International Journal of Ecosystems and Ecology Science (IJEES) **Vol. 14 (4):** 129-138 (2024)
https://doi.org/10.31407/ijees https://doi.org/10.31407/ijees14.4

ASSESSING BIODIVERSITY IN FOREST ECOSYSTEMS USING ECOLOGICAL INDICES CASE STUDY OF THE MEDITERRANEAN CONIFEROUS FOREST AT DIVJAKË-KARAVASTA NATIONAL PARK

Enea Malaj[1*], Doriana (Bode) Xhulaj[2]

[1]Forest Department, Faculty of Forest Sciences, Agricultural University of Tirana,1029 Tirana, Albania;*
[2]Department of Environment and Natural Resources, Faculty of Environment and Agriculture, Agricultural University of Tirana, 1029 Tirana, Albania;

[*]Corresponding Author Enea Malaj, email: emalaj@ubt.edu.al; dbode@ubt.edu.al;

Received September 2024; Accepted October 2024; Published November 2024;

DOI: https://doi.org/10.31407/ijees14.417

ABSTRACT

The association between habitat and tree diversity was examined using a tree data collection of 29 plots in the Mediterranean coniferous forest at Divjakë-Karavasta National Park. A total of 75 plant taxa—consisting of 17 orders, 34 genera, 24 families, and 833 individuals—were identified from the field observation. The three most prevalent tree species in the area were *Ulmus campestris* L. (10.4%), *Pinus halepensis* Mill. (15.6%), and *Pinus pinea* L. (30.7%). *Pinus pinea* L. had the maximum stand density of 256 individual's ha^{-1} and the largest base area of 20.36 m^2 ha^{-1}, with the highest number (22) found in S25. *Pinus halepensis* Mill. with 130 individuals ha^{-1} and a basal area of 20.31 m^2 ha^{-1}, had the second-highest stand density. A few species have dominated the forest structure in all 29 plots, and many species have fewer individuals, according to the Shannon index value (H'=2.35) for the entire research region. The Simpson index (D) data for the full test surface in the study indicates a good degree of variety among the forest trees observed on this surface, with a value of 0.8. The species richness index, which ranges from 0.14 to 1.6 for examined surfaces, shows variation in the measured values. The Berger-Parker Index's overall representative value for the study area is 0.3. The study provides baseline data for the management of protected areas in developing countries such as Albania and illustrates the potential of the *in situ* method in the conservation of natural resources.

Keywords: diversity index, stand structure, tree density, forestry economy, conservation.

INTRODUCTION

Forests are complex ecosystems with interrelated biological, functional, and physical components, according to Hansen et. al., (2021). This interaction is essential to preserving the resilience of the ecosystem and the ability to deliver ecosystem services (Watson et. al., 2018). Nevertheless, human-caused factors such altered land use pose a threat to forests and intensify the effects of climate change and biodiversity decline (Díaz et. al., 2019). Furthermore, by concentrating just on the loss of forest cover and ignoring other aspects of ecosystem functioning, biodiversity loss may not be successfully reversed. One of the main concerns in forestry and the allied scientific fields is

