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Population Structure and Regeneration Status of Woody Plants in Relation to the Human Interventions, Arasbaran Biosphere Reserve, Iran

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Abstract: Proper understanding of the diversity and natural structure of woody species and the impacts of human interventions are prerequisites for maintaining the remaining forests as well as restoration of deforested and degraded areas. This research was conducted to document the impact of human interventions on the population structure and the species diversity in the Arasbaran biosphere reserve in Iran due to the limited research and insufficient knowledge. The study area was divided into three adjacent sampling areas of low, medium, and high destruction intensity. Thirty fixed area 0.1-hectare plots were sampled to evaluate the composition, diversity, and species richness. Oak (*Quercus macranthera*), hawthorn (*Crataegus meyeri*), and maple (*Acer campestre*) were the top three dominant tree species at all the sites. The relative dominance of the top three species comprised 87.8% of the basal area of all species. The relative abundance of the top three species accounted for 68.1% of the species. The mean density and basal areas per tree across all three destruction statuses were 145 ± 59 stems ha^{-1} and 0.01 ± 0.005 m^2 ha^{-1}, respectively. The mean height of trees was different at low and high disturbance sites (4.6 ± 0.96 m and 3.37 ± 1.74 m, respectively). Due to the impact of human interventions on forest structure, composition, and diversity, conservation programs are recommended for implementation and in collaboration with local communities to employ management aimed at providing services for local people while restoring these forests. Basic ecological studies such as this study are the foundation to begin developing policies and management that meet multiple ecological and social goals.

Keywords: structural indices; human interventions; importance value index; *Quercus macranthera*; species diversity

1. Introduction

The Arasbaran biosphere reserve is one of the most important biodiversity hotspots in Northwest Iran. This area has about 1334 plant species from 493 genera and 97 families [1]. Species diversity plays a key role in the ecological aspects of forest ecosystems, influencing succession, resilience, and nutrient cycling [2]. In the last international conventions, especially after the Rio Convention on Biological Diversity, loss of biodiversity caused by human activities became a major source of concern for forest ecologists [3]. Human interventions, such as tree cutting, road construction, and non-timber forest product collection, can alter plant communities in terms of density and composition [4]. Animal grazing, fuel wood collection, recreation, and other human uses can cause destruction and alter species diversity and woody structure of forests. For instance, Rasquinha and Mishra

(2020) showed that tree density, basal area, and tree diversity were lower at sites with the small-scale fuel harvested than sites without harvest because harvesters targeted smaller size classes and particular species in harvested sites [5]. A study of traditional use in Iranian forests indicates human use impacts affect both the over and understory of woody vegetation [6].

Averting reduction and degradation of forest cover would require maintaining the remaining forests in their current status as well as the restoration of deforested and degraded areas. Success in these activities requires a proper understanding of the diversity and natural structure of woody species' establishment, such as causes, mechanisms, and factors that influence the process of regeneration, population change, and replacement through time [7]. In addition, knowledge about the population structure and regeneration of a given forest is important for developing management and conservation strategies of biodiversity [8]. Information on the population structure of a tree species indicates the history of the past disturbance to that species and, hence, used to better manage the future population trend of the particular species [9]. Furthermore, the overall pattern or structure of population dynamics of seedlings, saplings, and adults of a plant species can exhibit the regeneration profile, which is used to determine their regeneration status [10].

Some researchers have documented the population structure, species diversity indices, and regeneration status in understudied forest ecosystems in Iran and Southwest Asia. In Iran, these include exploring the regeneration and conservation of yew (*Taxus baccata* L.) and *Quercus macranthera* in Arasbaran forests [11], assessing impact of human factors on diversity of woody species in the Zagros forests [12,13], and investigating the effects of grazing on the natural regeneration in Hyrcanian forests [14]. In India, Singh et al. (2016) explored tree species richness, diversity, and regeneration status in different oak (*Quercus* spp.) dominated forests of Garhwal Himalaya [15]. In China, Atsbha et al. (2019) studied human factors on the regeneration status [16] and Chen et al. (2020) explored species diversity of primary and secondary forests in the Wanglang Nature Reserve [17].

Based on our knowledge, information about the population structure and regeneration status of woody species in zones subjected to a different degree of human interventions at the Arasbaran biosphere reserve in Iran is rare. Local human populations depend on forests to meet livelihood needs through livestock grazing, tourism, and other activities [18]. The impact of these activities on species diversity is the main management challenge for sustainable forest management. Hence, the main objective of this study was to fill the existing information gap in woody species structure, composition, and regeneration in this region of Iran to efficiently protect and manage this forest ecosystem and its associated services. The degree of anthropogenic modification of these forests could reduce ecosystem integrity and diminishes many of the benefits that these forest ecosystems provide. The specific objectives of the study were to: (i) analyze the population structure in terms of species richness, density, basal area, DBH (diameter at breast height) distribution, height class distribution, frequency, and importance value index, (ii) to assess the regeneration status of woody species, and (iii) to document the impact of human interventions on the population structure and the values of species diversity indices. Our hypothesis is that human interventions significantly impact the population structure and regeneration status of woody species in the Arasbaran biosphere reserve, Iran.

