FORESTRY IDEAS, 2019, vol. 25, No 2 (58): 227–236

EVALUATION OF ALTITUDE EFFECTS ON THE SPATIAL STRUCTURE OF CAUCASIAN OAK (*QUERCUS MACRANTHERA*) STANDS IN ARASBARAN PROTECTED FORESTS, NORTHWEST OF IRAN

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Received: 14 February 2019 Accepted: 01 July 2019

Abstract

This study investigated the relationships between physiographical factors and trees structural characteristics in Arasbaran forest, northwest of Iran. Systematic randomized sampling method was used to collect data and in sample plot used the distance method for determination of spatial distribution pattern. Results of spatial distribution pattern indices showed the clumped spatial distribution for Caucasian oak trees (*Quercus macranthera* Fisch. & C.A.Mey. ex Hohen). In addition, the altitude affected the tree's characteristics significantly. The greatest tree's diameter at breast height was found in R_3 and density of trees was decreased by increasing of altitude. Distance to neighbour index showed four to six meter distances between trees. DBH and height differentiation indices demonstrated uniformity in trees. Landform indices had the greatest average on R_3 and had a significant correlation with trees density and crown area. It could be concluded that the difference in physiographical condition is one of the main factors of the tree's spatial distribution and forest structure variation at physiographical units in this study area.

Key words: altitude range, distance method, physiography, structure indices.

Introduction

Physiographic factors modification including altitude, slope, and aspect could change forest characteristics such as forest type, structure, and spatial patterns. Therefore, forest ecosystems parameters modify within local physiography through a complex interaction of topography, vegetation composition, and structure (Gerhardt and Foster 2002, Kovacs et al. 2017).

The identification of structural attributes in forest stands (e.g. vertical complexity and spatial pattern) could help to maintain forest ecosystem function, improve conservation and management practices, preserving biodiversity and mitigation strategies against the effect of local and global changes (Kovacs et al. 2017).

Trees create the basic structure of forests ecosystems by the canopy and its variation stratification and horizontal spatial pattern (Redmond et al. 2017). Also, forest spatial patterns cover a wide range of factors, including environmental factors, land physiography, trees interaction, etc. spatial pattern study was known as recording the position of each individual tree on forest stand. Study on forest structure being used to assess the knowledge of natural distribution in the forest stand and heterogeneity in different topography condition can affect trees spatial distribution (Carrer et al. 2018). The spatial distribution pattern refers to the status of horizontal allocation or distribution of individual trees in a stand and reflects processes on stands (Gangying et al. 2007; Friedman et al. 2001).

Forest structure has been characterized by several ways but nowadays sampling methods, such as distance method, are used to analyse forest structure. In this method, the position of trees is considered (Ghalandarayeshi et al. 2017).

Numerous studies, worldwide, have described the interaction of forest structure and physiographic factors in forest stands. These studies focus on forest structure composition and spatial pattern. Gerhardt and Foster (2002) researched on physiographical effects on forest composition and structure as a major challenge of ecologists, conservationists and land managers in New England in the eastern United States and suggested that altitudes are one of the main factors controlling structure and composition of forests. To understand the effects of direction on forest composition and community structure, Sharma et al. (2010) studied seven natural forests types in Garhwal Himalaya and concluded that the value of the basal area and diversity indices were modified in different aspects. Askari et al. (2013) studied the spatial patterns of trees in a reserved area in the Zagros forest in the southwest of Iran. They used some indices and showed the clumped pattern in the studied area. Mirzaei et al. (2016) investigated the effects of physiographic factors (altitude, slope, and aspect) on the spatial distribution of *Quercus brantii* var. *persica* tree species in west oak forests of Iran and they concluded that physiographic condition had a key role in the variation of the spatial distribution pattern of trees.

Also, various oak forests are studied in Iran by Hoseini (2016), Pourbabaei et al. (2012), Valipour et al. (2013) and Safari et al. (2011).

Caucasian oak or Persian oak (botanic name: *Quercus macranthera*, Family Fagaceae) is a deciduous tree with up to 30 m height from southwest Asia (Iran and Turkey) (Anonymous 2018). In this study, we carried out to determine some structural characteristics of Caucasian oak (*Quercus macranthera*) stands and assessed physiographic factors such as slope, aspect, and altitude effects on forest structure indices. Analyses were conducted on Caucasian oak stands in Arasbaran protected forest in the east Azarbayjan province in the northwest of Iran.

