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STAND STRUCTURE DYNAMIC OF TURKISH PINE (*PINUS BRUTIA*) GROWN NATURALLY IN THE ATRUSH REGION, IRAQ

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SUMMARY

Coniferous woods of uneven age have a natural distribution in Atrush, Iraq, and this study selected 10 random samples from diverse places and densities to understand their stand dynamics, using a 17.9 m radius circular sample. The tree and stand variables and global tree coordinates measurements occurred for each sample. Using different diameters to measure total height determined the phases of tree seedlings. When the diameter was over 10 cm, the trees were over 1.3 m tall. Through analysis, it revealed that the densities of these trees spread in the study site and reached 28181.89 trees that varied widely. The number of tree members at the lower diameter was the highest, fluctuating from sample to sample, indicating variances in natural renewal between study sites. The site is rich in natural regeneration. Samples 2, 8, and 10 showed balance for the quantity of seedlings, juveniles, and trees, indicating stability in tree movement. The obtained results relied on mechanisms of community aggregation using tree spatial distribution data.

Keywords: Turkish pine (*Pinus brutia* Ten.), stand dynamic, pattern analysis, stand characteristics, diameter and height

Key findings: The study samples also showed diverse clear distribution patterns, mostly declining regularly and randomly while appearing minimally clustered. It was evident that most trees, whether of varieties, diameters, or heights, are in the first or second class, except the eighth, second, and tenth samples, indicating the strength of natural regeneration in the study area.

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INTRODUCTION

Turkish pine (*Pinus brutia* Ten.) is a species that belongs to the family Pinaceae and has natural distribution in the Eastern part of the Mediterranean and various areas in Turkey, Syria, Lebanon, Cyprus, and Northern Iraq. This species occurs at altitudes ranging between 600––1200 masl, has needle-like leaves, and shows resistance to drought and poor soils. Exploitation and unsustainable management during the past decades have led to a decline in the spread of this species (Chambel *et al.,* 2013).

Many stands of pine trees have low densities, hence the need to act and manage them towards sustainable regulations and raise their productive competence through applying various development processes for their regular and manageable transformation (Waston, 1983). The use of investment and cutting operations in managing stands will affect the structure, composition, and age of these stands. Therefore, the forest manager faces a vast challenge in regulating the spread of this species on the site through access to a fully developed stock and in determining the percentage of the intended goals. It means conserving the production elements, sustainable forest management, and restoration of biological diversity and the tree's composition at the site (Mason, 2004).

Unfortunately, little information existed about the natural structure and dynamic of the stand. In these forests (Northern Iraq), various species are widespread in addition to pine, and details for the natural regeneration and spatial distribution of the age stages are unavailable for this stand (Worrell, 1990). Therefore, working to increase both the species area and the biodiversity and its structure requires knowing the current structure of the trees to work out the best way to encourage natural revitalization.

Understanding the spatial distribution of maternal trees is necessary in addition to determining the current distribution of juveniles and seedlings in the sites of this species. It is also to identify the type and prepare a program to develop the site toward sustainable exploitation of production elements (Scott *et al*., 2000). The pine trees reach a height of 6.5 m from germination up to 20–25 years. However, there is no clear role of the developmental processes and the services provided to the trees at this stage in shortening this period and its impact on fixing these trees.

Determining the spatial distribution is crucial in exploring the best method of natural regeneration for the latest sites for management. Through natural renewal, the new production elements distributed over the sites gained introduction, which led to site exploitation. Therefore, understanding the spatial distribution of trees in the forest is imperative in maintaining and sustaining the production and the persistence of silviculture processes and investment for the current and future growing periods (Lindenmayer and Laurance, 2017).

The spatial allocation is also critical in determining the structure of the forests (Gadow *et al*., 2012). In mixed forests, determining the spatial models of trees depended on the layers of the crowns of trees found in the forests, known as the vertical distribution. The spatial space occupied by the crowns of trees is the horizontal distribution, and through these two distributions, the density of trees can be estimated with full stock, medium stock, and/or low stock (Gen *et al*., 2012). The observed spatial allocation in the horizontal distribution was clustered, regular, and/or random (Illian *et al*., 2007). The presented study aimed to determine the structure of the horizontal and vertical *Pinus brutia* stand and the movement of the trees for the diverse spatial distribution models by relying on the trees' different growth stages (seedlings, juveniles, trees).

