Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 5, No. 3, p. 299-307, 2014
http://www.innspub.net

RESEARCH PAPER

OPEN ACCESS

Spatial pattern of *Pistacia atlantica* desf. in zagros forests of Iran

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Article published on September 25, 2014

Key words: Spatial pattern; Nearest Neighbor Index; Winkelmass Index; *Pistacia atlantica* Desf.; Qalajeh.

Abstract

Studying the spatial pattern of plant community is to understand and recognize this community and is essential to understand many ecological and forest management issues. The purpose of this study was to investigate the performance of Winkelmass index in determining the spatial pattern of *Pistacia atlantica* Desf. in Zagros forests. A field with an area of 30 hectares was selected in Qalajeh forests inthe Westof Iran. Completed sampling was conducted and stem map of *Pistacia atlantica* Desf. was produced. The absolute spatial pattern of *Pistacia atlantica* Desf. was determined using Nearest Neighbor Index. In order to determine the spatial pattern of *Pistacia atlantica* Desf. Using Winkelmass index, 60 sampling points were selected on the stem map and the required angles were measured. The values of Nearest Neighbor and Winkelmass Index were 1.09 and 0.45, respectively, which indicated uniform tended to random pattern in both indices for *Pistacia a tlantica* Desf. Therefore, it is concluded that the Winkelmass index has suitable performance in evaluating the spatial pattern of *Pistacia atlantica* Desf. in Zagros forests.

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Introduction

The position of trees in a forest can be shown as a series of points by determining their coordinate to each other. A series which includes these points is called the spatial pattern of trees (Akhavan *et al.,* 2010). Generally, there is three patterns in plants communities; uniform, random and clumped (Baddeley, 2010). Different factors such as morphological, environmental, phitosociological properties and disturbances occurred in ecosystem cause the formation of different patterns (Dale, 1998).

Spatial pattern

Spatial pattern of trees is an important property of forest stands which can be used to investigate the symbios of species (Wiegand *et al.,* 2007), to evaluate the effects of silvicultural interferences on stand, to determine the biological relationships among different trees (Tsitsoni *et al.,* 2003), to select the suitable sampling design (Trifković and Yamamoto, 2008), to plan suitable management programs, to describe ecosystem stability and recovery functions (Mouro *et al.,* 2007) and toevaluate the development of plant community (Grabarnik and Särkkä, 2009). Besides, it is an important tool in environmental and protection programs (Pommerening and Stoyan, 2008).

Literature review

Different methods have been developed to study the spatial pattern of trees owing to the importance of investigation of spatial pattern to plan the management programs of forest stands. In forest inventory, two general methods of sampling and completed inventory are used (Stamatellos and Panourgias, 2005). When completed inventory is used, the spatial pattern of trees can be analysed using three methods of quadrat-variance (Ludwig and Reynolds, 1988), nearest neighbor index (Krebs, 1999) and K function (Ripley, 1977). In quadrat-variance method, the points within each quadrat are investigated, while the points among the quadrats are not considered and this leads to errors in pattern determination (Erfanifard *et al.,* 2008). Also, using K-Ripley function has restrictions; for example, the shape and size of the study area have direct effect on spatial pattern due to edge effect (Mitchell, 2005). But, nearest neighbor index is a powerfull index, as the precision of other indices is evaluated with this index (Moustakas *et al.,* 2008).

In the case of using the sampling methods offixed area plot (Stamatellos and Panourgias, 2005), measuring the trees distance to neighbor trees or distance indices (Krebs, 1999) and measuring the angles among trees (Corona *et al.,* 2005; Schmidt *et al.,* 2006;Gangying*et al.,* 2007; Stephens *et al.,* 2008; Trifkovic and Yamamoto, 2008; Fucai *et al.,* 2010), it is possible to analyze the spatial pattern of trees. In fixed area plot method, determining thepattern is affected by the plot area if the spatial pattern is not random (Wong and Lee, 2005). Different indices which are used in distance methods have restrictions and different pre-hypotheses, and have different abilities to detect varius patterns (Erfanifard *et al.,* 2009; Jannat Rostammi *et al.,* 2009).However, using angles among trees does not have theme tined restrictions. In this method, different indices such as Winkelmass are used. Thus, in the current research the results of Winkelmass index was compared to nearest neighbor index to investigate the performance of W_i index in determining the spatial pattern of trees.

