The distribution, mixture, and diversity models of woody species in Spatial Pattern of Persian oak (Quercus brantii var. persica) forests

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ABSTRACT

Collection of quantitative and qualitative data from trees is necessary for appropriate management and planning of forest stand. The model of spatial distribution, mixture status, and their diversity are some of the important features of forest stand. The final objective for evaluation of spatial pattern is formation and presentation of the relevant hypotheses regarding ecologic communities, which are crucially important in forest sustainable management. The present study is aimed to examine spatial distribution pattern, mixture status, and diversity of forest wooden species in forests of Mid Zagros Zone (Zarabin Iam, Shoorab, and Ghalehgol in Lorestan province) by means of Nearest Neighborhood Index (Clark & Evans). The100%inventory of stand was employed to extract accurate land data. The results of Clark and Evans’ Index showed the Clumped Pattern for zones of Shoorab and Ghalehgol and the Uniform Pattern for Zarabin region. In order to examine way of arrangement of various species along each other, Mixture Index was applied. With respect to mixture and biological diversity indices, the uniform pattern may be produced due to modification in clumped pattern, which caused by increase in distance among basal sprout due to aging and further diversity of species.

INTRODUCTION

The forests in Zagros vegetation are considered as the second recoverable cellulosic resource in Western Iran and one of the most valuable deposits of oak tree in the world. Arch-like Zagros Range is elongated like a colossal wall from the northwest to southwest of Iran and it represents one of the greatest natural phenomena in this country. Zagros Range is divided into three parts i.e. northern, central, and southern zones; Mid Zagros (central) is assumed as the peak point of Zagros stratifications. The current area of these forests is about 5 million hectares and the dominant constituent type of these forests is Persian oak trees, which make up the dominant tree species of these forests along with other oak species [30]. With their unique species diversity which including several plant species, these forests are deemed as the paramount natural ecosystems in Iran [19, 30].

With respect to distribution of these forests, study on spatial pattern diversity, dispersion, mixture, and quantification of structural patterns are some of important issues. Distribution pattern and its result in demographic dynamism and ecosystem are two essential subjects in ecology [24]. One of the foremost tools in forestry management is quantification of structure. The method of achieving an appropriate structure can be possible with study on their current status. One could conserve biologic diversity and forest reliability by employing appropriate silviculture operation and simulation of natural structures in the managed stand[8]. Spatial distribution patterns may vary at temporal and spatial scales [36, 40& 47]. Spatial distribution structure is one of the foremost effective factors in biologic diversity in forest ecosystems [38]. This important issue is assumed as one of the noticeable and necessary subjects, especially in the course of silviculture close to nature objective [18]. Generally, there are three main types of spatial patterns in the nature:
a) Clumped or cumulative; b) Uniform or regular; c) Random (fig-1) [27].

**Fig 1:** Types of spatial patterns [27].

It has been that the change occurs in spatial pattern among plant communities at any point of time and in many processes like distribution of seeds, mortality, topography, soil, and microclimate or disorders [42]. It is mainly aimed at discovering spatial pattern and formation and presentation of the related hypotheses concerning to structure of ecologic communities [9]. It is necessary to acquiring spatial data about structure and mixture of forest plants at large scales for proper management of forests and ecological researches. Information about quality of distribution pattern may improve our perception about ecological processes such as establishment of stand, competition, birth and mortality [23]. Evaluation of spatial pattern of plants may be useful in recognition of their mechanisms, description of ecosystem stability, preparation of management appropriate plan, protective and revival measures, and implementation of growing and silviculture interventions [41]. Of the conducted studies on analysis of spatial pattern, it can be referred to the following cases: By employing sum of squares method, Alavi et al (2005) introduced spatial pattern for Wych Elm species in Namkhaneh forests from Khizrood educational and research arboretum beside Noshahr city among clumped and random models. Basiri et al (2005) introduced spatial pattern of oak, pear, and hawthorn species as clumped model in Marivan forests. Erfanifard et al (2007) introduced spatial pattern of Zagros forests as spares model by means of Clark and Evans Index. Safari et al (2010) introduced spatial pattern of Persian oak trees as clumped pattern in Bayangan forest at Kermanshah. Hajji Mirza Aghaei et al (2010) denoted spatial pattern of species of hornbeam, witch-hazel, oriental beech, cappadocian maple, and Persian maple as clumped pattern. Pourbabaei et al (2012) declared spatial pattern of oak species as random pattern in Marivan Chenare forests. Farhadi et al (2013) introduced spatial pattern in Khorramabad Ghalehgol forests as clumped pattern. Akala et al (2007) implied spatial pattern of trees in Quebec forests as clumped pattern. Zenner and Peck (2009) introduced trees spatial pattern in US forests as pseudo-uniform pattern.