biodiversity and its protection (Gross, 2016). According to Swingland (2001), biodiversity is the variety of living forms on Earth and is comprised of three levels: genetic, species, and environmental diversity.
Rich species composition protects forest ecosystems against severe attacks by entomologists and phytopathologists (Freer-Smith & Webber, 2015). This is because these organisms are frequently linked to particular species that serve as their hosts.
Evenness and richness are two essential elements of biodiversity (Hurlbert, 1971; Magurran, 2004; Stirling & Wilsey, 2001). Swingland (2001) asserts that whereas richness is linked to the diversity of species present in the examined area, evenness indicates the homogeneity (and heterogeneity) of these species' abundance. Quantitative analysis provides information on the floristic status and distribution pattern of tree species diversity, which could help safeguard biodiversity. Biodiversity inventories are commonly used to collect quantitative data to determine the distribution and type of biotic resources in the area that has to be maintained (Rennolls & Laumonier, 2000). Given that tree species provide supplies and habitat for a variety of species and contribute to the structural characteristics of the forest, measuring the distribution and abundance of these species is a crucial undertaking (Huang et. al., 2003). Twenty percent of all vascular plant species are trees, and they are essential to the biosphere's overall health. Before the first human settlers arrived thousands of years ago, trees are thought to have covered 82% of the territory in the Mediterranean Basin, one of the 36 global biodiversity hotspots (Medail et. al., 2019). Due to their unique combination of characteristics, Mediterranean forests are both naturally beautiful and visually pleasing, but they are also highly delicate, necessitating cautious management and conservation techniques. The Mediterranean region is characterized by an extraordinarily wide range of environmental variables. While the environment might restrict the establishment and succession of forests, it can also, more frequently than not, give rise to lush, mesic forest ecosystems that resemble those found in central Europe (Mugnozza et.al., 2000). Understanding the dynamics of the forest ecosystem is important for the conservation of nature, and data on tree composition and forest structure helps save economically valuable and threatened species. The aim of the current study is to evaluate the variety of trees in the Mediterranean coniferous forest at Divjakë-Karavasta National Park.

MATERIAL AND METHODS

Study area
The study was conducted at Divjakë-Karavasta National Park, a protected area in the coastal area of Albania. The park lies between latitudes 40° and 55° N and longitudes 19° and 29° E. It is bordered by the Shkumbin River in the north, the Divjaka hills in the east, the Myzeqe Canal and the Seman River in the south, and the Adriatic Sea in the west.
Data collection
The data on the ecological features were collected during March-May 2023, in one of the habitats of the National Park of the Divjakë-Karavasta: the Mediterranean coniferous forests (Divjaka forest), defined as a forest with a variable mixture of at least two native coniferous species constituting ≥70 percent of the forest cover on sandy soils. A GIS procedure was used to randomly select plots in the forest area with at least 70 percent tree canopy cover. The center of the plot was located according to a systematic sampling design at the intersection of a 100×100-meter grid. About 29 circular plots with a radius of 11.28 meters (0.1 hectares) were designed.
Data analysis
Species presence indicators are often used to monitor the effectiveness of a particular forest management treatment in maintaining biodiversity. For this research, a set of indices of tree species composition was calculated to examine the heterogeneity in the composition of the studied communities, including the Shannon index (H'), a special measure of evenness (J') by index standardization Shannon, Species richness (DMn), the Simpson index, the Berger-Parker index (d) and the Clark-Evans (R).

a. The Shannon's diversity index (H'), (Shannon, 1948) to determine tree diversity is calculated using the following equation:

$$H' = -\sum_{i=1}^{s} pi * \ln pi$$

Where H' is the Shannon index of general diversity, pi is the ratio (n/N) of individuals of a given species found (n) divided by the total number of individuals found (N), ln is the natural logarithm, Σ is the sum of measurements, and s is the number of species.

b. The Shannon evenness index (J') (Elliot et. al., 1997) as a measure of the relative abundance of the different species in the same area, is calculated as:

$$J' = \frac{H'}{H'max} = \frac{H'}{lnS}$$

Where H' is the number derived from the Shannon diversity index H'max is the maximum possible value of H': $Hmax$ is the maximum level of diversity possible within a given population and S is the total number of species.

c. The Simpson index (D) (Simpson, 1949) is based on the probability that two random individuals from a large community belong to the same taxon, which is calculated as below:

$$SDI = 1 - \frac{\sum n * (n-1)}{N * (N-1)}$$

Where N is the total number of individuals of each species found, n is the total number of individuals found for the species of interest.

d. The species richness using Menhenick's index (Magurran, 2004) is calculated following the rule:

$$DMn = \frac{S}{\sqrt{N}}$$

Where S is equal to the number of different species represented in the sample, and N is the total number of individuals in the sample.

e. The Berger-Parker index (Berger & Parker, 1970), which expresses the proportional abundance of the most abundant species, is calculated as below:

$$d = \frac{Nmax}{N}$$

Where $Nmax$ is the number of individuals of the most abundant species and N refers to the total number of individuals.

f. To measure the spatial relations between the members of the tree population we used the Clark-Evans (Clark & Evans, 1954) equation as below:

$$R = \frac{\overline{r_0}}{\overline{r_e}} \qquad \overline{r_o} = \frac{\sum_{i=1}^{n} r_i}{n} \qquad \overline{r_e} = \frac{1}{2 * \sqrt{\rho}} \qquad \rho = \frac{n}{S}$$

Where: ro is the average observed distance, re is the average expected distance, ri is the distance from the reference tree to the tree closest to it, n is the number of trees in the plot and ρ the number of trees per surface.