Aim of this research

Pistacia atlantica Desf. is one of the important tree species in Zagros forest with high economical and social levels in the region owing to its valuable fruit and resin. It has previously been harvested and now many people in villages with high frequency of *Pistacia atlantica* Desf. Utilize it (Jazirehi and Ebrahimi Rastaghi, 2003). This study was an attempt to introduce an appropriate method todetermin the spatial pattern of *Pistacia atlantica* Desf. Trees in order to protect and revive this valuable source, because determining the spatial pattern of plants can be useful to prepare the management plans and suitable inventory as well as to protect, revive and perform silvicutural interference operations.

Materials and methods

Study area

Qalajeh forestis located in the West of Iran in Kermanshah province. This forest is part of Zagros forests. Qalajeh forest with an area of 2110 hectares is located between the latitude 33° 58´ 42´´ to 34° 01´ 26´´ N and longitude 46° 18´ 05´´ to 46° 22´ 18´´ E. The altitude is from 1500 to 2000 meters (Porma *et al.*, 2010). The climate is Mediterranean and the mean annual rainfall is 516.7 mm. The soil is silty-clays tending to clays. The canopy cover of Qalajeh forests is less than 30% and the annual diameter growth of *Pistacia atlantica* Desf. trees is 2-6 mm (Pourreza *et al.*, 2008).

Data collection

First, a stand with an area of 30 hectares was selected; then, the position of all trees was determined by measuring the distances and azimuth of *Pistacia atlantica* Desf. trees to each other and finally, the stem map was produced. To calculate W_i index, 60 sampling points were determined on the stem map using systematic random sampling design. In each sampling point, the nearest tree to this point was determined and recorded as the central tree. 4 neighbor tress (Pommerening, 2006; Corral *et al.*, 2010) which had nearest distances to the central tree were selected (Fig. 1). Finally, the produced angle between each pair of neighbor trees near the central trees was calculated.

Data analysis

Nearest neighbor index

In this study, nearest neighbor index (R)was used to determine the absolute spatial pattern of *Pistacia atlantica* Desf. In the field (Pommerening, 2006). This index is calculated from the relation of mean distances between each tree and its nearest neighbor in the studied plot to the mean distances in a completely random spatial pattern (Eq. 1)(Gonçalves *et al.,* 2010; Sousa-Souto *et al.,* 2013). Z statistics was used to test the significant difference of the determined pattern with this index and random pattern (Eq. 2). After the calculation of R and Z, the spatial pattern of trees was determined using Table 1 (Krebs, 1999).R and Z were calculated using Arc GIS software.

$$R = \frac{\bar{r}_A}{\bar{r}_E} \quad (1)$$

Where R is the nearest neighbor index, $\bar{r}_A$ is the mean distance of each tree to its nearest neighbor in the studied plot, $\bar{r}_E$is the mean distance of each tree to its nearest neighbor in a completely random pattern.

$$z = \frac{\bar{r}_A - \bar{r}_E}{Sr} \quad (2)$$

whereSr is thestandard error of expected distance to nearest neighbor (Krebs, 2001).

W_i index

W_i index is a simple and rapid method to investigate the spatial pattern of forest stands and is done by measuring the angle among neighbor trees (Pommerning, 2002; Corona *et al.,* 2005; Gangying *et al.,* 2007). W_i index is the percentage of measured angles which is less than standard angle (α_o) (Pommerning, 2002). The standard expected angle among neighbors is calculated using Equation 3 (Hui *et al.,* 2007). W_i index is used to analyze the spatial pattern of trees from calculation and graphic viewpoints.

$$\alpha 0 = 360°/(1+n/) \quad (3)$$

where the number of neighbor trees to central tree.

Calculation method

In this case, the standard expected angle is calculated and then different values of W_i are calculated for each sampling point using Equation 4.

$$W_i = \frac{1}{n}\sum_{i}^{n} z_{ij} \quad (4)$$

$$\text{where} z_{ij} = \begin{cases} 1, \text{ if the jth } \alpha < \alpha_o \\ 0, \text{ if the jth } \alpha > \alpha_o \end{cases}$$

where n the number of neighbor trees to central tree (Gangying *et al.,* 2007; Hui *et al.,* 2007).

n+1 value is possible for W_i if n neighbor tree to central tree is investigated. For example, if 4 neighbor trees to central tree are investigated, 5 values are possible for W_i which are 0, 0.25, 0.5, 0.75 and 1.