MATERIALS AND METHODS

The study area is in the Northeast of Iraq in the Atrush region, with a latitude ranging between 36° 31′ – 36° 51′ North, a longitude ranging between 43° 20′ – 43° 21′ East, a height above sea level between 728–1136 m, and an average slope between 3.65%–18.91%. The site includes many trees of mixed types in different extents and diverse characteristics. Therefore, the random distribution of 10 samples over the study site appeared with varying densities.

The study samples extended over different geographic areas and environments resulting in notable variances in the characteristics of this forest stand showed for the number of trees ha^{-1}, the base area per unit area, the average diameter, and the average height. The varying diameters in each at measuring the total height helped determine the different stages of the trees according to the methodology used by Gen *et al*. (2012).

According to the scale (Table 2), the obtained samples from the study site incurred division according to the trees' different growth stages to determine the nature of their movement. The usual conventional statistical methods applied and the geographical distribution process aided in providing a better understanding of the spatial allocation of the pine trees. The data analysis of the studied samples for the pine trees in the Atrush region, Iraq to estimate Ripley's K(r) function and test its significance, engaged the Monte Carlo method using the PASSaGE V.2 program. This function is a statistical tool used to analyze the spatial distribution of objects or events within a study area. It measures whether objects are clustered, dispersed, or randomly distributed across the study area (Rosenberg and Anderson, 2011).

RESULTS AND DISCUSSION

The natural forest trees were in a state of continuous dynamics with time; some elements are outside the production process and others entered. Hence, for the forest management to find a balance between the input and the outside elements, the production elements in the age stages of the trees were seedlings < juveniles < trees, and thus reach administratively, it leads to a state of balance in the composition of vegetation, with the same results also indicated by Stride *et al*. (2018).

The study samples also exhibited scattering across density ranges (Table 1), with 278 to 725 trees/ha. It significantly impacted the traits of the trees thriving in these stands. It was visible that these stands' average diameter at height widely varied, reflecting in the basal area that also grew. Based on the tree features themselves, depending on the diameter at the total height, it was also noticeable that the trees' distribution was according to the growth stages (Table 2) because each growth stage has traits that set it apart from the others. Distinguishing the growth stages and the concerned parameters resulted from using these measurements (Dukenov *et al*., 2023; Rinaldi *et al*., 2023).

Table 1. Stand characteristics of pure and mixed pine trees of the study site samples.

No.	Stand Characteristics			
	Number (ha^{-1})	Basal area (m^2 ha^{-1})	Mean diameter (cm)	Mean height (m)
1	755	2.1372	3.3	2.1
2	339	2.6500	4.0	2.0
3	318	0.1443	5.6	2.4
4	278	3.3239	6.3	2.8
5	725	1.9104	6.9	3.6
6	437	3.8607	6.1	2.7
7	337	0.9249	4.7	2.3
8	377	2.1821	3.2	3.7
9	646	2.6149	10.9	4.1
10	477	2.2340	5.2	2.3
Variance	28181.89	1.0336	4.5096	0.494
Standard deviation	8001.65	1.0260	2.0499	0.9445

Table 2. The scale used to determine the stages of development of tree growth.

Stages develop	Item	Diameter (cm)	Height (m)
Seedlings	A	$d_{1.3} < 5$ cm	H < 1.3 m
Juveniles	B	$5 < d_{1.3} < 10$ cm	H > 1.3 m
Trees	C	$d_{1.3} > 10$ cm	H >1.3 m

Table 3. Classes diameters and heights for samples of different densities in the Atrush region.

Sample No.	Classes diameter					Classes height				
	0 – 5cm	5.1 –10cm	10.1–15cm	15.1–20cm	>20cm	0 – 1.3m	1.4 – 3m	3.1 – 6 m	6.1 – 9m	>9m
1	316	197	106	80	56	352	210	84	65	44
2	98	39	40	96	66	104	46	48	81	58
3	168	32	19	69	30	160	32	25	69	32
4	58	57	46	65	51	65	58	60	53	42
5	397	134	75	69	50	413	121	83	69	41
6	173	121	85	41	17	169	128	89	35	16
7	114	67	61	47	48	122	66	57	52	40
7	55	47	46	139	90	62	48	50	148	83
9	471	59	46	39	31	462	62	58	36	28
10	129	91	84	99	67	142	93	89	92	61
Variance	21271.6	2714	689.5	949.1	488	21705.6	2903.6	453.7	1078.8	357.3
Standard deviation	145.8	52.1	26.2	30.8	21.1	147.3	53.8	21.3	32.8	18.9

Characterization of the forests scattered in the Atrush region, Iraq, depended on their varying plant composition in densities. Accordingly, the random samples with different densities sustained dividing according to the classes of diameters and heights to prepare the tree table to determine the trees' allocation scattered in the site and in which tree formation stages (Table 3). The highest number of trees, whether of the classes, diameters, or height, was in the first or second class, except for the eighth, second, and tenth samples, indicating the strength of natural renewal in the study area.