We tested the following hypotheses: Is there any relationship between physiography aspects and Caucasian oak distribution pattern?, and Are forest structural indices influenced by the interaction of altitudes and species structure and special pattern in Caucasian oak stands? Therefore, the main aim was to study on the most suitable physiographic factor in the Caucasian oak habitat in the northwest forest of Iran.

Materials and Methods

Study area

Arasbaran is located in the northwest of Iran at the border with Armenia and Azerbaijan. The area is 9478.690 ha and located at 38°43′41″ N – 39°8′11″ N latitude and 46°39′50″ E – 47°1′48″ E longitude (Fig. 1). Arasbaran is a high mountainous region with an altitude ranging from 256 m to 2896 m a.s.l. The Arasbaran vegetation has particular importance because of the uniqueness in Iran. In this vegetation area there are more than 1000 plant species (Talebi et al. 2014).

Fig. 1. The location of the study area.

Sampling design

For characterizing the physiographic effect on stand structure, three *Quercus macranthera* dominated stands were selected in three ranges of altitude: 1200–1400 m (R_1), 1400–1600 m a.s.l. (R_2) and 1600–1850 m a.s.l. (R_3), in the Arasbaran forest. In each stand, three hectares sampling plot was established. To characterize structural characteristics within stands, 25 × 25 m grid of sampling points stabilized as a systematic random method (Fig. 2). In each point, the distance method was used to identify a single nearest oak tree as a reference tree and its DBH≥7.5 cm and total height was measured and the distance between the reference tree and the three neighbouring trees was measured (Moridi et al. 2015, Sefidi et al. 2015). Also, the DBH and the total height of all neighbouring trees were measured. And, physiographic characteristics including slop (%), aspect and altitude (m a.s.l.) in eight geographic directions in the centre of sampling plot for each reference and neighbour trees was measured and recorded (Sefidi et al. 2015). Totally, 81 sampling points (27 points in each altitude range) were determined for this study.

Data analysis

Distance indices were used to analyze the spatial distribution and stand structure including uniform angle index, species

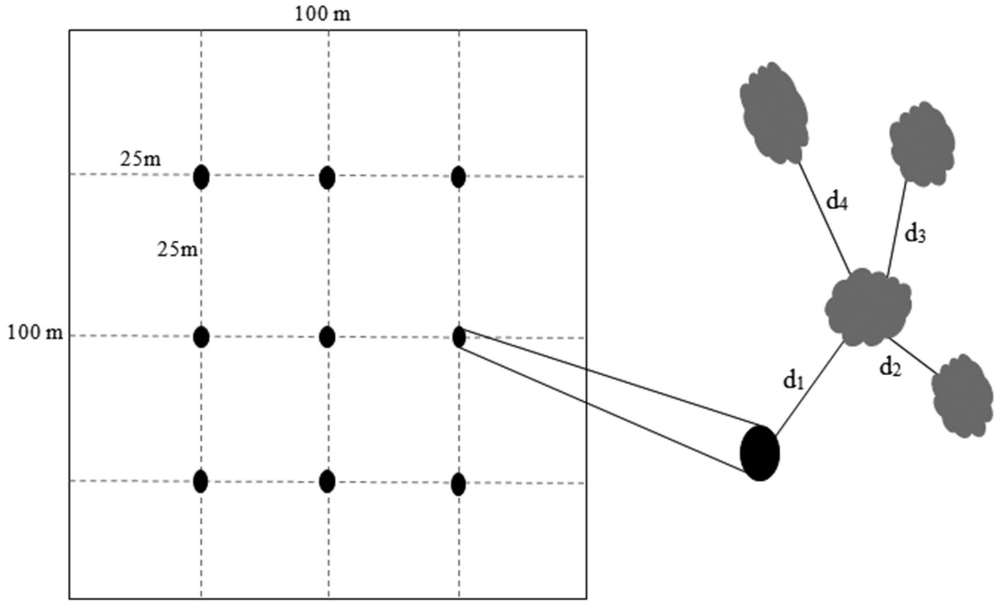

Fig. 2. Sampling and plot design used in the study.

Note: Centre of sampling plot, d1: plot centre distance to reference tree, d_2, d_3 and d_4: distance of the reference tree to the first, second and third neighbour trees, respectively.

combination, DBH differentiation, height differentiation and distance to neighbour (Pommerening 2006). Afterward, the spatial structure indices including Hopkins, Eberhart, and Johnson – Zimmer in each range of altitude were measured (Askari et al. 2013). For physiography's effect, the analysis in following indices was measured: Landform Index (LI), is the mean of slope gradients plot to the skyline, divided by 100 to convert percent to a decimal value. Terrain Shape Index (TSI), the mean of slope gradients from plot centre to boundary in eight directions separated by horizontal angles of 45 and aspect slope index (AS)=cos(45−Aspect)+1 was calculated for land physiographic condition study (Beers et al. 1966; McNab 1989, 1993; Sefidi et al. 2016) (Table 1).