With respect to economic and ecologic importance of Zagros forests and severe dependency of local communities on these forests, it requires conducting comprehensive studies concerning spatial distribution patterns in order to investigate in status quo and proper regional management by considering the current status. The present study is purposed to determine spatial pattern of Zagros oak trees by means of nearest neighborhood index.

**MATERIALS AND METHODS**

**Study area:** Spatial pattern of trees in a stand should be determined under homogeneous conditions [44]. To conduct this survey, some parts of Mid Zagros forest were selected in Lorestan and Ilam provinces (Iran) in which they were homogeneous in terms of environmental aspects (physiography and soil) and the existing conditions inside the given site (Fig-2). The dominant pattern of these forests is mainly covered with spatial pattern of Persian oak trees. The geographical area and features of the studied zones including Zarabin is situated in Ilam province with area of 1538 hectares longitude (East: 33°8'25" and 33°9'14") and latitude (North: 52°56'9" and 52°56'9"). Shoorab forest park is located in Lorestan province with area of 571 hectares among longitude (East: 49°10'17" and 48°10'33") and latitude (North: 33°25'4" and 33°25'35"), Ghalehgol region is situated in Lorestan province with area of 9491 hectares and among longitude (East: 48°31'20" and 48°35'33") and latitude (North: 33°15'4" and 33°17'51"). The aforesaid regions include semiarid (Mediterranean continental) climate and in terms of topography Shoorab and Ghalehgol are covered with rough hills and the Zarabin zone is located on piedmont.
Fig. 2: Map of Iran and the studied zones.

Research methodology:

After excursion in forest and recognition of the physiographic status of sites in Zarabin and Shoorab and Ghalehgol zones in this investigation, the relatively homogeneous sites with area about 30 hectares were selected in such a way that they might indicate the appearance of Mid Zagros forests. The 100% inventory of stand may provide possibility for determination of tress absolute spatial patterns [9]. With respect to research objectives and the studied indices, the full statistical sampling was done. Some attributes including type of species, distance, and azimuth per tree in respective of certain points were recorded in each site. These data may facilitate using nearest neighborhood index. It should be noted that in sparse (thin) forests, using the three near neighbor methods can result in better outcomes (Fig-3) [11, 21 & 38]. In order to compute all of the used indices, Crancood (v.1.3) software was employed [37].

Fig.3 : The quality of placement of three neighbors surrounding the reference tree [5]

The used indices are as follows:

Clark and Evans Index (CE):

This index is used to determine the rate of deviation of a forest stand from Poisson forest ratio (a forest with random distribution). In this index, the mean distance between a tree and its nearest neighbor \( r_d \) and the expected mean in the case of random position of trees \( r_e \) is compared. The mean value of this index can be calculated from Eq. (1) [22].
In the above expression, $r_i$ denotes distance between tree $i$ and its nearest neighbor ($m$); $N$ indicates total number of trees inside the given plot; $A$ stands for the typical cross sectional area ($m^2$); and $P$ is perimeter of sample plot ($m$). When distribution of trees follows a random pattern in the studied forest CE value is 1 while CE value less than 1 indicates the clumped pattern and CE value greater than 1 expresses the uniform position of trees [22].

**Mixture Index ($DM_i$):**

In order to examine the way of arrangement of various species, mixture index was employed. The basis of analysis in this index is of this index is similar to uniform angle index. The value of mixture index may be computed by Eq. (2):

$$DM_i = \frac{1}{3} \sum_{j=1}^{3} V_{ij} \left[ \begin{array}{c} 1 \rightarrow j \text{(species)} \neq i \text{(species)} \\ 0 \rightarrow j \text{(species)} = i \text{(species)} \end{array} \right]$$

Eq. (2)

In this formula, $i$ denotes reference tree and $j$ indicates neighbor trees. With respect to relative frequency and position of species placement with each other, value of this index varies between 0-1. Like uniform angle index at time of employing three neighbors in a structural group, one of the values will be zero (all neighbors similar to reference species), 0.33 (one neighbor different from reference species), 0.67 (two neighbor different from reference species), and or 1 (none of neighbors is similar to reference species) [11, 21 & 38].