Over time, the dynamics of competition will lead to a change in these numbers due to stratification, as observed in the second, eighth, and tenth samples. The entrance of the administrator into the forests through various silviculture processes can obtain a healthy ecological balance and quickly resolve any environmental disturbance in the balanced site. By observing the variance and the standard deviation of the samples, there were extensive differences in the different classes of diameters and heights, and it confirms that these stands were of diverse ages and have varying densities. Therefore, the decision maker must work through the different silviculture processes to find a balance between the age stages of the forest stand.

This purpose requires identifying the number of trees in the forest stand, the percentage of the occupied area, and the nature of its horizontal and vertical spread because it will explain the nature of the balance of the stand itself (Table 4). The observations also authenticated that samples 1, 3, 5, and 9 came from sites of the young stand due to the number of seedlings constituting 68%, 54%, 57%, and 75%, and also samples 6, 7, and 10 (Table 2).

In the juvenile stage, the mature trees of samples 2, 5, and 8 formed the highest percentage of 48%, 42%, and 64%, respectively, and a significant variation among the studied samples and their standard deviation occurred (Table 4). In Figure 1, from the age stages of the pine stand under study, it was also conclusive that a wide variation in the locations and stand needs many silviculture processes to reduce the disparities among them and make them more stable (Zhang *et al*., 2015).

Table 4. Number of trees for the uneven age stand of pine tree stages for the study samples.

No.	Total number (ha^{-1})	Stages develop					
		Seedling	%	Juveniles	%	Trees	%
1	755	516	0.68	99	0.14	139	0.18
2	339	99	0.29	79	0.23	159	0.48
3	318	168	0.54	49	0.15	99	0.31
4	278	59	0.21	99	0.35	119	0.42
5	725	407	0.57	188	0.26	129	0.17
6	437	168	0.38	208	0.48	59	0.14
7	337	109	0.32	129	0.39	99	0.29
8	377	49	0.13	89	0.23	238	0.64
9	646	487	0.75	59	0. 10	99	0.15
10	477	129	0.27	198	0.41	149	0.32
Variance	3131	32186	-	3424	-	2331	-
Standard deviation	176.9	179.4	-	58.5	-	48.2	-
Min.	278	49	-	49	-	59	-
Max.	755	516	-	208	-	238	-

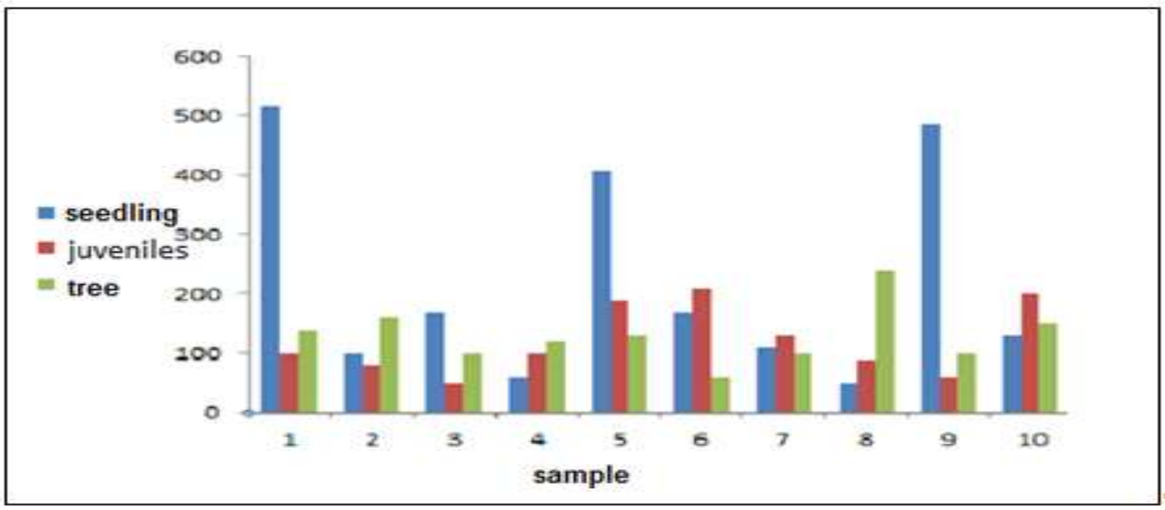

Figure 1. Age stages of pine tree samples growing in the Atrush region.