The structural composition of trees was analyzed by comparing the tree height distribution and diameter classes.

RESULTS AND DISCUSSION

Species richness and diversity

A total of 75 plant taxa that belong to 17 orders, 34 genera, 24 families, and 833 individuals, were recorded from the field observation, in the 29 plots of our study area. Three tree species dominated the area, *Pinus pinea* L. presented in 14 of the plots with a total number of 256 individuals (30.7%), *Ulmus campestris* L. in 12 of the plots with a total number of 87 individuals (10.4%), and *Pinus halepensis* Mill. in 17 of the 29 plots under observation, with a total number of 130 individuals (15.6%) (Figure 1). Eight tree species (*Quercus cerris* L; *Paliurus spina-christi* Mill.; *Prunus spinosa* L.; *Crataegus monogyna* Jacq.; *Carpinus betulus* L.; *Erica arborea* L.; *Pinus pinaster* Ait. and *Colutea arborescens* L.) were recorded in only one of the plots each.

The plant families that presented the major diversity in the species' number: were Rosaceae and Oleaceae, each with 5 species, followed by Pinaceae, Leguminosae, and Fagaceae with 3 species each. Seven families (Cupressaceae, Salicaceae, Corylaceae, Rhamnaceae, Cornaceae, Juncaceae and Liliaceae) had 2 species each, and a single species represented 12 families.

Analyzing the individuals for each study plot, these three top species *Pinus pinea* L., *Ulmus campestris* L., and *Pinus halepensis* Mill. accounted for 56.7% of the dominance in the 29 plots of the forestry economy of Divjaka pine.

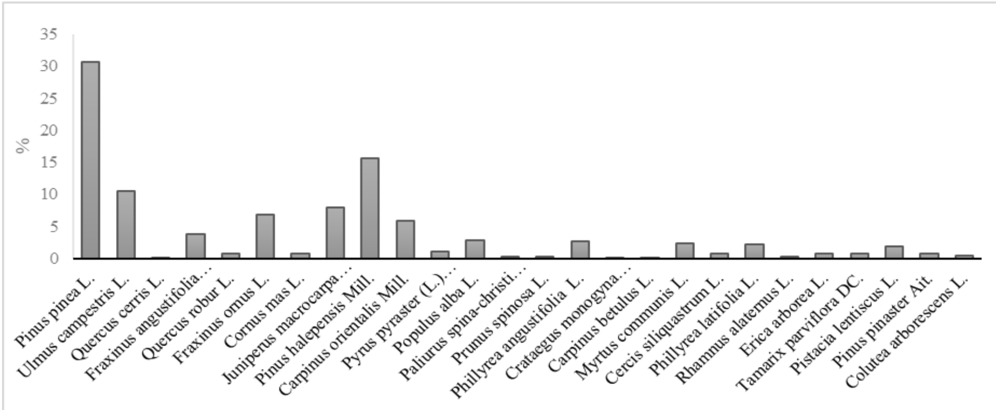

Figure 1. Tree species composition at Divjakë-Karavasta National Park.

One of the traits of Mediterranean woodlands is their species diversity. This variable number of species is the simplest approach to characterize diversity in communities and regions, and it serves as the foundation for many ecological models of community organization. A trustworthy tool for determining a research site's degree of diversity is the richness of tree species at designated study sites and in minimum diameter classes (Premavani, Naidu, & Venkaiah, 2014). The abundance of comparable plots inventoried in other parts of the Mediterranean can be compared to the current data.

