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Influence of Traditional Forest Harvesting on Woody Species Diversity at Different Vertical Layers of Oak Forest: A Case Study

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ABSTRACT

The aim of this study was to assess the influence of traditional harvesting on woody species richness and diversity at different vertical layers in the northwest of Zagros forests, Iran. Two forest stands including disturbed and less disturbed with similar physiographic condition were selected. 30 circularly shaped plots with 1000 m surface area were selected based on random-systematic sampling with 50×50 m network dimensions. The means of different diversity indices in total and at different vertical strata were calculated and student's t-test was used to compare the mean of all indices difference in the treatments. Importance Value Index (IVI) of different species at different layers was calculated. The results showed that the mean of all indices in the disturbed stand were significantly lower than in the less disturbed one, however, the mean of evenness index did not statistically show any significant differences between two stands. In total, the Shannon diversity, Simpson diversity and Margalef richness indices of the disturbed stand were 47.59 %, 36.62% and 63.72%, respectively lower than in the less disturbed stand. In the disturbed stand, the most important species were Quercus infectoria (with 70.48% IVI), Quercus libanii (with 50.79% IVI) and Crataegus spp. (with 33.59% IVI). These species were also important species in the less disturbed stand with 61.38%, 54.89% and 43.11%, respectively importance value. As a whole, the results revealed that the traditional harvesting threats the forest species diversity and also simplifies the structure of these precious forests. Our results showed that the current traditional harvesting and grazing reduced the woody species diversity and simplified the forest structure to only one story.

Keywords: Zagros Forests, Traditional Harvesting, Diversity Indices, Importance Value Index, Vertical Layers, Disturbed Stand, Less Disturbed Stand.

Mathematics Subject Classification: 00A22, 97F80

Journal of Economic Literature (JEL) Classification: Q23

1. INTRODUCTION

Zagros forests cover a vast area in the Zagros Mountain ranges in Iran and include five million hectare out of 12 million hectare of total forest cover in Iran. These forests have semi-Mediterranean climate with extremely cold winters (Jazirehei and Ebrahimi 2003, Bazyar et al. 2013). Oak (Quercus spp.) species are the most abundant species in these forests so that, these forest named as oak forests (Imani et al. 2013, Soltani et al. 2015). Because of the long history of settlement and utilization, Zagros forests have lost their merchantable wood production capacity, but they are still important since their environmental, social and economic aspects (Djamali et al. 2009).

In Zagros forests, dwellers heavily depend on the forests, as their livestock graze them for almost seven months per year. In these forests, especially in northern part, there is a kind of traditional ownership and conventional forest management system. According to this system, individual households harvest their privately owned forests via ground and canopy level cutting of oaks trees. In ground level cutting, the trees or shoots are cut near the ground to facilitate regeneration of new sapling or shoots. At canopy level cutting, dwellers usually harvest branches and foliage (less than 5 cm thick) from oak trees which is called in local term “Galazani” (Coppicing) (Haidari et al. 2014). In addition to coppicing and grazing, the important traditional forest harvesting practices includes harvesting of fuel and construction wood and also non-wood forest products (Valipour et al. 2014). Beside the traditional forest harvesting, population growth as well as weakness of economic and cultural development have led to the degradation of Zagros forests (Haidari and Rezaei 2013). In this regard, the government have been implemented different Forest Management Plans (FMPs) during past 40 years. However, Human manipulations have prevented success of FMPs and posed a serious threat to the survival of these natural forests (Jazirehei and Ebrahimi 2003).

Studies which were conducted in Zagros forest, demonstrated that degradation of these forests greatly affects the biodiversity and structural characteristics of forests communities (e.g. Ghazanfari et al. 2004, Heydari et al. 2012, Jalilvand et al. 2013, Valipour et al. 2014). The forests temporal and special changes which have created by human activities could be monitored by Biodiversity indicators (Boutin et al. 2009, Gao et al. 2014, Ahmad, 2015). Species diversity (e.g. Shannon diversity and Simpson’s diversity indices), species richness (e.g. Margalef’s richness index) and species evenness (Shannon’s evenness index) are important indicators of forest biodiversity. There are various studies which were done to investigate the traditional Zagros forest harvesting impacts via implementing biodiversity indicators (e.g. Abasi et al. 2009, Jahantab et al. 2010, Parma and Shataee Jouybari 2010, Haidari et al., 2014).