Numerous biological studies provided models of spatial point analysis of living organisms, as this analysis showed the degree of distribution of trees and their appearance in a particular location without the other. In other words, it showed the distribution of community densities for a characteristic of trees in a specific unit area of land. Therefore, the previous analysis has used the pattern in recognizing the distribution shape of a phenomenon, and it can also be adopted as a basis for determining the gathering of the phenomenon and analyzing it statistically (Zang and Biondi, 2015). Through the data of a phenomenon, determining the degree of the aggregation of the community under study can be possible.

One of the essential functions used in pattern analysis is Ripley's K(r) function (Ripley, 2005). Evaluating the quality of the typical distribution of trees in a given space can be easy when plotting K(r) values with distances. When the value of K(r) = zero, the shape of the distribution is a complete spatial random distribution, and such an assumption, the trees' distribution is almost homogeneous in the study site. However, if the value of K(r) > zero, the trees appear in an aggregate

Table 5. The results of the pattern analysis test for the age stages of the pine stand and all samples.

Sample No.	Number of trees	Aggregates space (m)	Sum (m)	Random space (m)	Sum (m)	Regular space (m)	Sum (m)
1	755	0 – 13.5	13.5	0	0	0	0
2	339	0 – 7.5	7.5	7.5- 14.5	7	0	0
3	318	0 – 13.5	13.5	0	0	0	0
4	278	0 – 6	6	6.5-15	8.5	0	0
5	725	0 – 10	10	10-13.5	3.5	0	0
6	437	0 – 6.5	6.5	6.5- 14.5	8	0	0
7	337	0 – 13.5	13.5	0	0	0	0
8	377	0	0	9.5-13	3.5	1 - 9.5	8.5
9	646	0 – 13.5	13.5	0	0	0	0
10	477	13 – 15	2	1-2, 5.75-13	8.25	2 - 5.75	3.75
Total	4689		86		38.75		12.25

distribution. Meanwhile, if the value of K(r) < zero, the distribution will be uniform, and the trees are approximately equal distances among themselves and closer to the distribution (CSR). All samples' tests appeared at a significant level of 0.095, prepared through the Monte Carlo method, testing the significance of observations resulting from places for n points (Scott *et al*., 2000; Akhavan and Daliri, 2010). Each point does not depend on the location of its previous point.

The data analysis of the study samples of the pine stand in the Atrush region to estimate K(r) and test its significance using the Monte Carlo method incurred estimates using the PASSaGE V.2 program. For the study samples, the number of trees ranged from 278 to 755. The spread of these trees represents a homogeneous community of pine trees, and therefore, the method of distribution of this community can receive testing through the earlier stated analysis (Table 5).

The study samples showed different shapes in the distribution pattern of the phenomenon, showing deliberate aggregation in samples 1, 3, 7, and 9 and aggregating randomly in samples 6, 5, 4, and 2, and either regular or random in sample 8 (Table 5). Meanwhile, regular, random, and aggregate occurrences in sample 10 can be visible from the distinct drawing of the estimated K(r) values when plotted with the distances, as in Figures 2, 3, 4, and 5. These figures also revealed that the estimated K(r) values, appearing in red, emerged above and below the limits of the Monte Carlo test and within the test limits, indicating the different forms of the phenomenon.

In Table 5, samples 1, 7, 3, and 9 seemed to have a uniform distribution of the phenomenon, and were at a distance of 0–13.5 m, as it appeared in an aggregate pattern, and it indicates that the trees were in the stage of an initial stand. It was the reflection of the natural stand dynamic of the interactions taking place within the tree, which resulted in the emergence of a regular distribution in the advanced stages of life trees, while the samples appeared aggregate and random in samples 6, 5, 4, and 2, showing with uniformly distributed distances (0–8), (0–6), (0–6.5), and (0–10), respectively, and were random with distances of 8–14.5. These patterns of distribution of the phenomenon indicate that the trees were in the juvenile stage and mature trees. It is one of the stages in which growth is superior, and the differences in these samples result from the competition processes between trees when progressing in the age stages (McMillan *et al.,* 2008).