2. Materials and Methods

2.1. Study Area

The research was done in the Arasbaran biosphere reserve in Northwest Iran at the border of Armenia and Azerbaijan between 38°35′ N–39°00′ N latitude and 45°45′ E–47°05′ E longitude (Figure 1). Forest types are natural, mixed hardwood and broad-leaved deciduous forests with an area about 153,000 ha. The climate is semi-humid with an average annual temperature of 14 °C and an average rainfall of 400 mm per year. The main species in these forests are oak (*Quercus macranthera* Fisch. & C.A.Mey. ex Hohen.), hornbeam (*Carpinus betulus* L.), maple (*Acer campestre* L.), yew (*Taxus baccata* L.), wayfaring

tree (*Viburnum lantana* L.), reddish-black berry (*Ribes petraeum* Wulfen), and walnut (*Juglans regia* L.). The occupations of the local people in the target watershed are primarily based on combinations of animal husbandry, farming, carpet-weaving, beekeeping, and cultivation or extraction of forest products [18,19].
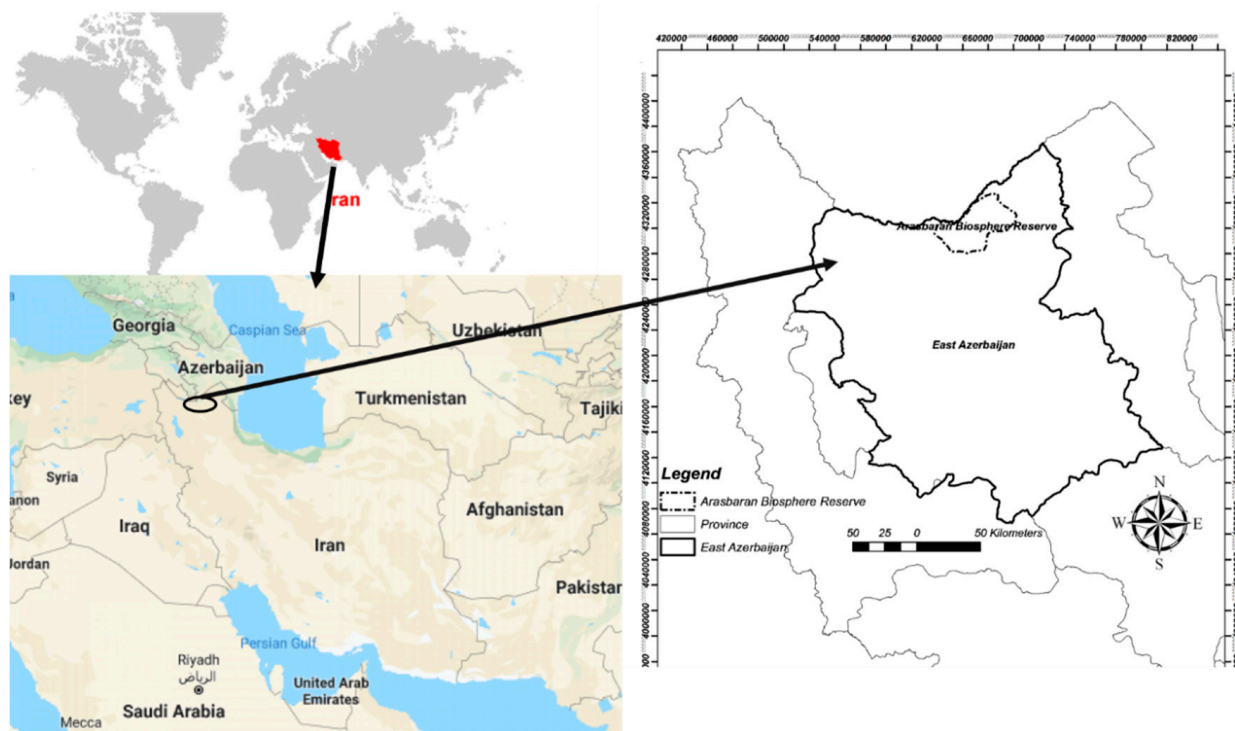

Figure 1. The location of the Arasbaran biosphere reserve in context of a global position (world map, upper left), Iran (country map, lower left), and the Province of Azerbaijan (provincial map section, right).

2.2. Study Design

To provide a better understanding of the effects of human intervention on the structure and regeneration of woody species, three regions with different human interventions were selected based on the history of a human presence and distance from the critical hotspots. The intensity of human interventions (disturbance index) was determined based on observations of the effects and signs of destruction and the distance from a village as the critical grazing center. We coded regions by the level of observed human impact (few too many signs of cutting and grazing livestock) as numerical values 1, 2, and 3 for low, medium, and high levels of destruction [20]. Disturbance index (*DI*) in each region was computed by multiplying the distance from the village (meter) in the numerical value of the intensity of destruction. The *DI* indicated destruction status (low destruction (*LD*), medium destruction (*MD*), and high destruction (*HD*) within the study area. For context, *LD* is near to the desired reference condition, but it is not the target for a management implication. All areas studied are affected by human use. Our study aimed to highlight the variation among different levels of a destruction status.

2.3. Sampling

The structure and occurrence of woody species were studied to evaluate the composition, diversity, and species richness in each destruction class. One 600-m transect was laid parallel from the forest edge (near the village) and into the forest interior for each destruction class (three transects in total). Each transect was approximately 150 m apart. Ten sample plots were equally spaced at intervals of 60 m along each transect. Each sample plot was 1000 m^2 (0.1 ha) with dimensions of 10 by 10 m. In total, 30 sample plots were established from the study area [21–23]. In sample plots, all trees with ≥5.0 cm DBH

(diameter at breast height, 1.3 m above the ground) were identified to species and measured using a diameter tape. The height of trees was measured using Suunto PM5/360PC Clinometer made in Finland. Mature trees are defined as woody plants with DBH $\geq$ 5 cm and height $\geq$ 1.5 m. Regeneration (seedlings and saplings) was defined as woody species with DBH < 5.0 cm and height < 1.5 m. The regeneration density of species is simply counted by species. The species identification was done by referring to the Iranian flora books and botanical knowledge of researchers. We calculated, for each species, maximum DBH, frequency, and maximum height of stems.

2.4. Data Analysis

The Pearson correlation test was used on *DI* with quantitative variables such as number of trees, mean on height and DBH, the number of seedlings, and *IVI* of three important specie with the destruction classes. We performed a one-way ANOVA test as an exploratory test to determine differences in destruction status in terms of the stand structure and regeneration density of woody plants (variables listed in Table 1). The normality of data distribution and homogeneity of variance was tested with the Kolmogrof-Smirnof and Levene's test, respectively [17]. Statistical tests were calculated using R version 3.5.3 [24] and Microsoft Excel (2013) depending on the type of analysis. All statistical tests were conducted at a significance level of $\alpha \leq 0.05$.