Table 1. Determination of spatial distribution pattern using distance indices (Mirzaei et al. 2016).

Spatial pattern	Hopkins	Johnson-Zimmer	Eberhart
Clumped	>0.5	>2	>1.27
Random	=0.5	=2	=1.27
Uniform	<0.5	<2	<1.27

Results

The number of trees per hectare showed that the largest number of Caucasian oak is in the R_3 as the highest altitude plots (1600–1850 m a.s.l.) (Fig. 3).

Oak trees diameter distribution showed that the most number of large trees are at high altitude range (Fig. 4).

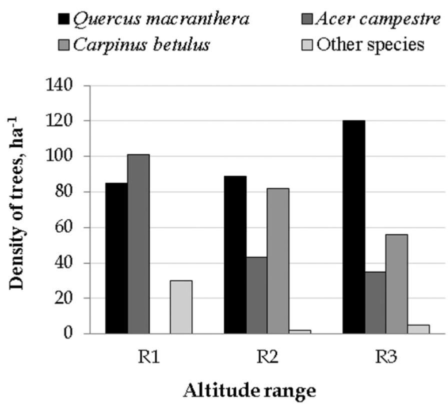

Fig. 3. Density of trees in three altitude ranges.

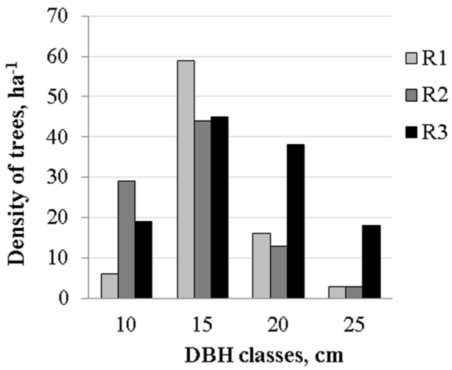

Fig. 4. DBH distribution of trees in three altitude ranges.

According to findings of the stand spatial structure distribution indices, the Hopkins index showed the clumped pattern in all three altitudes; Johnson-Zimmer and Eberhart indices showed a uniform spatial distribution pattern in all altitude ranges (Fig. 5).

Uniform angle index showed the most amount in 0.6–1 class in all altitude ranges and the amount of this class was the highest in R_3 (Fig. 6).

Species interspecific index showed the most species interspecific composition in the lowest altitude (1200–1400 m a.s.l.) and in class 100 % (Fig. 7).

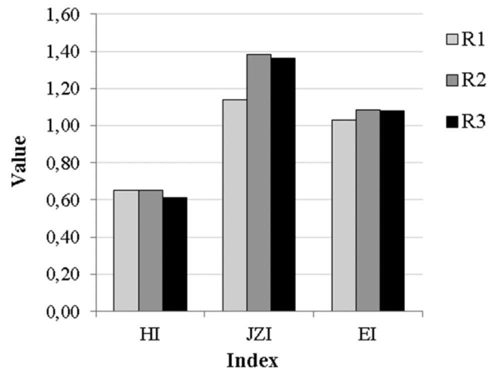

Fig. 5. Spatial distribution pattern indices in the study area.

Note: HI – Hopkins index, JZ – Johnson-Zimmer index, EI – Eberhart index.

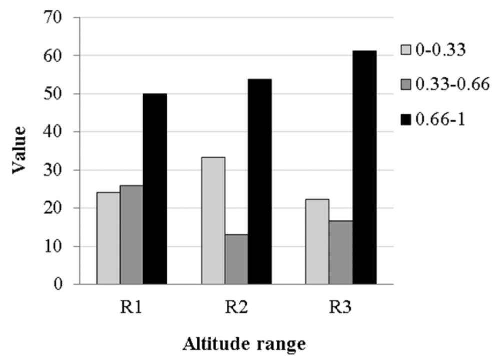

Fig. 6. Uniform angle index in three altitude ranges.

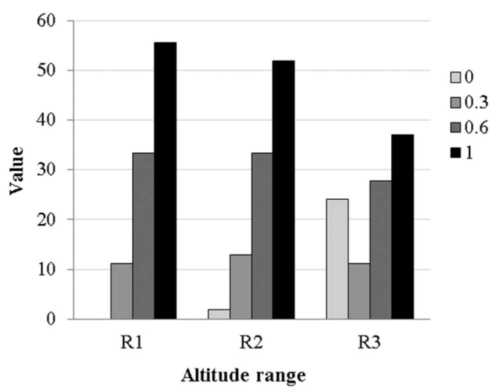

Fig. 7. Species interspecific index in three altitude ranges.