After determining W_i in each sampling point, the mean of these values is calculated and $\overline{w}$ is obtained (Eq. 5). The pattern is uniform if $\overline{w}$ is equal to 0, the pattern is random if $\overline{w}$ is 0.5 and the pattern is clumped if $\overline{w}$ is 1. It is better tousethe confidence limits of $\overline{w}$ to analysethepatterns by W_i. For random pattern, the mean of W_i index in distances 0.517 and 0.475 for clumped pattern is $\overline{w}$>0.517 and for uniform pattern is $\overline{w}$<0.475 (Stephens *et al.,* 2008; Fucai *et al.,* 2010).

$$\overline{w} = \frac{1}{n}\sum_{i=1}^{n} w_i = \frac{1}{4\text{n}}\sum_{\text{i}=1}^{\text{n}}\sum_{j=1}^{4} z_{ij} \qquad (5)$$

where n is the number of sampling points, i is each central tree, j is each of four neighbor trees to central tree.

Graphic method

In this method, a graph is designed based on the frequency percentage of W_i values. The pattern is random if the distribution frequency of the W_i is the same at both sides of the diagram. The pattern is uniform if the frequency at the left side is more than the right side and in inverse status the pattern is clumped (Gangying *et al.,* 2007; Hui *et al.,* 2007).

Results

The density of the *Pistacia atlantica* Desf. In the study area was 10.4 trees per hectare and the total number of this species in the stand was 312 trees. Figure 2 shows the spatial distribution of *Pistacia atlantica* Desf. in the study area.

Table 1. Determining the spatial pattern of trees based on R and Z values.

Spatial pattern	R	z
Clumped	1<R	-1.96<z
Random	1 = R	+1.96<z<-1.96
Uniform	1>R	+1.96>z

Nearest neighbor index

Results showed that the R value for *Pistacia atlantica* Desf. was 1.09. According to the definition of nearest neighbor index (Table 1), the spatial pattern of this species is uniform tended to random, because the R value is more than 1 and is close to it. Therefore, the null model or random spatial pattern is rejected and the pattern introduced by index is confirmed, because the Z value for *Pistacia atlantica* Desf. is more than 1.96 (Fig. 3, Table 2).

Table 2. The values of nearest neighbor index and Z value.

Species	R	z	Spatial pattern
*Pistaciaatlantica*Desf.	1.09	3.43	Uniform tended to random

W_i index

Calculation method

The mean of W_i index for *Pistacia atlantica* Desf. was 0.45. So, the spatial pattern of *Pistacia atlantica* Desf. was uniform tended to random, because the W_i value was more than 0 and lower than 0.5. Based on the confidence limits of the mean of W_i, the spatial pattern of *Pistacia atlantica* Desf. was also uniform tended to random, because 0.45 wasless than 0.475 and close to it.

Graphic method

In Figure 4, the frequency of W_i is shown based on the calculated values. According to Figure 4, the frequency of W_i is more at the center and left side of the diagram, therefore, with the use of graphic method, the spatial pattern of *Pistacia atlantica* Desf. is introduced as uniform tended to random.

Discussion and Conclusion

Spatial pattern of plants is one of the important aspect of plant ecology and is a basic and necessary tool for measuring and investigating plant cover in each site (Dale, 1998; Jayaraman, 1999). Thus, it is not surprising that ecologists have paidmore attention to the analysis ofspatial pattern and development of several methods to quantify this pattern in the recent decades (Dale, 1998; Perry *et al.,* 2002).In this research, two indices of nearest neighbor and Winkelmass were used to investigate the spatial pattern of *Pistacia atlantica* Desf. and to assess the performance of W_i index in the analysis of spatial pattern, the results of the given index was compared to the nearest neighbor index as the original method. Results showed that both functions of Winkelmass index had suitable performance in determining the spatial pattern of *Pistacia atlantica* Desf. in their researches, Kint *et al.* (2000) Gangying *et al.* (2007) and Ruprecht *et al.* (2010) confirmed the performance of W_i index in the analysis of spatial pattern of trees.

The distribution of plant species is not random on earth, because each plant community includes a series of plant species with similar nature and ecological requirements which, under the influences of environmental conditions such as soil and moisture, select a special site for establishment and growth. Presence of clumped pattern in distribution of plants is common except for artificial ecosystem and ecosystems under the human and wildlife activities and interferences (Poltkin *et al.,* 2002; Detto and Muller-Landau, 2013).Presence of pressure and different interferences in Zagros forests and thestudy area such as grazing and unusual harvesting of secondary products and collecting fruits of *Pistacia atlantica* Desf. by native people have cause destruction of a series of trees and lack of regeneration has caused the removal of the clumped pattern and finally, production of uniform tended to random pattern in the study area. Pourreza *et al.* (2008) reported that severe harvesting of this species by villagers cause the decreasing diameter and lack of establishing *Pistacia atlantica* Desf. regeneration in Qalajeh forests. Alavi *et al.* (2005) found that the reason of the spatial pattern of *Ulmus glabra* Huds. Was removing trees due to illegal wood harvesting and Dutch elm disease. Mantgem *et al.* (2011) indicated that the spatial pattern of the study species was the consequence of removing trees by fire. Luis *et al.* (2008)reported that the reason of spatial pattern is lack of regeneration.