Although recent studies have identified the Zagros forests degradation negative impacts on forest biodiversity and structure (Khalyaniand and Mayer 2013; Bazyar et al. 2013; Valipour et al., 2014) but more detail information is needed to accurately adapt FMP with forest stands changes. Forest stands diversity may not be properly and accurately represented by tree species diversity alone, so the forest structure by different tree sizes and ages should also be taken into account. Therefore, the purposes of this study were to (1) quantify woody diversity on the basis of the vertical stratification and (2) compare the diversity indices between the disturbed and the less disturbed stand.

2. GENERATION OF THE DATA

2.1. Study site

The study was conducted in Sardasht region, northern part of Zagros forests, and western Iranian state. Due to the long history of utilization most of the existent forests in Sardasht region are disturbed. These forest stands have become even-age, homogenous with almost one stratum. The disturbed stand in this study is located in longitude of 45˚ 36´ east and latitude of 36˚ 9´ northwest. In order to find out the influence of traditional forest harvesting on woody species diversity there is a need to choose a less disturbed forest stand as a control. So, the less disturbed stand was selected near the disturbed one which has remained almost intact (about 100 years) because of its ethical importance. Both stands were located at 1430 m above sea level and have same physiographic condition. Mean annual precipitation is 795.1 mm, mean annual temperature is 12.1° C, and the length of dry season is 5 months (based on Embrothermic curve) from June to September.