Table 1. Indices used to quantify forest structure and composition diversity. For each index, the equation used to calculate it. Its description and bibliographic references are provided.

Equation Number	Index	Equation	Description and Reference
1	Relative density (*RDe*)	$RDe = \frac{\text{number of individuals of a species}}{\text{total number of individuals}} \times 100$	[4,7]
2	Species Richness (*S*)	$S = \frac{\text{Number of species}}{quadrat}$	[7,16]
3	Simpson index of Dominance (*D*)	$D = \sum (p_i)^2$	where *D* = Simpson index of dominance, where p_i = the proportion of important value of the *i*th species ($p_i = n_i/N$, n_i is the important value index of *i*th species and *N* is the important value index of all the species) [7,25]
4	Simpson's evenness (*E*)	$E = \frac{\left(\frac{1}{D}\right)}{S}$	*E*: Simpson's evenness, *S*: species richness [7,16,25]
5	Shannon-Wiener's index of diversity (*H*)	$H = -\sum\limits_{i=1}^{s} (p_i)(\ln p_i)$	where $p_i = n_i/N$; n_i is the number of individual trees present for species i, and *N* is the total number of individuals [7,16,25]
6	Frequency (%)	$F\,(\%) = \frac{\text{Number of quadrats in which a species occurred}}{\text{Total number of quadrats studied}} \times 100$	[7,17]
7	Relative frequency (*RF*)	$RF = \frac{\text{Frequency of a species}}{\text{Sum of all frequencies}} \times 100$	[4,7]
8	Abundance	$\text{Abundance} = \frac{\text{Total number of individuals of a species in all quadrats}}{\text{Total number of quadrats in which a species occurred}}$	[7]
9	Relative dominance (*RDo*)	$RDo = \frac{\text{Total basal area for a species}}{\text{Total basal area of all species}} \times 100$	[7]
10	The importance value index (*IVI*)	$IVI = RDo + RDe + RF$	[4,7,22]

The tree diameter was measured at the breast height (dbh, diameter at 130 cm). The diameter was used for determining a tree basal area and calculated as $BA = \pi r^2$ (where *r* is the radius). Total basal area is the sum of basal area of all species present in the forest. The basal area (m²/ha) was used to determine the relative dominance of tree species [16,22]. In addition, the other 10 indices were calculated to describe the stand structure (Table 1). To analyze the dominant species composition, we first calculated the importance values index (*IVI*) of species. Then, we sorted the plants according to these values and screened the most important tree species. The *IVI* of tree species was determined as the sum of relative frequency, relative density, and relative dominance [4].

3. Results

3.1. Species Composition and Dominant Species

In total, 10 woody plant species belonging to six families were recorded in a different destruction class. Fagaceae and Rosaceae families constituted 88.9% of total basal area in the study area. *Q. macranthera*, hawthorn (*Crataegus meyeri*), and *Acer campestre* were the top three dominant tree species in a different destruction class. These three species accounted for 90.5% of the cumulative value of the total basal area. The remaining species accounted for 9.5% of the basal area. The *IVI* helps to understand the ecological significance of tree species in a community structure. *Q. macranthera* had the highest *IVI* during the high destruction. Medlar (*Mespilus germanica* L.) and spindle (*Euonymus* sp.) were observed in the *LD* and *HD* class, respectively. At the *LD* and *HD* sites, *Q. macranthera* had the highest *IVI*, 168.5 and 196.3, respectively (Table 2). Plum (*Prunus domestica* L.) and *Euonymus* sp. were not observed at *LD* and *MD* sites. The conditions were for *M. germanica* L. at *MD* and *HD* sites. The relative dominance of the top three species comprised 87.8% of the basal area of all species. These were *Q. macranthera* (60.2%), *C. meyeri* (23%), and *A. campestre* (4.6%). The relative abundance of the top three species accounted for 68.1% of the species. These were *Q. macranthera* (30.3%), *C. meyeri* (22.7%), and *A. campestre* (15.1%).

Table 2. Tree (DBH $\geq$ 5 cm and height $\geq$ 1.5 m) composition and structure by species in a naturally-regenerated broadleaf forest in the Arasbaran biosphere reserve in Iran (*n* = 30). The Important Value Index are presented by a destruction class. Equations for the Importance Value Index and Basal Area are listed in Table 1. Destruction classes were developed with a Disturbance Index (*DI*) that incorporated levels of observed human impact (few too many signs of cutting and grazing livestock) (see methods). For context, *LD* is near to the desired reference condition, but it is not the target for a management implication. Cumulative is a summation of the Percent Basal Area column.

| Species | Family | Importance Value Index | | | Basal Area (m² ha⁻¹) | Percent Basal Area (%) | Cumulative Percent of Basal Area (%) |
		Low Destruction (*LD*)	Medium Destruction (*MD*)	High Destruction (*HD*)			
Quercus macranthera	Fagaceae	168.5	144.6	196.32	1.76	65.1	65.1
Crataegus meyeri - Pojark.	Rosaceae	56.01	95.32	134.78	0.56	20.8	85.8
Acer campestre L.	Sapindaceae	49.15	51.48	32.62	0.13	4.7	90.5
Fraxinus excelsior L.	Oleaceae	32.16	34.86	14.03	0.09	3.4	94.0
Corylus avellana L.	Betulaceae	58.62	31.89	63.74	0.08	3.0	97.0
Malus orientalis	Rosaceae	26.72	0	45.93	0.04	1.6	98.5
Pyrus communis L.	Rosaceae	29.56	8.3	0	0.02	0.9	99.4
Mespilus germanica L.	Rosaceae	31.43	0	0	0.01	0.4	99.8
Prunus domestica L.	Rosaceae	0	0	22.83	0.004	0.1	99.9
Euonymus sp.	Celastraceae	0	0	6.04	0.002	0.1	100