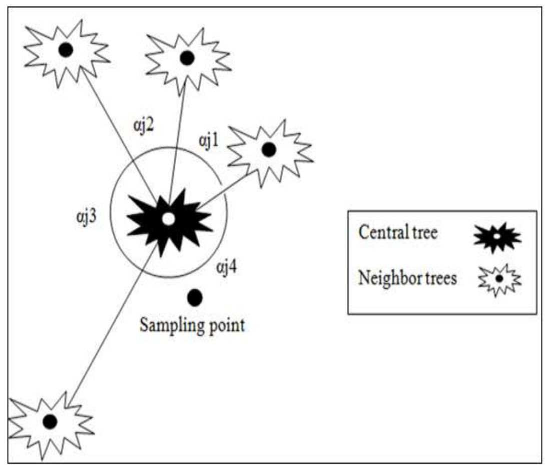

Fig. 1. Determining the trees in each sampling point.

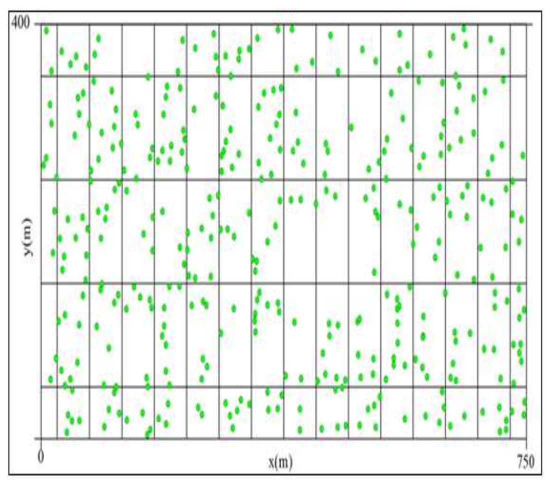

Fig. 2. The map of spatial distribution of *Pistacia atlantica* Desf. Trees.

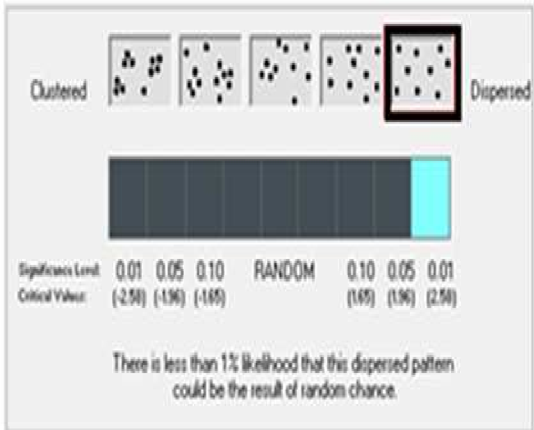

Fig. 3. The spatial pattern (gray color border) of *Pistacia atlantica* Desf. using graph in nearest neighbor index.

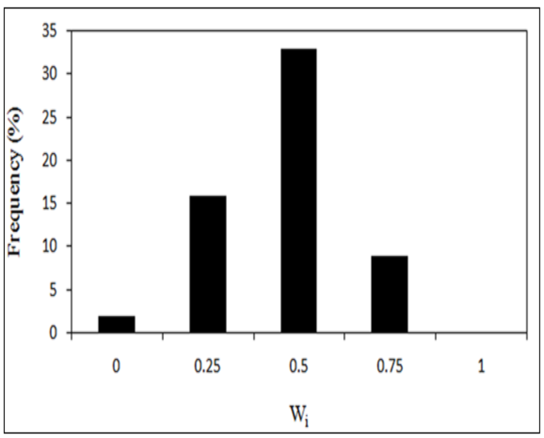

Fig. 4. Frequency of the calculated W_i.

Results of this research were not in agreement with the findings of Erfanifard *et al.* (2012) and Karimi *et al.* (2012). These studiesintroduced the spatial pattern of *Pistacia atlantica* Desf. as clumped and random, respectively. This difference is due to the scale difference of the study area, because all ecological processes depend on the scale and can affect the pattern (Makana and Hibbs, 1999; Wiegand and Moloney, 2004). Generally, based on our findings, Winkelmass index can be used as a rapid and cost effective method to determine the spatial distribution pattern of trees in Zagros forests.

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