**Shannon Index ($H'$):**

Species diversity is one of the very important aspects in forest sustainable management so that in order to examine this aspect several indices have been developed. The work basis in Shannon Index differs from other utilized indices in this investigation and it is placed in the independent class of indices from distance (non spatial) with the conducted classifications but it is usually used as complement with mixture index in study on species diversity and its effect on spatial structure. This index can be calculated from Eq. (3):

$$H' = -\sum_{i=1}^{n} P_i (\ln P_i)$$

Eq. (3)

Where, $n$ denotes number of existing species in the studied zone; $P_i$ is the ratio of frequency for a certain species in relation to total trees; and $H'$ expresses Shannon Index that may vary among zero and five.

**Distance to Neighbors Index ($D_i$):**

Most of the employed indices in this survey deal with quantification of forest spatial structure regardless of distance among trees. Hence, these indices act weakly in describing difference between forests with equal structure but various densities. In order to alleviate this problem, Distance to Neighbors Index was employed. In Eq. (4), the technique of computation of this index has been indicated for a structural group with four neighbor trees.

$$D_i = \frac{1}{3} \times \sum_{j=1}^{3} S_{ij}$$

Eq. (4)

Where, $S_{ij}$ denotes distance among reference tree to its $j^{th}$ neighbor. Similarly, by calculation the mean values from this index for all structural groups, the mean value of this index will be acquired for total studied forest.

**Nearest Neighbors (NN) Index:**

The margin of boundary trees was corrected to form structural group by means of this index. In this case, all neighbors of a certain tree are observed inside the sample plot. If distance from the border of sample plot is less than distance from $n^{th}$ neighbor it is probably that one or more neighbors are placed outside the sample plot so this tree will be excluded from this range as a reference tree [5].

**Results:**

Number of trees was recorded in Ghalehgol, Shoorab, and Zarabin Zones as 2982, 1875, and 2256 trees respectively based on the 100% inventory method. Out of this total number, there were 6005 Persian oak basal In coppice spatial patterns, 487 cases of high forest, and 623 basal patterns from other ligneous species (Fig-4) (Table-1). The effect of marginal point of statistically sampled zones was corrected on formation of structural groups by means of indices in spatial pattern and technique of margin of the nearest neighbor.
Table 1: The condition of recorded trees in every zone

<table>
<thead>
<tr>
<th>Zones</th>
<th>Spatial pattern (coppice)</th>
<th>Spatial pattern (high forest)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ghalehgol</td>
<td>2741</td>
<td>92</td>
</tr>
<tr>
<td>Shoorab</td>
<td>1823</td>
<td>0</td>
</tr>
<tr>
<td>Zarabin</td>
<td>1439</td>
<td>395</td>
</tr>
</tbody>
</table>

Table 2: Distance up to neighbors for the studied zones (m).

<table>
<thead>
<tr>
<th>Zones</th>
<th>First neighbor (m)</th>
<th>Second neighbor (m)</th>
<th>Third neighbor (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zarabin</td>
<td>5.52</td>
<td>6.28</td>
<td>7.76</td>
</tr>
<tr>
<td>Shoorab</td>
<td>4.32</td>
<td>4.93</td>
<td>5</td>
</tr>
<tr>
<td>Ghalehgol</td>
<td>4.85</td>
<td>5.90</td>
<td>7.10</td>
</tr>
</tbody>
</table>

The numerical value of Clark and Evans Index (CE) was acquired 3.24 in Zarabin zone that indicates the uniform pattern. This index was calculated 0.70 and 0.43 for Shoorab and Ghalehgol zones respectively, which signify the clumped pattern for these zones.

Mixture index was utilized to examine species mixture in the studied zones. The values of this index were computed for Zarabin, Shoorab, and Ghalehgol zones as 0.09, 0.04, and 0.05 respectively. The results from this index may suggest that oak species is placed with greater mixture ratio among other species in Zarabin zone. The rate of mixture of species is less in Ghalehgol and Shoorab zones. Shannon-Weiner Index was used in order to examine species diversity. The values of this index were derived 0.53, 0.22, and 0.23 for these regions respectively.

Discussion:

It is necessary to collect quantitative and qualitative data from tree for optimal forest management and planning [32]. The spatial distribution pattern for woody species is one of the important quantitative characteristics in forest communities. The ecologic processes in forest systems are directly affected by pattern of trees [35]. For example, spatial pattern directly affects on competition status, growth of young trees, survival, and shape of trees canopy [40]. This study is mainly intended to introduce spatial pattern of Persian oak trees forest in Mid Zagros zone. Likewise, out of the effective factors on structure of spatial pattern of trees distribution, factors of diversity and mixture were also explored.