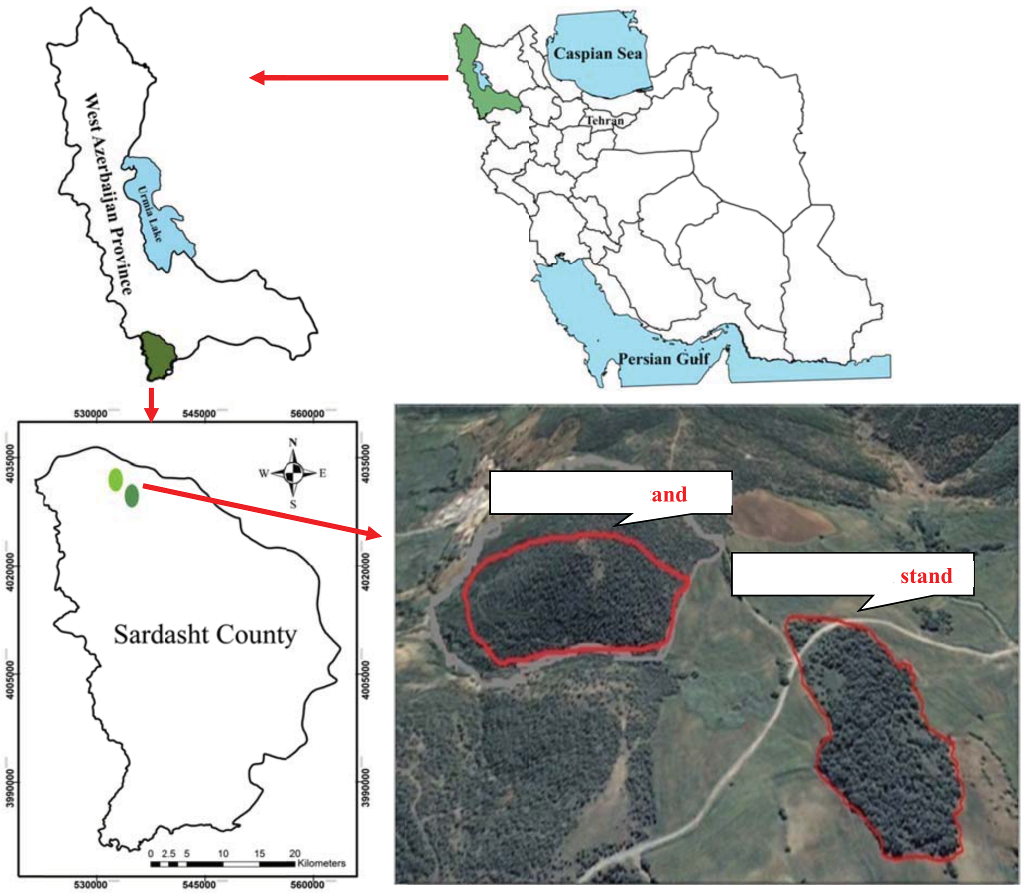

Figure 1. Location of study area

1.2. Methodology

In order to calculate different biodiversity indices, it is necessary to know the number of species in a given region. In this study, 30 circle shaped plots (1000 m^2) were chosen by random-systematic sampling method with 50×50 m network dimensions. Since in a typical deciduous forest herbs are 20 cm tall, shrubs rise up to 2.5 m, understory trees are up to10 m tall, and canopy trees are up to 21 m tall, four different vertical layers were sampled: 0–0.20, 0.20–2.50, 2.50–10 and over 10 m (Aizpuru et al. 2000; Onaindia et al. 2004). In each sample plot, variables such as type of species, number of tree and shrub species, and their location in vertical layer were recorded. Also, in the disturbed stand the number of observed evidence of traditional harvesting factors include cutting, grazing, disbranching were recorded and the ratio of them were calculated.

1.3. Data analysis

In the study, the biodiversity was quantified by means of four indices: species richness (S), Shannon's diversity index (H') (Shannon 1949) and Simpson's diversity index (D) (Simpson 1949) and Pielou's evenness index (*J*) Also, in order to indicate the overall ecological importance of species in each stand and at vertical layers the Importance Value Index (IVI) was calculated (Dash, 1993).

1.3.1. Species Richness

The simplest measure of biodiversity is species richness (S) and it is a count of the number of different species in a given area but, this measure is strongly dependent on sample plot size. However, Margalef's richness index (Magurran 1988) tries to solve this problem. So, in this study Margalef's richness index was used and calculated as below [Eq. 1]:

$$D_{Mg}=\frac{(S-1)}{\ln N} \qquad (1)$$

S = total number of species

N = total number of individuals in the sample

In = natural logarithm

1.3.2. Species Diversity

Shannon index (H') was calculated as [Eq. 2]:

$$H'= -\sum_{i=1}^{s} p_i \ln p_i \qquad (2)$$

Where pi is the proportion (*n/N*) of individuals of one particular species found (n) divided by the total number of individuals found (*N*), In is the natural log, Σ is the sum of the calculations, and *s* is the number of species (Magurran 1988).

Simpson index (D), is a diversity index and it is heavily weighted towards the most abundant species in the sample while being less sensitive to species richness, was calculated as [Eq. 3]:

$$D=1-\sum_{i=1}^{s} p_i^2 \qquad (3)$$

In this equation the p_i and s were calculated in same way as Shannon index. Simpson index is usually expressed as 1-D or 1/D. In this study, the former expression (i.e. 1-D) was used (Magurran 1988).

1.3.3. Species evenness

The Pielou's evenness index (J) is calculated as the relation between the value of the Shannon diversity index for the sampled population (H′) and the maximum possible value of the index for the given species number and sample size (H'_{max}) according to formula [Eq. 4] (Magurran 1988).

$$J=\frac{H'}{H_{max}}=\frac{-\sum_{i=1}^{s} p_i \ln p_i}{\ln S} \qquad (4)$$

1.3.4. Importance Value Index (IVI)

Dominance of a species was defined by Importance Value Index (IVI) of the species [Eq. 5]:

$$IVI=\left(\frac{n_i}{\sum_{i=1}^{s} n_i}\times 100+\frac{a_i}{\sum_{i=1}^{s} a_i}\times 100+\frac{f_i}{\sum_{i=1}^{s} f_i}\times 100\right)/3 \qquad (5)$$

Where n_i is the number of individuals of the *i*th species, a_i is the basal area at a breast height of trees belonging to the *i*th species, f_i is the number of quadrats in which the *i*th species appeared (Wu et al. 2011).