Distance to neighbour index showed that the lowest altitude had the most distance in 4–6 m distance category and this distance decreased to neighbour trees with increasing altitude (Fig. 8).

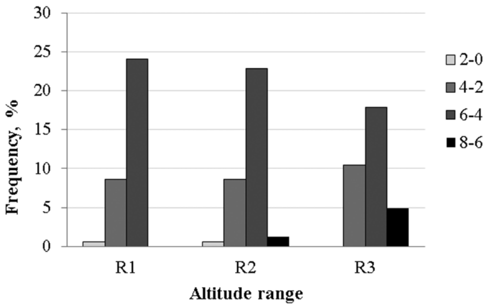

Fig. 8. Distance to neighbour index in three altitude ranges.

Diameter differentiation index showed that the most number of diameter differentiation was accrued in the lowest altitude and in the smallest classes (Fig. 9).

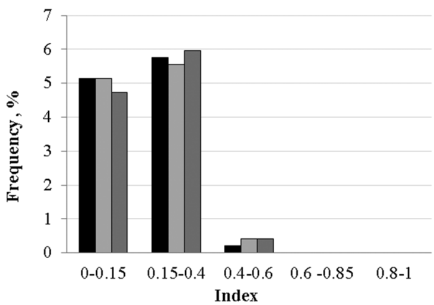

Fig. 9. DBH differentiation index in three altitude ranges.

Height differentiation index showed that the most number of height differentiation was accrued in the lowest altitude and in the smallest classes of height (Fig. 10).

Box plot of the relation between altitudes ranges (horizontal axis) and landform indices (Landform Fig. 11-a, TSI Fig. 11-b, A′ Fig. 11-c respectively in the vertical axis and Table 2) showed that all landform indices had the greatest average in the highest altitudes (R_3).

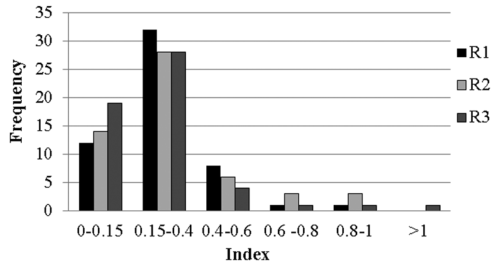

Fig. 10. Height differentiation index in three altitude ranges.

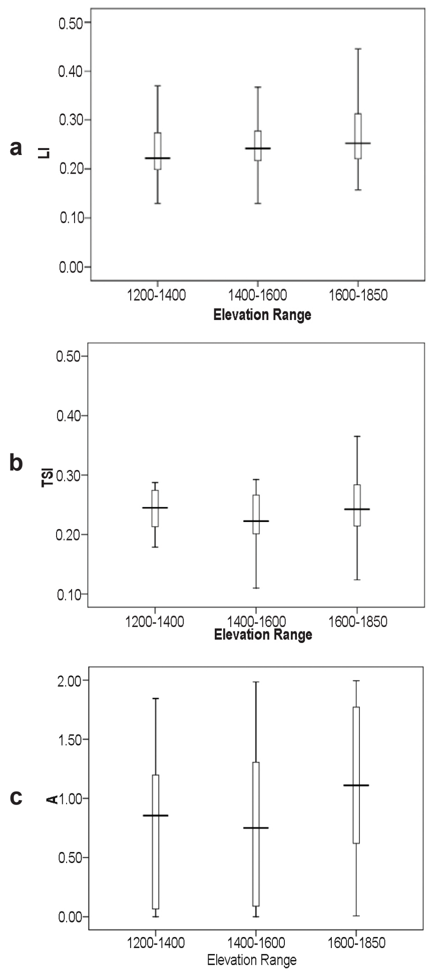

Fig. 11. Box plots of the comparison of landform indices in altitude ranges.
Note: a – LI index; b – TSI index; c – A′ index.

Table 2. Pearson correlation and correlation test between structural quantitative characteristics and physiographic characteristics.

