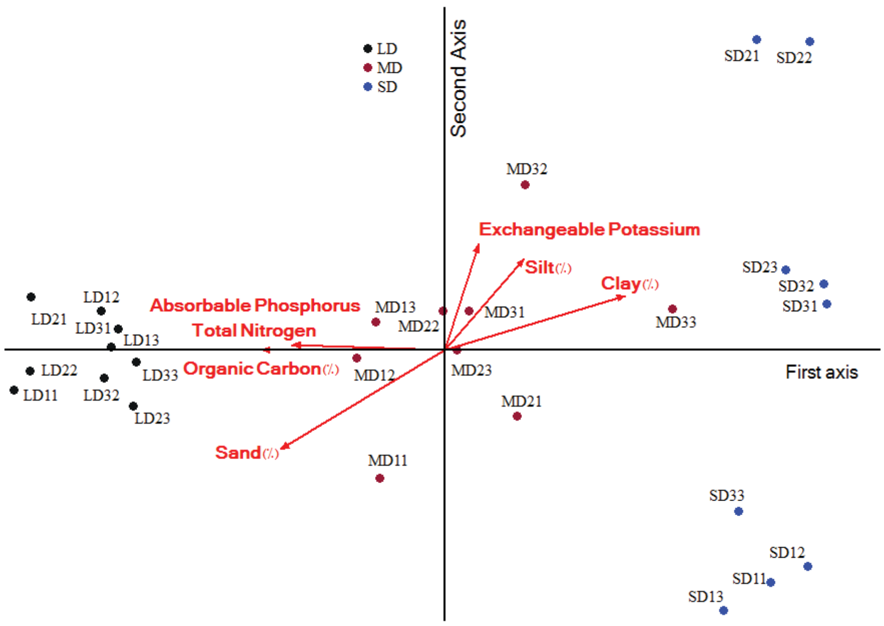

Fig. 4. Detrended correspondence analysis ordination result of the sample plots taken at the less, moderately and severely disturbed areas

LD – less disturbed area, MD – moderately disturbed area, SD – severely disturbed area

aparine Linnaeus, *Galium tricornutum* Dandy, *Lamium album* Linnaeus subsp. *album*, *Milium vernale* Marschall von Bieberstein, *Pimpinella tragium* Villars, *Ranunculus demissus* de Candolle, *Rumex tuberusus* Linnaeus, *Scorzonera mucida* Rechinger f., *Symphytum kurdicum* Boissier & Haussknecht, *Silene conoidea* Linnaeus, *Tragopogon bornmuelleri* M. Ownbey & Rechinger f., *Tragopogon buphthalmoides* (de Candolle) Boissier var. *buphthalmoides*, *Tragopogon vaginatus* Ownbey & Rechinger f., *Vicia variabilis* Freyn & Sintenis;

(*ii*) Indicator species of MD area: *Chaerophyllum macropodon* Boissier, *L. inconspicuus* var. *inconspicuus*, *S. phaeopappa*, *Torilis leptophylla* (Linnaeus) Reichenbach f., *Ziziphora capitata* Linnaeus subsp. *capitata*;

(*iii*) Indicator species of SD area: *Aegilops triuncialis* Linnaeus, *Echinops orientalis* von Trautvetter, *Echinops haussknechii* Boissier, *Helianthemum ledifolium* (Linnaeus) Miller var. *ledifolium*, *Heteranthelium piliferum* (Banks & Solander) Hochstetter, *Taeniatherum crinitum* (von Schreber) Nevski, *Torilis heterophylla* Gussone.