3.2. Species Diversity

The species richness (*S*), Simpson index of Dominance (*D*), Simpson's evenness (*E*), Shannon-Wiener's index of diversity (*H*), and the importance value index (*IVI*) are presented in Table 3. Forest sites with a different destruction class showed marked differences in terms of various community characteristics including the density, basal area, species richness, Simpson index of dominance, Simpson's evenness, Shannon-Wiener's index of diversity, and the importance value index (*IVI*). The highest density of woody plants was recorded in *LD* while the lowest was recorded in *HD* (Table 3). The mean density for all forest sites with a different destruction class was 145 $\pm$ 59 stems ha⁻¹. The mean basal area of the forest sites studied was 0.01 $\pm$ 0.005 m² ha⁻¹. The basal area increases with a decreasing destruction. *LD* and *MD* sites had the highest and lowest basal areas, respectively. Results showed that the *HD* site had the least species richness. Shannon's index, which increases with a decreasing destruction class, indicated that the *HD* site had the lowest species diversity (Table 3).

Table 3. Stand structure and composition by a destruction class of trees DBH $\geq$ 5 cm and height $\geq$ 1.5 m in a naturally-regenerated broadleaf forest in the Arasbaran biosphere reserve in Iran (*n* = 30). Equations for variables are listed in Table 1. See Table 2 for a description of the destruction class.

Variable	Destruction Class			Mean	SD
	LD *	**MD ***	**HD ***		
Density (no. ha^{-1})	211	115	102	145	59
Basal Area (m^2 ha^{-1})	0.16	0.11	0.09	0.01	0.005
Species Richness (no. ha^{-1})	2.9	2	1.7	2.2	1.51
Simpson Dominance	0.6	0.3	0.6	0.52	0.35
Simpson's Evenness	0.75	0.50	0.59	0.63	0.32
Shannon-Wiener's Diversity	2.6	1.8	1.3	1.87	1.7
Importance Value Index	87.6	74.5	92.12	86.6	70.1

* *LD*: Low Destruction. *MD*: Medium Destruction. *HD*: High Destruction.

3.3. Height and DBH Class Distribution and Stem Density

Results showed a pattern of an increasing destruction class with a decreasing tree height. The average height of trees varied from 2 m to 7.5 m. The mean of height trees was 4.6 $\pm$ 0.96 m and 3.37 $\pm$ 1.74 m at *LD* and *HD* sites, respectively. A higher proportion (65.2%) of woody plants had a height of between 3–5 m. The following individuals with a class >5–7 m in height (29.2%). While individuals with less than 3 m in height were 5.53% of all the woody plants. Density of trees at the height of class 3–5 m had a higher frequency than other classes at the three-destruction class (Table 4).

Table 4. Tree (DBH (diameter at breast height) $\geq$ 5 cm and height $\geq$ 1.5 m) density (no. ha^{-1}) by height classes (m) and destruction class in a naturally-regenerated broadleaf forest in the Arasbaran biosphere reserve in Iran (*n* = 30). *LD* = Low Destruction, *MD* = Medium Destruction, *HD* = High Destruction. See Table 2 for description of a destruction class.

Height Class (m)	Destruction Class		
	LD	**MD**	**HD**
$\leq$3	6	3	15
>3–5$\leq$	117	43	123
>5–7	107	11	9
Mean $\pm$ SD	4.6 $\pm$ 0.96	4.12 $\pm$ 2.53	3.37 $\pm$ 1.74