With respect to numerical values, Clark and Evans index (CE) was computed for Zarabin zone with uniform spatial pattern and for Shoorab and Ghalehgol zones with the clumped spatial pattern. In their studies, Manabe et al (2000) and Taylor and Quin (1998) concluded that spatial pattern in many species in forest communities is in the clumped and or uniform pattern. Random distribution rarely takes place in the forest since trees are related mutually with each other in forest. These mutual relations are one of the major factors in formation of spatial structure of trees. When the presence of an individual tree does not extremely affect on other species distribution, these individual species is randomized. The uniform distribution usually takes place when the individuals' domain are certain and these equal zones are identical. If majority and or all individuals in a population tend to presence in certain parts of an environment their distribution follows of the clumped pattern [17].
Maltez-Mouro et al. (2007) expressed in their investigations that germination of oak trees is based on the clumped pattern and they are related to their parent trees. Oak is one of species with heavy seeds, which need to nursing trees during first years of its life cycle [34]. Habashi et al. (2007) as well as Hassani and Amani (2010) assumed the reason for the clumped distribution of trees with heavy seeds like a variety of oriental beech in ecologic features of this species such as heavy seeds and its spot germination. Hegazy and Kabiel (2007) observed that the adjacent sprouts to parental trees might follow up the clumped pattern. Hence, most of the conducted investigations in this regard [1, 6, 10, 14, 17, 20 & 48] indicate the clumped pattern for Zagros forests.

In their study, Pourbabaei et al. (2012) introduced the random pattern for model of oak trees distribution in a region in Zagros (Chenare Marivan). This means that each of oak basal trees could be placed randomly in every point of this zone. They stated that wind plays no role in transfer and pollination of oak heavy seeds but some animals like boar and rodents such as mice and Indian porcupines, which are found in these zones, might play role in transferring the seeds randomly. Similarly, Likewise, they deem sprout basal species as a reason for creation of random pattern in these regions and this fact is not consistent with the current study. Probably the absence or less presence of wild life that may play role in transferring of seeds randomly are the reason for this difference. Of course, dimensions of trees also affect on observation of random pattern. Hegazy and Kabiel (2007) observed that the adjacent sprouts to parent trees have followed up the clumped pattern but they will result in random pattern with increase in growth and enlargement of dimensions. The random pattern may be produced as a result of change in the clumped pattern due to competition among neighbor basal sprouts [25].

It should be acknowledged that in many former studies, trees distribution pattern has been extracted mainly based on statistics of distances among the studied samples and they utilized less from total spatial pattern on trees in determination of distribution pattern. This has caused that every basal sprout of a group to be considered as a neighbor to the adjacent sprouts of the same sprouted group and as a result the estimated spatial pattern has not been assumed as the spatial pattern inside the germination groups (sprouting groups) and the real spatial pattern that should be based on parental basal sprouts (center of sprouting groups).

Rising of distance among parent basal sprouts with distribution pattern may be developed from the clumped mode to random and uniform pattern [35]. The given results from distance to neighbors index, which indicates mean distance among first and second and third neighbors from reference trees, expresses further distance from neighbor trees in Zarabin zone. One of the reasons for acquisition of uniform pattern for these forests may be in rising of distance among basal sprouts and as a result age of woody basal sprout has been increased in this zone. The higher rates of mixture and diversity indices of woody species in this region are also a reason for less destruction in this site and older age of its trees. Pommerening (2002) stated that species mixture is influenced by spatial situation of trees and species with the clumped pattern may be usually less mingled. With respect to results of mixture index, it can be implied that the higher rate of their mixture may be another reason for this point that Zarabin zone has the uniform spatial pattern. The rate of Shannon-Weiner Index is twice greater in Zarabin zone than other regions and this reflects further diversity in woody species in Zarabin zone.

The increasing trend of destruction in Zagros forest and occurrence of degeneration phenomenon will lead the majority part of these sites to annihilation. It seems necessary to analyze spatial aspects of structure in order to be aware of the status quo and for revival and returning of these forests to the subsequent progressive trend. The spatial aspects of forest structure form under the influence of several factors including Germination state germination (sprouting), human-driven interventions, animals, method of management, and disturbances. With respect to the effective ecologic disturbances and crises in this area, it is suggested to study on their effect on structural changes.

REFERENCES