The indices were calculated for all plant species at vertical layers within each sample plot as previously reported (MacArthur and MacArthur 1961) using *PC-ORD* for Windows 4.14 (McCune and Mefford 1999). Statistical tests were conducted using SPSS 18.0. The Kolmogorov-Smirnov test (KS-test) was used to determine the normality of distributions. Since the data were distributed normally, the student's t-test was used to test whether there were significant differences in the species richness, diversity and evenness indices among the different vertical layers and in total.

3. RESULTS

3.1. Distribution of various kinds of traditional harvesting destructive factors

Figure 2 shows a proportion of various kinds of anthropogenic influences due to practicing traditional harvesting in the disturbed stand. Grazing had the highest share (33%) followed by disbranching, and integrated disbranching and cutting, respectively.

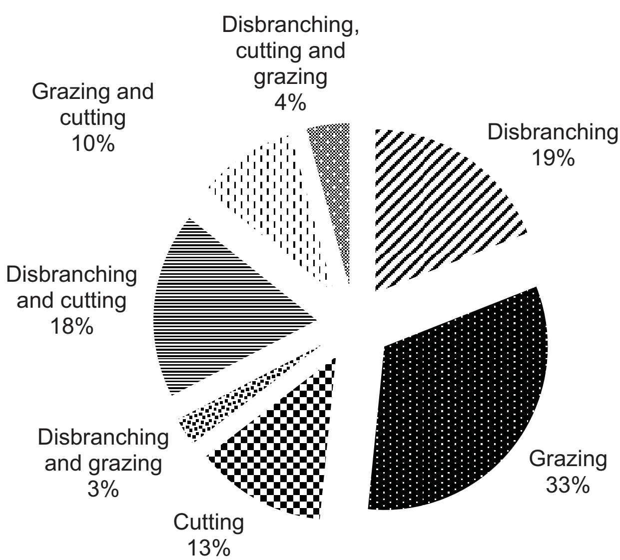

Figure 2. Distribution of various kinds of traditional harvesting destructive factors

Figure 3 and 4 demonstrate species number per hectare at various vertical strata in the less disturbed and the disturbed stands. In the less disturbed stand, totally 13 woody species were recorded in sampling plots, while only 5 woody species were recorded in the disturbed stand. Species such as *Acer monspessulanum*, *Pistacia atlantica*, *Prunus divaricata*, *Amygdalus scoparia*, *Malus orientalis*, *Cotoneaster* sp., *Daphne* sp., *Fraxinus rotundifolia* were not found in the disturbed stand.

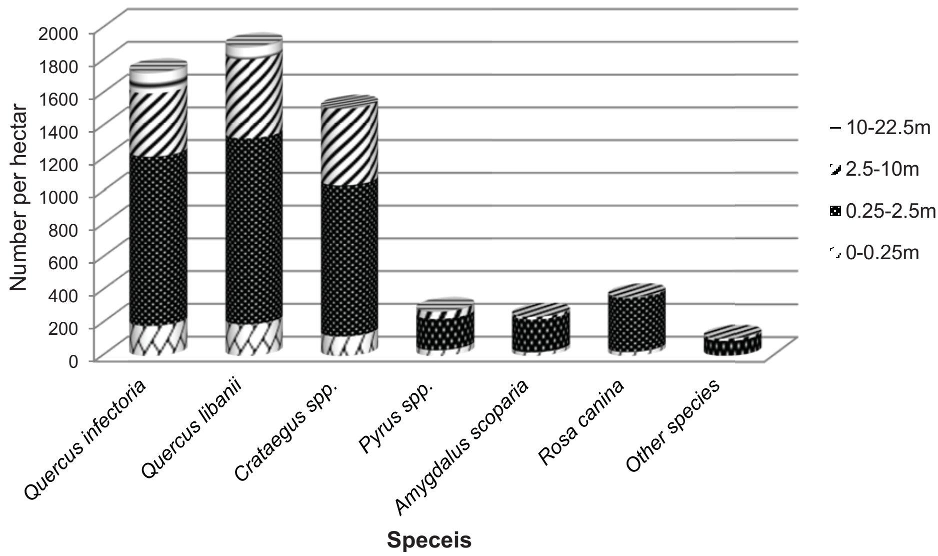

Figure 3. Number of trees per hectare at different vertical strata in the less disturbed stand