DISCUSSION

In this study, 195 plant taxa were recorded in the investigated oak forests in which 47 and 25 species were just recorded in LD and MD areas respectively. Also, 15 species were solely present in the SD ones. The presence of some of the species in the SD site was due to their resistance to grazing and trampling of human and cattle (Eshaghi Rad et al. 2009). In this study some genus like *Scariola* F.W. Schmidt, *Cirsium* Miller, and *Cousinia* de Cassini of Asteraceae family were frequent only in SD area due to the destructive and animals over grazing situation (Habibi, Satarian 2013). According to cluster and DCA analysis results, the sample plots of LD, MD and SD can be classified into the three groups in which a disturbance gradient is the most important factor affecting the distribution of plant species in the region. These findings are related to large open gaps within highly disturbed patches that create a dry microclimate reducing the herbaceous species richness (Esther et al. 2014). Large open gaps within the highly disturbed forests create a dry climate which interferes with the small amount of herbaceous establishment. This reduces herbaceous species richness and diversity in the long run. Also, because of the position of these open spaces in the highly disturbed stands, wind increases water loss from the soil surface and decreases air humidity, which could be unfavourable for some plant species (Harper et al. 2005). Based on all calculated indices, the species richness and diversity in the LD area was higher than MD and SD areas (Table 3). Human activities, like grazing, seeding and fertilizing, can cause a serious change in biodiversity, aggravating the appearance of invasive species (Zimdahl 2004). In this study, a progressive reduction in species richness and diversity from the LD to the SD area showed that how natural communities are influenced by anthropogenic disturbances, that it agrees with findings of Bhuyan et al. (2003) in a tropical wet evergreen forest in Arunachal Pradesh, northeast India and Mishra et al. (2004) in northeast India and Esther et al. (2014) in Kakamega forest, western Kenya. In similar results, Majumdar and Datta (2015) illustrated that the effects of anthropogenic disturbances in Northeast India resulted in declining the levels of all diversity indices. Moreover Onaindia et al. (2004) investigated the biodiversity in various destructive conditions of mixed oak forests in the north of Spain and found out that the species richness of the herbs were higher in masses with less destruction.

The results of this investigation show the significant differences in some soil physical and chemical properties in three sites. Clay percentage was higher in MD and SD areas than LD and sand percentage was vice versa. The bare soil in MD and SD areas (with low canopy cover and high soil compaction) were exposed to direct impact of raindrops which resulted in soil erosion. Refahi (1996) stated that smaller soil particles were more sensitive to erosion. Therefore, more percentage of sand in the LD area could be related to more canopy cover and lower erosion.

Organic carbon and total nitrogen concentration were higher in the LD plots than in the MD and SD ones. Reduction of these soil factors in the disturbed areas could have resulted from traditional utilization and grazing livestock and the decreasing the number of trees per hectare, canopy cover and leaf litter. Disturbance may result in degradation of soil properties (enhancement in soil compaction and decrease in soil macroporosity, infiltration) and may cause a decrease in site productivity (Solgi 2014). There is the risk of nutrient loss if soils are not noticed in our forest management strategies, especially where multiple disturbances may interact. Harvesting and removal of biomass can result in the reduction of soil nutrients (Maynard et al. 2013).

The difference in the ability of plants, especially trees, in changing soil environment, mainly occurs due to increases in organic matter and its effect on nutrient cycling (Salehi et al. 2005). On the other hand, the canopy of trees and shrubs prevent the formation of soil crusts, which would increase infiltration capacity and soil moisture (Janeau et al. 1999; Pariente 2002). So, in SD area with less than 10% canopy of trees the bare soil is exposed to direct radiation and wind, which promotes higher evaporation. Also, it is subjected to the direct impact of raindrops and therefore experiences higher soil compaction. These bare soil features lead to drier conditions and poor organic matter and nutrient content (Rostagno, del Valle 1988). In this context, Moreno et al. (2007) stated that harvesting trees and pollarding them leads to the reduction of organic matter and soil quality. Bickham (2013) found significant depletions in soil moisture following salvage-logging and total soil carbon and nitrogen levels will be lower in logged areas than control areas. The remarkable changes of soil characteristics that represent soil fertility can have great influences on ecosystem stability, success of future regeneration and structure of plant communities (Mokarram Keshtiban et al. 2013).

CONCLUSIONS

In general, the results of the current study illustrated that LD forests were more diverse than MD and SD areas of oak forests in Zagros forests. By increasing the intensity of destruction, the number of species would be decreased and the community structure and species composition would be changed. Also, anthropogenic disturbance decreased the amount of organic matter (carbon and nitrogen) according to the degree of man-made disturbances. Therefore, a comprehensive program should be considered for forest conservation in this region and to transform the highly disturbed forests to moderately disturbed ones in the short time plan.

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