The eighth sample was regular and random with collective distances (1–9) while random (9–13), signifying the maturity of these stands and were the result of the previous renewal process and the self-thinning operations that occurred in the site, leading to a decrease in the density during the death of a part of trees within a spot (Li and Zhang, 2007; Gray and He, 2009). The tenth sample showed regular, random, and aggregate distances varying immensely between them, and it is a phenomenon of a regular pattern of

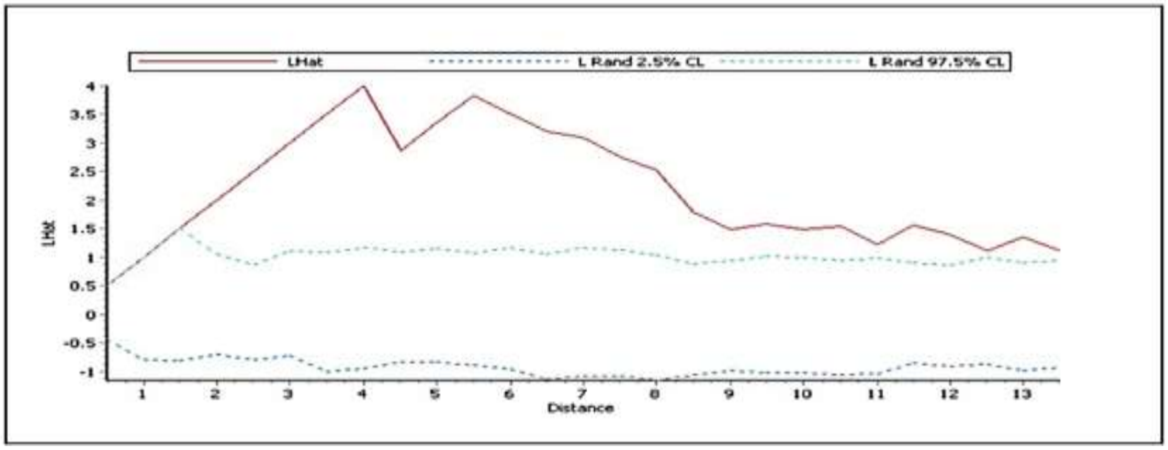

Figure 2. K(r) values estimated by sample distances (1).

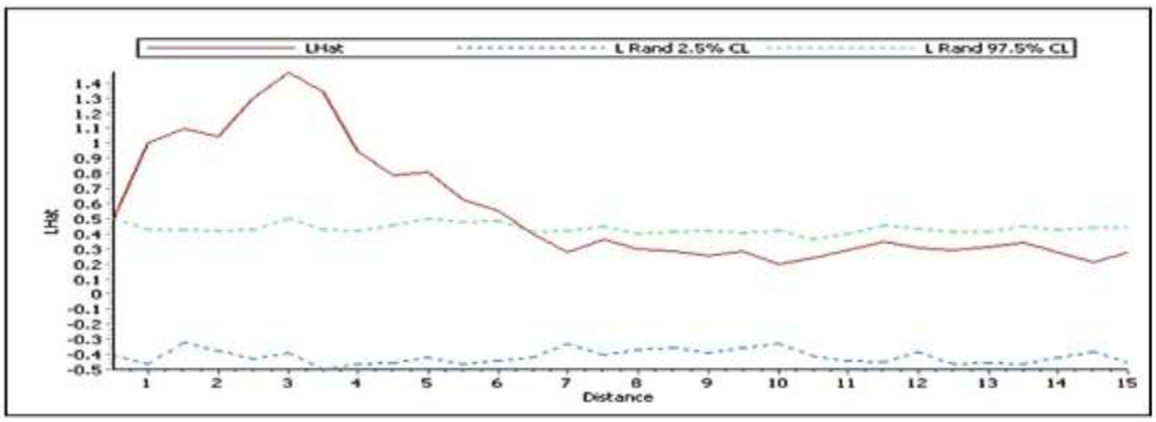

Figure 3. K(r) values estimated by sample distances (6).