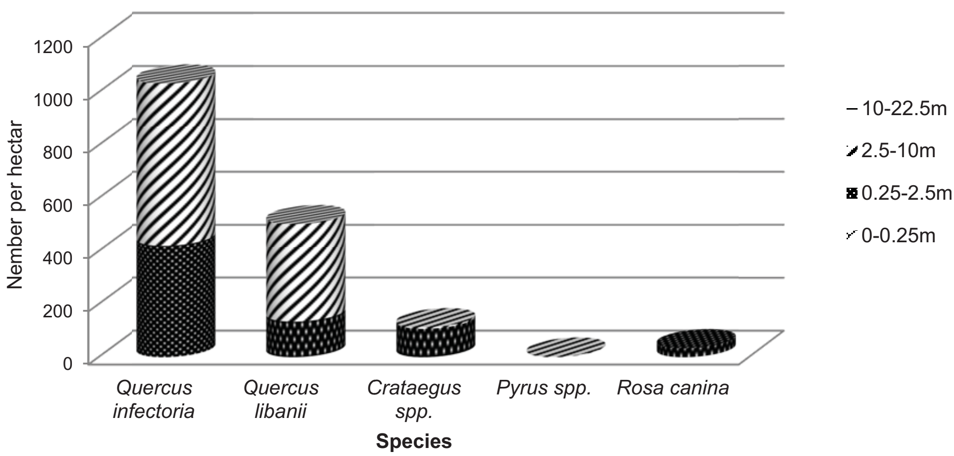

Figure 4. Number of trees per hectare at different vertical strata in the disturbed stand

Species diversity indices in the disturbed and the less disturbed stands at different vertical strata were shown in Table 1. The disturbed stand not only had significantly lower values of tree species richness and tree species diversity than the less disturbed ones, but also it had lower value of tree species richness and species diversity in different vertical strata. The evenness index did not show any significantly difference between two stands.

Table 1. Diversity indices among different strata in the disturbed and the less disturbed stands (Ds=disturbed stand, Lds= less disturbed stand).

Vertical stratification (m)	Stand	H'	D	D_{Mg}	J
0-0.25	Ds	0	0	0	0
	Lds	1.241±0.27	0.66±0.12	0.91±0.23	0.836±0.12
0.25-2.5	Ds	0.85±0.18a	0.50±0.12a	0.49±0.97a	0.78±0.14a
	Lds	1.55±0.22b	0.74±0.07b	1.21±0.27b	0.757±0.97a
2.5-10	Ds	0.60±0.15a	0.40±0.12a	0.37±0.14a	0.66±0.21a
	Lds	1.14±0.22b	0.62±0.11b	0.84±0.21b	0.71±0.12a
>10	Ds	0	0	0	0
	Lds	0.61±0.22	0.41±0.15	0.42±0.21	0.75±0.27
Total	Ds	0.76±0.17a	0.45±0.12a	0.42±0.84a	0.68±0.49a
	Lds	1.45±0.20b	0.71±0.70b	1.14±0.23b	0.70±0.94a

In the less disturbed stand, *Quercus infectoria* and *Quercus libanii* were the most dominant species which occupied almost half of the individuals of the total stand and mainly appeared in all four layers with high IVI. The highest IVI value (74.9%) was recorded for *Quercus infectoria* in the less disturbed stand, while in the disturbed stand, *Quercus infectoria* and *Quercus libanii* were dominant only in the second (0.25- 2.5 m) and third layers (2.5-10 m) with lower height and basal area (Table 2).

Table 2. IVI percent at vertical stratifications in the disturbed and the less disturbed stands (Ds= disturbed stand, Lds= less disturbed stand).