The DBH class distribution of woody species in all destruction classes reflected a somewhat reversed J-shape (L-shape) (Figures 2 and 3). This includes where species frequency distribution had the highest frequency in the lower diameter classes and a relatively gradual decrease toward the higher classes (Figure 2). Individual trees having DBH < 7.5 cm accounted for 76% and 73% of all trees recorded at the *LD* and *HD* sites, respectively (Figure 3). The range of DBH was between 5.3 to 21 cm. At the species level, *C. meyeri* tree density reflected a similar distribution to the stand scale (Figure 3). Diameter distributions of *Q. macranthera* trees were irregular. For the *A. campestre*, a high percentage of trees were <7.5 cm and none were found in the two large DBH classes (13.5–16.5 cm and >16.5 cm).
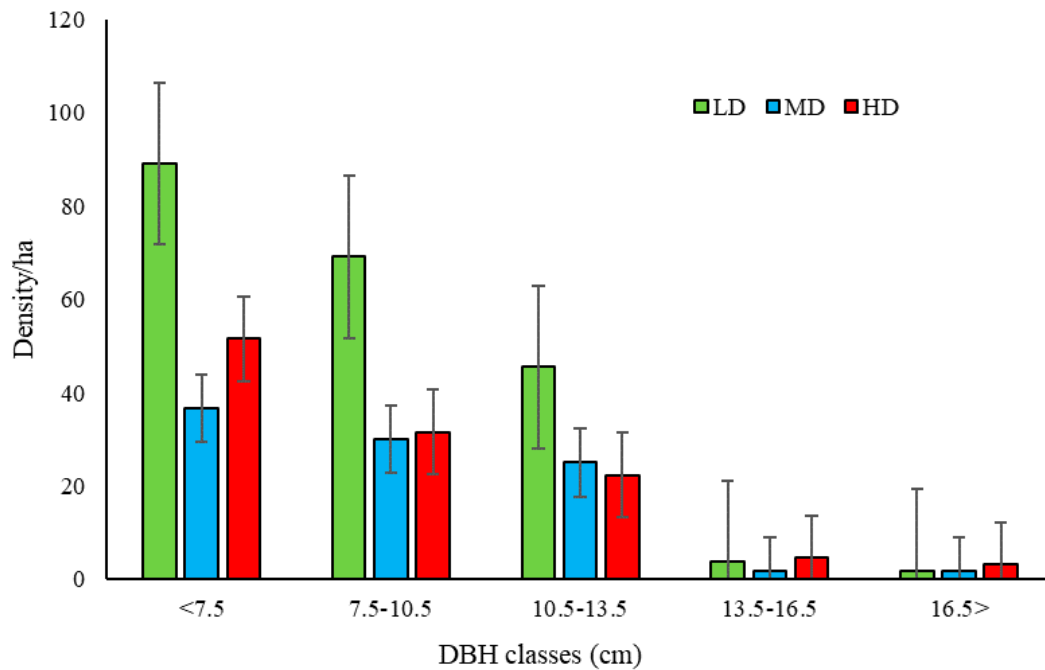
Figure 2. Tree (DBH ≥ 5 cm and height ≥ 1.5 m) density by diameter at breast height (DBH) class and destruction class in a naturally-regenerated broadleaf forest in the Arasbaran biosphere reserve in Iran (*n* = 30). *LD* = Low Destruction, *MD* = Medium Destruction, and *HD* = High Destruction. See Table 2 for a description of the destruction class.
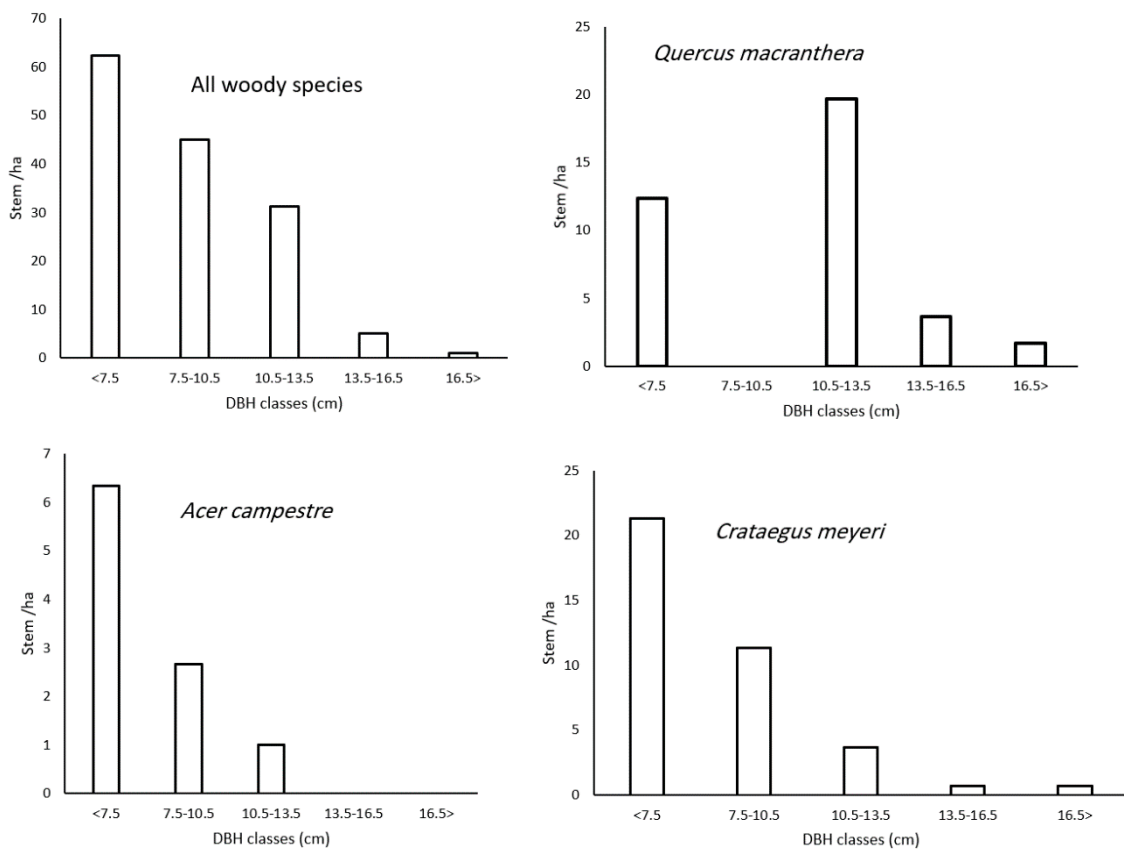

Figure 3. Tree (DBH ≥ 5 cm and height ≥ 1.5 m) density by diameter at breast height (DBH) class and species in a naturally-regenerated broadleaf forest in the Arasbaran biosphere reserve in Iran (*n* = 30).

3.4. DBH and Density Distribution and Destrucion Class

The different destruction class shows its impacts on the forest structure. Frequency of trees and their DBH classes at a low disturbance index is high (Figure 4). Density of trees at a low *DI* tended to be in high DBH classes (Figure 5). The high density of trees at a high *DI* was observed in the low DBH classes.
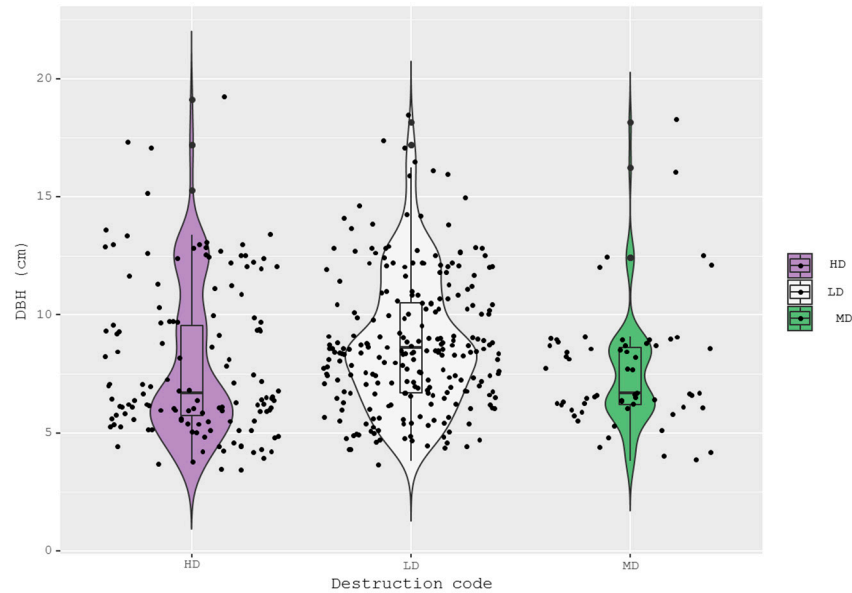

Figure 4. Violin plot (box plot plus kernel density envelop) of tree size (DBH) and disturbance index (by destruction class) distribution in a naturally-regenerated broadleaf forest in the Arasbaran biosphere reserve in Iran (*n* = 30). LD = Low Destruction, MD = Medium Destruction, and HD = High Destruction. See Table 2 for description of the destruction class.