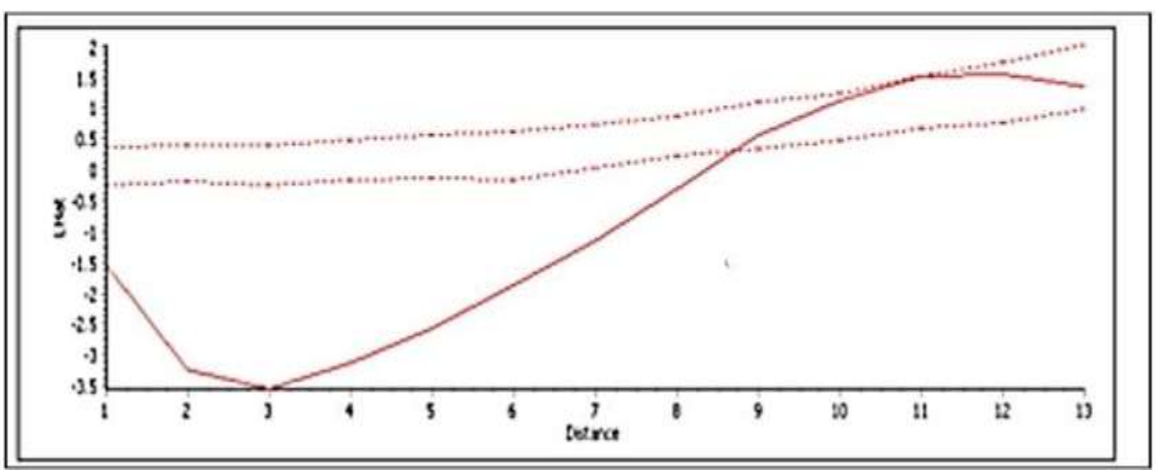

Figure 4. K(r) values estimated by sample distances (8).

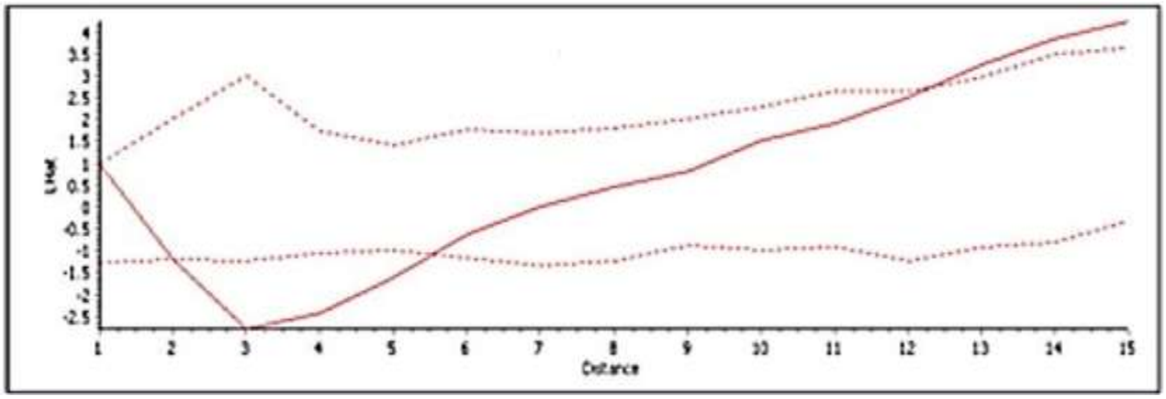

Figure 5. K(r) values estimated by sample distances (10).

distances (2.5–5.57) and also random for each of the distances (0–2) and (5.75–13). The phenomenon is an aggregate for distances 13.0–15, and upon close examination of the spatial structure, the different age stages and their interaction with each other can be evident. The pine stand, where samples came from, and the pattern and function of K(r) analysis appear in Table 5. The general pattern of tree distribution was in aggregate to high random, while the regular phenomenon was the lowest, and here, the forest administrator must take into account these models and implement the developmental foundations in the management of these stands in a way that leads to the sustainability of these forest stand.

CONCLUSIONS

By observing the variance and standard deviation of the samples, there were wide differences in the different classes of diameters and heights, confirming that the locations under study have different ages and densities. Therefore, the decision-maker must work through the different silviculture processes to find a balance between the age stages in the forest. For this purpose, it is necessary to know the number of trees in the forest stand and the percentage of the area they occupy, as well as, recognize the nature of their horizontal and vertical spread because it will clarify the nature of the ecological balance between forest plants.

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