Species	Vertical stratification (m)									
	0-0.25		0.25-2.5		2.5-10		>10		Total	
	Ds	Lds	Ds	Lds	Ds	Lds	Ds	Lds	Ds	Lds
Quercus infectoria	0	45.09	53	51	78	55.1	0	74.9	70.48	61.38
Quercus libanii	0	44.4	41	53	54	55.4	0	56	50.79	54.89
Crataegus spp.	0	39.57	38	48	17	49.6	0	0	33.59	43.11
Pyrus spp.	0	18.7	0	35	6	31.8	0	12.8	6.37	33.85
Amygdalus scoparia	0	20.8	0	37	0	25.8	0	0	0	34.89
Rosa canina	0	8.9	0	33	0	0	0	0	0	34.88
Pistacia atlantica	0	0	0	14	0	9.35	0	0	0	14.27
Acer monspessulanum	0	2.9	0	9	0	3	0	0	0	8.5
Fraxinus rotundifolia	0	0	0	6	0	0	0	0	0	5.58
Prunus divaricata	0	2.8	0	12	0	8.4	0	0	0	14.06
Malus orientalis	0	0	0	9	0	0	0	0	0	8.34
Daphne spp.	0	0	0	3	0	0	0	0	0	2.79
Cotoneaster spp.	0	0	0	14.07	0	0	0	0	0	14.06

4. DISCUSSION

Traditional harvesting is used mostly in many developing countries as well as Iran. Due to practicing traditional harvesting, the quality and quantity of the forest changes mostly toward deterioration (Czajkowski et al. 2009, Nduwamungu and Habyarimana 2011, Erfanifard and Soleimani 2013). Biodiversity indices show the amount of destruction in the natural stand which is important for forest management plans. Conserving forest biodiversity is a key element of regional, national and international forest management policies, agreements and guidelines (Dalei and Gupt, 2014). A key principle of biodiversity conservation in native forests managed for multiple commodities is the maintenance of stand structural complexity (Barbier et al. 2008, Eyre et al. 2010). In this study, an influence of traditional harvesting on the natural stand of oak forest under two harvesting intensities was studied. Due to limited number of natural forest stands, demographic structure, and distance from forest, and increasing demand for forest product and service by local people the result of the study may have value not only in the Zagros forest but also in other forests with similar conditions.

Our results clearly show that traditional harvesting and the resulted disturbance have a strong influence on species richness and biodiversity indices. The Shannon diversity, Simpson diversity and Margalef richness indices of the disturbed stand were 47.59, 36.62 and 63.72 percent, respectively lower than in the less disturbed stand. The observed reduction in diversity indices due to traditional harvesting in this study was similar to other studies which previously conducted (e.g. Abasi et al. 2009; Schleuning et al., 2011; Haidari et al. 2013; Durães et al. 2013). The results of species evenness did not show a significant difference. The species evenness index shows how close in numbers of each species in an environment are and it is considered high when it varies near value of 1. In both stand the evenness values are range from 0.66 to 0.83 and these results are different from previous studies (Feroz et al., 2015, Shirima et al. 2015). This discrepancy could be due to differences in forest tree structure and the nature of forest harvesting practices.

The results of this study revealed that, the diversity is in close relation with anthropogenic disturbance and traditional harvesting. Theoretical analyses often predict a peak in species diversity at intermediate disturbance intensity (with no or little disturbance), while at sufficiently high level of disturbance only resistant species can survive, therefore, the species diversity will decline (Huston 1979, Sagar et al. 2003). Thus, the disturbed stand of the present study can be considered as of high disturbance intensity because it contains lower species diversity and tree density (Rao et al. 1990).