Figure 5. *Cont.*

Figure 5. Density frequency distribution of tree size (DBH) by the destruction class in a naturally-regenerated broadleaf forest in the Arasbaran biosphere reserve in Iran (*n* = 30). LD = Low Destruction, MD = Medium Destruction, and HD = High Destruction. See Table 2 for description of the destruction class.
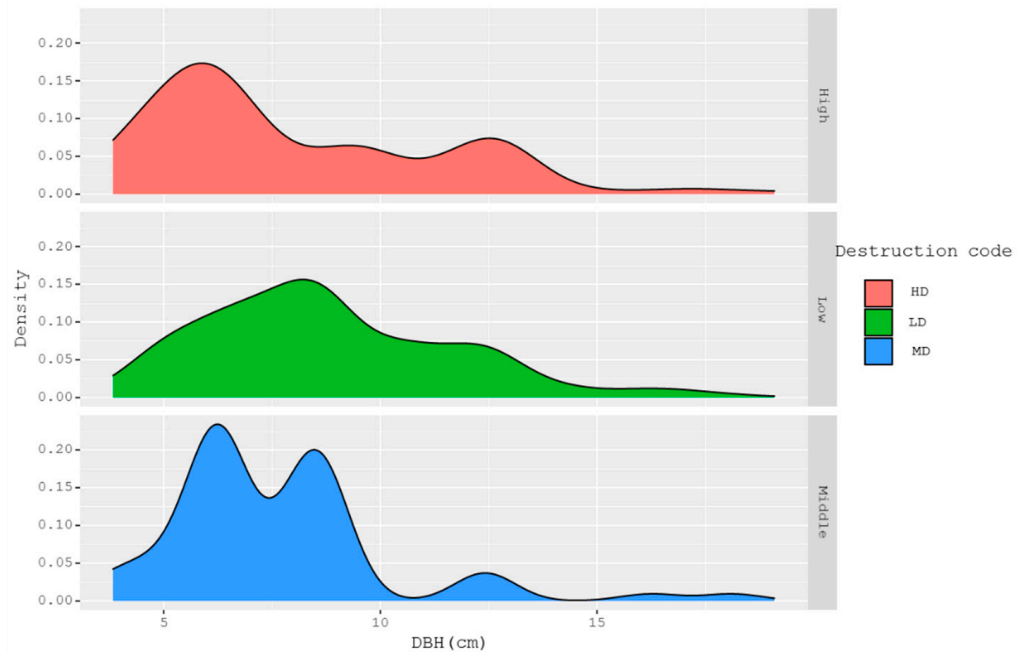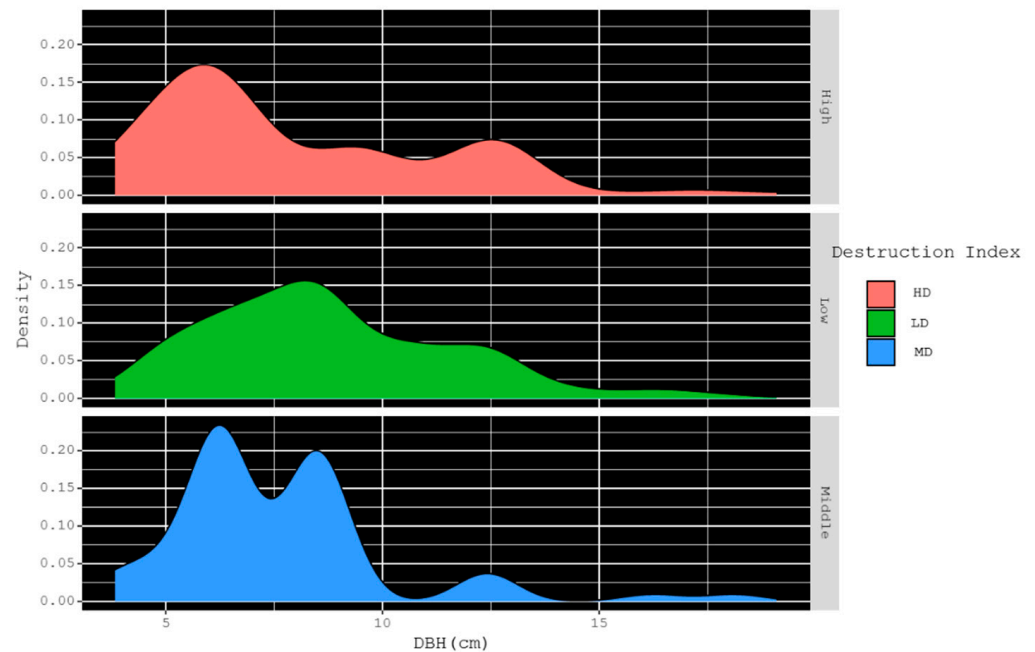
3.5. Disturbance Index and Population Diversity and Structure

The correlation analysis showed that a negative and significant correlation was between the disturbance index and the number of trees, height mean, QIV (*Q. macranthera* Important value), and positive and significant correlation with CRIV (*C. meyeri* important value) (Table 5). Diversity indices including *H*, *S*, and *E* did not show a significant correlation with a disturbance index. ANOVA results showed that none of the variables were significant at 0.05 percent at the different destruction class with a different disturbance index (Table 6).