Structural quantitative characteristics	Altitude Range	LI		TSL		A′	
		r	Sig.	r	Sig.	r	Sig.
Density, N/ha	R_1	0.114	0.570	0.014	0.944	0.111	0.584
	R_2	-0.095	0.637	-0.070	0.730	0.074	0.713
	R_3	-1.28	0.524	0.520	0.005	0.007	0.970
Crown area, cm^2	R_1	-0.249	0.211	0.027	0.894	-0.578	0.002*
	R_2	0.259	0.192	-0.380	0.851	-0.575	0.002*
	R_3	0.248	0.212	-0.235	0.237	-0.147	465/0
Basal Area, cm^2/ha	R_1	-0.340	0.082	-0.920	0.647	0.103	0.608
	R_2	0.019	0.926	0.024	0.906	-0.161	0.422
	R_3	-0.446	0.002*	-0.317	0.107	-0.156	0.437

Note: * – correlation is significant at 5 %.

Discussion

Description of the composition, structure and special patterns of forests and determining environment important roles on biological communities can be used to design conservation or management strategies for similar forest types (Chokkalingam and White 2001, Gerhardt and Foster 2002).

The preliminary results of our quantitative studies suggest that the most density and the biggest DBH classes were present in R_3. This can be related to anthropogenic disturbance and close to rural areas and human-made degradation of oak stands in the lower altitudes in the study area.

Erfanifard et al. (2012) stated that clumped spatial distribution was due to the heavy seed of some tree species, the anthropogenic disturbance, and grazing livestock. Wei-dong et al. (2001) suggested that the spatial distribution pattern of a species population is affected by many ecological (e.g. forest biodiversity, species seed distribution habit, etc.) and growing condition (interference human activities, conservation status, etc.). In addition, they emphasized that tree species with heavy fruits and seeds cannot easily distribute by means of natural factors, such as wind and water.

Mirzaei et al. (2016) showed the clumped distribution pattern for *Quercus brantii* var. *persica* stands in the Zagros forests in the west of Iran. They argued that spatial distribution pattern is depended on physiographic factors including altitude, slope (%) and aspect because the stands are available to livestock and local people. Also with increasing altitude and slope, the density of trees reduced and temperature and rainfall changed, therefore these reasons may change the spatial distribution pattern of oak trees in different physiographic conditions.

Pourbabaei et al. (2012) reported that HI and JZI indices showed a random pattern for three oak species (*Quercus libani* G. Olivier, *Q. brantii* Lindl. and *Q. infectoria* Oliv.) stands in the west forest of Iran. Distribution of seeds, reaching the stage of maturity of the seedlings and competition was identified as the effective factors in that spatial distribution pattern.

According to the uniform angle index, it showed a clumped distribution in our study area. Gangying et al. (2007) performed in the analysis of the tree spatial distribution pattern and concluded that the uniform angle index is a suitable alternative for practical field assessment and it is more effective and feasible than other indices. They stated that if the frequency was larger on the left side in the diagram of uniform angel index than on the right side, then the distribution is random; if on the contrary, the distribution is a clump. Therefore, this index was introduced as accurate in determining the spatial distribution pattern of forest stands (Gangying et al. 2007).

Diameter and height differentiation indices indicated that the average size of neighbour trees was 0–40 % larger or smaller than oak trees. Values of these indices closer to 0 indicated uniformity in size and values closer to one indicated greater heterogeneity in size (Sefidi et al. 2015). This study showed a moderate level of diameter and height differentiation. Also, three altitude ranges had almost the same values of diameter and height differentiation and showed uniformity in trees size.

In this study, the most distance to the neighbour tree (four to six meter) was in R3. We concluded that increasing the altitude could increase the species distance to the neighbour. This result is corresponding to Mirzaei et al. (2016) who stated that reduction of temperature and rainfall could affect the trees density reduction in low altitude ranges.

There was a significant correlation among the physiographic indices, different altitude ranges and trees structural characteristics (density, crown area, and basal area). The effects of altitude factor on oak stands were shown in this study. Therefore, we observed the variability of forest characteristics depending on different altitudes. Many factors have played an important role in shaping the regional forest structure consisting of natural (physiography, climatic condition, etc.) and anthropogenic factors (livestock, forestry activities, etc.) (Mirzaei et al. 2016, Fortuny et al. 2017).

Conclusions

Our finding suggested that the sensitivity of oak stands to the difference in local physiography and forest structural characteristics varied with site conditions. These must be considered as an important part of the ecological basis to develop sustainable management guidelines, especially if increasing human uses are expected on these ecosystems. Our study emphasized the importance of introducing environmental variables and their effects on forest ecosystems characteristics, such as spatial distribution pattern. It seems that human destruction and access to the forests are the most important reasons for changing the spatial pattern in this study. The forest structure has improved due to reduced access to forest stands in high altitude. Other factors, such as climatic conditions, can also be considered in subsequent studies. Finally, based on our results, the forest structure can directly be affected by the physiographic condition.

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