Anthropogenic disturbance affects species richness and species diversity by altering habitat structure (Astrom et al. 2005). These kind of disturbance not only cause quantitative destruction by reducing forested areas, but also change forest stand quality by reducing forest stands height and strata in vertical structure (Ebrahimi Rastaghi 2003). The results illustrated that factors such as livestock grazing and disbranching were the main reasons of forest destruction in the area. Grazing was the most important destructive factor which affects plant species belonging to all different growth-forms including woody and herbaceous species. These results agreed with Benhin and Hassan (2014). Disbranching was a hindering factor for tree growth and creates stands with low crown cover. Most of the disbranched trees were heavily injured, making them susceptible to fungi or insects attack (Parma and Shataee Jouybari 2010). These two factors changed the vertical structure and composition of forests not only in the study area but also in all semiarid ecosystems (Carmel et al. 2001, Metzger et al. 2005).

Species such as *Quercus infectoria* and *Quercus libanii* seem well adapted to grazing due to their potential of producing shoot which resulted in higher intensity of shoots in the disturbed stand. And also, the existence of these species can be rooted from the dwellers tendency to keep them in local ecosystems (Valipour et al. 2014). Species such as *Acer monspessulanum*, *Pistacia atlantica*, *Prunus divaricata*, *Amygdalus scoparia*, *Malus orientalis*, *Cotoneaster* sp., *Daphne* sp., and *Fraxinus rotundifolia* were not recorded in the disturbed stand and they showed more vulnerability to anthropogenic disturbance in comparison with *Quercus infectoria* and *Quercus libanii*. These results are in conformity with the findings of Erfanifard and Soleymani (2013) and Mishra et al. (2011), which revealed that disturbance factors mainly affect the species composition and biodiversity of the forest stands. The emphasis of traditional management on coppice methods and supporting certain species has caused the decline of non-productive species and loss of gene flow in the harvested area (Ghazanfari et al. 2004).

In total, in the disturbed stand the most important species were *Quercus infectoria* (with 70.48% IVI), *Quercus libanii* (with 50.79% IVI) and *Crataegus* spp. (with 33.59% IVI). The traditional harvesting in disturbed stand increases the dominance and reduces the basal area of this species. These species were also important species in the less disturbed stand with 61.38%, 54.89% and 43.11%, respectively importance value. The IVIs of the *Quercus infectoria* in the disturbed stand was 12.91% higher than in the less disturbed stand, agree with the findings of other researches (e.g. Visalakshi 1995, Kadavul and Parthasarathy 1999, Mishra et al. 2004). In the disturbed stand, species such as *Quercus infectoria*, *Quercus libanii* and *Crataegus* spp. were recorded only in the second and third layers while in the less disturbed stand, the number of species were higher than in the disturbed stand and species were found in the all vertical layers. In forest ecosystems, woody species regeneration and herbaceous plan almost found at the lowest layer (near ground layer) of stand, due to the high intensity of traditional practices and grazing in the disturbed stand, no woody species were observed in the first layer. The same condition has occurred in the top layer of disturbed stand and the woody plant did not have a chance to reach the top layer. In the disturbed stand, these species were resistant to destructive factors due to their tolerance in very adverse situations such as grazing, disbranching and other destructive factors. Also these species could tolerate the adverse situation, but their average height have declined and changed from uniform to clumped dispersion.

5. CONCLUSION

In the Zagros forests, the traditional harvesting threats the forest species diversity and also simplifies the structure of these precious forests. Our results showed that the current traditional harvesting and grazing reduced the woody species diversity and simplified the forest structure to only one story. The results depicted that the oak species (*Quercus infectoria* and *Quercus libanii*) are approximately resistance to the anthropogenic disturbance and the species such as *Acer monspessulanum*, *Pistacia atlantica*, *Prunus divaricata*, *Amygdalus scoparia*, *Malus orientalis*, *Cotoneaster* sp., *Daphne* sp., and *Fraxinus rotundifolia* were vulnerable. The species richness and diversity indices showed that the overall diversity was low in disturbed stand. The forest structure and its different layers clearly illustrate that excessive traditional harvesting changes the forest natural structure through reducing the stand height and structural diversity. Considering these results, the forest managers should pay attention to the natural structure and biodiversity of forest communities and also the needs of local people. Disturbed forests are increasingly common in Zagros landscapes therefore, they need to be protected in order to recover and restore lost forest due to practicing traditional harvesting.

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