Table 5. Correlation coefficient matrix of the stand structure and composition with the disturbance index of trees (DBH $\geq$ 5 cm and height $\geq$ 1.5 m) in a naturally-regenerated broadleaf forest in the Arasbaran biosphere reserve in Iran (*n* = 30). Equations for variables are listed in Table 1. The Disturbance Index incorporated levels of observed human impact (few too many signs of cutting and grazing livestock) (see methods).

Pearson Correlation	Disturbance Index	Number of Trees	Height Mean	DBH Mean	DBH Max	Seedling (No)	QIV ***	ACIV ***	CRIV ***	*H*	*S*	*E*
Disturbance index	1											
Number of trees	−0.437 *	1										
Height mean	−0.428 *	0.615 **	1									
DBH mean	−0.287	0.533 **	0.843 **	1								
DBH max	−0.310	0.456 *	0.758 **	0.769 **	1							
Seedling (No)	−0.333	0.099	0.006	0.010	−0.073	1						
QIV	−0.492 **	0.259	0.650 **	0.577 **	0.457 *	0.342	1					
ACIV	−0.221	0.165	0.305	0.422 *	0.352	−0.063	0.209	1				
CRIV	0.383 *	0.207	0.199	0.206	0.242	−0.374 *	−0.451 *	−0.225	1			
H	−0.346	0.648 **	0.0523 **	0.480 **	0.617 **	−0.067	0.172	0.403 *	0.151	1		
S	−0.360	0.687 **	0.658 **	0.610 **	0.705 **	−0.053	0.319	0.414 *	0.190	0.975 **	1	
E	−0.180	0.360	0.761 **	0.637 **	0.692 **	−0.283	0.491 **	0.160	0.297	0.285	0.425 *	1

* Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed). *** QIV: *Q. macranthera* Important value. ACIV: *A. campestre* Important value. CRIV: *C. meyeri* important value. *H*: Shannon-Wiener's index of diversity. *S*: Richness. *E*: Simpson's evenness.

Table 6. Analysis of Variance results for stand structure and composition of trees (DBH $\geq$ 5 cm and height $\geq$ 1.5 m) in a naturally-regenerated broadleaf forest in the Arasbaran biosphere reserve in Iran (*n* = 30). Equations for variables are listed in Table 1. QIV: *Q. macranthera* Important value. ACIV: *A. campestre* Important value. CRIV: *C. meyeri* important value. H: Shannon-Wiener's index of diversity. S: Richness. E: Simpson's evenness.

Variable	Sum of Squares	df	Mean Square	F	*p*-Value
Density (no. ha^{-1})	768.750	2	384.375	3.083	0.062
Height (m) mean	20.143	2	10.071	3.502	0.044
DBH (cm) mean	46.915	2	23.457	1.791	0.186
DBH (cm) max	121.318	2	60.659	1.735	0.196
Seedling (No. ha^{-1})	583.285	2	291.642	1.837	0.179
QIV	53,795.605	2	26897.802	3.968	0.031
ACIV	1346.655	2	673.328	1.180	0.323
CRIV	18,167.971	2	9083.986	2.078	0.145
H	10.085	2	5.043	1.835	0.179
S	9.122	2	4.561	2.135	0.138
E	0.287	2	0.144	1.436	0.255

3.6. Regeneration Status

The number of regenerating woody tree species varied at the different destruction class from 320 individuals ha^{-1} to 431 individuals ha^{-1}. The regeneration density at the *LD* sites (387 Ind. ha^{-1}) tended to be lower than the *MD* sites (431 Ind. ha^{-1}) and *HD* sites (320 Ind. ha^{-1}). Hazelnut (*C. avellana*), wild rose (*Rosa canina*), and *Q. macranthera* comprise 56% of regeneration density in our study area. The density of *Q. macranthera*, as an important species of Arasbaran forests, at the *LD* sites (93.6 Ind. ha^{-1}) was 3.5 times higher than *HD* sites (26.2 Ind. ha^{-1}). We observed similar patterns for *Viburnum lantana*, *P. domestica*, ash (*Fraxinus excelsior*), *A. campestre*, *Euonymus* sp., and *M. germanica*. In contrast, density of *C. avellana*, *R. canina*, *C. meyeri*, buckthorns (*Rhamnus* sp.), smilax (*Smilax excelsa*), and Greek whitebeam (*Sorbus graeca* Lodd. ex Schauer) tended to be higher at the *HD* sites than the *LD* sites (Table 7). The only woody species found in the mature trees but not the regeneration was the wild apple (*Malus orientalis* Mill.).

Table 7. The density of regenerating woody trees (DBH < 5.0 cm and height < 1.5 m) by species, destruction class, and total and cumulative frequency in a naturally-regenerated broadleaf forest in the Arasbaran biosphere reserve in Iran (*n* = 30). *LD* = Low Destruction, *MD* = Medium Destruction, and *HD* = High Destruction. See Table 2 for the destruction class description. Cumulative is the summation of the density frequency column.

Species	Family	Density (No. ha^{-1})			Density Frequency (%)	Cumulative Frequency of Density (%)
		LD	MD	HD		
Corylus avellana	Betulaceae	61.8	148.3	93.8	25.37	25.37
Rosa canina	Rosaceae	37.3	98.3	66.2	16.9	42.27
Quercus macranthera	Fagaceae	93.6	35.0	26.2	14.45	56.72
Crataegus meyeri	Rosaceae	22.7	46.7	36.2	9.1	65.82
Viburnum lantana	Caprifoliaceae	40.9	25.0	19.2	7.9	73.72
Prunus domestica	Rosaceae	32.7	25.0	20.8	7.1	80.82
Fraxinus excelsior	Oleaceae	37.3	20.0	6.9	5.63	86.45
Acer campestre	Sapindaceae	21.8	16.7	16.9	5.1	91.55
Euonymus sp.	Celastraceae	18.2	6.7	5.4	2.82	94.37
Mespilus germanica	Rosaceae	17.3	6.7	3.1	2.45	96.82
Rhamnus sp.	Rhamnaceae	0.0	0.0	12.3	1.45	98.27
Smilax excelsa	Smilacaceae	0.0	1.7	10.8	1.37	99.64
Pyrus communis	Rosaceae	1.8	0.0	0.0	0.18	99.82
Sorbus graeca	Rosaceae	0.0	0.0	1.5	0.18	100

4. Discussion

Today, the biodiversity-oriented forest management has gained much attention in temperate forests of the world [26]. Maintaining species diversity in forest ecosystems is one of the most important goals in forest management plans. Tree species diversity in forests differs significantly from location to location, and can be related to human impacts [27].

The high *IVI* of some species such as *Q. macranthera*, *C. meyeri*, and *C. avellana* in the *HD* sites and *P. communis* and *M. germanica* in the *LD* sites indicates that they were dominant species in their respective environment. The number of light demanding, deciduous species, such as *Q. macranthera*, *C. meyeri*, *P. domestica*, and *C. avellana*, were higher in the unprotected *HD* area because they took advantage of the canopy openings. The *IVI* indicates the structural significance of species in a given ecosystem [28]. Thus, species with high *IVI* values are deemed to be more important than those species with low *IVI*. *Q. macranthera* has been reported to be a high value *IVI* in Arasbaran forests [29]. Therefore, its abundance in these forests is considered to be the establishment sign of early succession for the ecologists and forest managers. In terms of conservation, species with low *IVI* require high conservation approaches and, thus, should be prioritized for conservation. In this study, some of the species that should be prioritized for conservation due to their low *IVI* include wild pear (*P. communis* L.), *M. germanica* L., *P. domestica* L., and *Euonymus* sp.

Species diversity is an important characteristic of the forest community [17]. Density of trees differed between these three destruction classes. The density recorded in this research varied between 102 and 211 tree ha^{-1} at different destruction classes. Similarly, as reported by Reference [4], the stem density was 222 trees ha^{-1} and 181 trees ha^{-1} at *LD* and *HD* sites, respectively, from different destruction classes of Himalaya. In a research study about the effects of human use and livestock on woody species composition in the northern beech forests of Iran, revealed that tree density, the mean of tree DBH, and total basal area were significantly higher in the protected than in the unprotected area, which are proxies for *LD* and *HD* in our study area [30]. This also emphasized that species diversity indices have decreased in areas subject to intensive human exploitation and livestock grazing [31]. Grazing reduced both evenness and species diversity by removing and reducing the coverage of some sensitive species [30]. Therefore, species diversity was at maximum when the disturbance index was low, as reported for other ecosystems [31,32]. Many other studies have shown that species diversity is reduced by similar human intervention factors such that many sensitive species have been eradicated [4,14,17,31,33]. Contrary to some reports, our study did not show differences. This may be due to the type and regime of anthropogenic disturbances in this region. The primary driver for change in composition is tree removal that is rare in the study area. Livestock grazing as a frequent human-based disturbance in this area highly affects the herbal story in comparison with the trees and shrubs that are less frequently disturbed by grazing. The villages near the Arasbaran forests are not as impactful as other subsistence communities [14].

Higher tree density of all species in the small diameter classes (Figure 2) indicates that these forests have tree regeneration, establishing and recruiting into large diameter classes or canopy positions. Tree density in *LD* tended to be higher than *HD* sites. Lower tree density in large DBH classes as compared to other DBH classes could be the result of tree senescence in the *LD* sites and by the cutting of some of these trees by local people in *HD* sites [30]. A J-shape distribution of diameter classes indicated a likely continuous and good regeneration and/or a stable population of woody species [16]. In contrast, bell-shaped and interrupted reversed J-shape distribution of woody species in communal grazing lands indicated a hampered regeneration status due to several disturbance factors, including deforestation by local people in addition to frequent browsing and trimming by livestock [16], which were not observed at the stand scale at our sites.

5. Conclusions

Woody plant species are key components of the forest ecosystem and influence the overall composition and structure of forest communities. Documenting the structure of

tree diversity and human intervention impacts provides a good database that is useful for management measures in these forests. A comprehensive approach to forest management is needed for the conservation of dominant tree species that are necessary for the canopy formation as well as maintaining the socio-ecological balance of the forests to reduce potential losses in ecosystem services and avoid the impact in the ecosystem processes and properties of this complex forest. The preservation of these forests is crucial not only for conservation of their rich biodiversity, but also for meeting the basic needs of the local population. Due to the impacts of human interventions on the forest structure, composition, and diversity, the conservation programs are recommended to implement in collaboration with local communities to employ management aimed at providing services for local people while restoring these forests. Basic ecological studies, such as this study, are the foundation to begin developing policies and management that meet multiple ecological and social goals. There are ecological studies of Iranian forests.

Tree species density, distribution, and population structure analyzed in this study are example empirical metrics to compare with for restoration or management of forests experiencing human impacts similar to these. This research tries to evaluate the impact of human interventions on the population structure and the values of species diversity indices. According to our results, high destruction (human intervention intensity) impacts tend to be negative on diversity, richness, and the evenness index. For this reason, understanding the impact is essential for evaluating forest management and the ecosystem supply. It could also inform policy and practice for meeting societal demand. In this research, conservation does not mean do nothing. We simply present the human impact data on three scenarios, and this information could help make future decisions about the appropriate level of management to preserve ecosystem services and ecosystem integrity. Decision-makers must gather and consider data before making a choice. Clearly, doing nothing could also be considered a management criterion, but this is not the objective of this work. In future research, we will try to determine the potential capacity to provide ecosystem services and calibrate the appropriate levels of human activity on these ecosystems. While human impacts were isolated to select characteristics (e.g., tree height) in our study area, humans are likely having greater influence than our study captures. Understanding the impact of human interventions on the stability of stands can inform policy and practice for meeting societal demand, preserving biodiversity. Human interventions can regulate regeneration processes, benefiting light-demanding species with high capacity to adapt to disturbances, as noted in this study. In future research, a greater number of sites and adding a reference area would facilitate this area of research.

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