The results obtained from the measurements carried out in the field suggest that in our study area, we find a medium presence of tree diversity related to the Shannon index (H'=2.35) (Table 1). This parameter is presented in 29 of the tested surfaces, with values that range from a minimum of 0 to a maximum of 1.84 (S8 and S17). Three of the observed surfaces (S1, S19, and S25) result in a Shannon index value of 0, as they have only one tree species present (simple cluster with a single species). Among 29 of the plots that were observed only four of them, presented a medium level of diversity (S8, S12, S13, and S17). Plots 8 and 17 were the most species-rich, each respectively with 10 and 7 species presented in them. The presence of this level of species in the study area indicates the uniform nature of the tree composition of this forest ecosystem. The value of the Shannon index (H'=2.35) for the total area under study, indicates that in all the 29 sites few species have dominated the forest structure, and many species comprised of fewer individuals. Our results are also under those of previous studies (Nadiu et. al., 2018). The Shannon index considers the degree of evenness (J') in species abundance as a heterogeneity measure. Evenness Index values range from 0-1. For value 0, we have no equality or uniformity (regularity) of species distribution; for value 1, we have complete uniformity. According to the calculated values, this index for the 29 plot surfaces under study, differs from the minimum values of 0 (S1, S19, and S25) to a maximum of 0.94 (S17). Three other plots that also presented high values for this index among the 29 measured are S11, S12, and S13. These plots also resulted in higher values of species diversity (H'). These higher values of the index found in these plots indicate higher evenness values, with the species evenly represented in the population and a high diversity level.

Table 1. Data analyzing of the tree inventory of the study are Mediterranean coniferous forest at Divjakë-Karavasta National Park.

Diversity index/29 plots	**Shannon**	**Evenness**	**Richness**	**Simpson**	**Berger-Parker**	**Clark-Evans**
	H' value	**J' value**	**D_{Mn} value**	**D value**	**d value**	**R-value**
	2.358	0.724	0.900	0.8	0.307	4.361
Average	0.970	0.679	0.796	0.527	0.602	3.032
Min	0	0	0.145	0	0.241	0.683
Max	1.840	0.945	1.605	0.9	1	5.187
Variance	0.279	0.079	0.154	0.063	0.047	1.197
Standard deviation	0.528	0.281	0.392	0.251	0.218	1.094
Coefficient of variation	54.48	41.51	49.28	47.76	36.28	36.08

The Simpson index (D) is one of the most meaningful diversity measures available. It captures the variance of the species abundance distribution. The data of the whole surface of the test in the study show a value of 0.8 of this index, so they suggest a good level of diversity of the forest trees observed on this surface. However, we have differences in the results between the 29 tested plots for this ecological index, ranging from the lowest value of 0% in three observed surfaces (S1, S19, and S25) to 0.9% measured in only surface S17. The high diversity of forest species is not only found in this test area but also in three others (S8, S12, and S13) which are presented with the same value of (D) of 0.8%. These measured values are similar to the values of the Shannon index, reinforcing the opinion that the diversity of forest species is the highest among the 29 areas tested in the S17 plot. The species richness index used to calculate the biodiversity in the 29 plots under study, suggests a variance of the measured values from the lowest measured in the S1 and S25 surfaces of 0.14 to the maximum measured value of 1.6 in the two test surfaces S17 and S13 (Figure 2). Plot 8 (1.47) is also presented with a good value of forest species diversity. The low values calculated for this ecological index also correspond to those presented above for the same test surface for the Simpson index. Meanwhile, for this index as well as for those calculated above, the highest ecological diversity observed for 29 of the test areas in Forestry Economy of Divjaka Pine results in the same plots S17, S13, S8, and S12. The total representative value of the Berger-Parker Index for the entire study area Forestry economy Pisha e Divjaka is 0.3, suggesting that the diversity for the areas under study is high (since the closer to 0 this parameter is, the higher it is and the observed biological diversity). According to the observations and measurements carried out in the field, for this index the test area which resulted in the highest value of diversity and therefore with a higher richness of species is S12 (0.2) followed by S17 and S13 with the respective values of 0.31 and 0.32. Among the highest values of this index (d=1), but which suggests that the areas S1, S19, and S25 also in this case have a low diversity of forest species among the 29 plots studied.

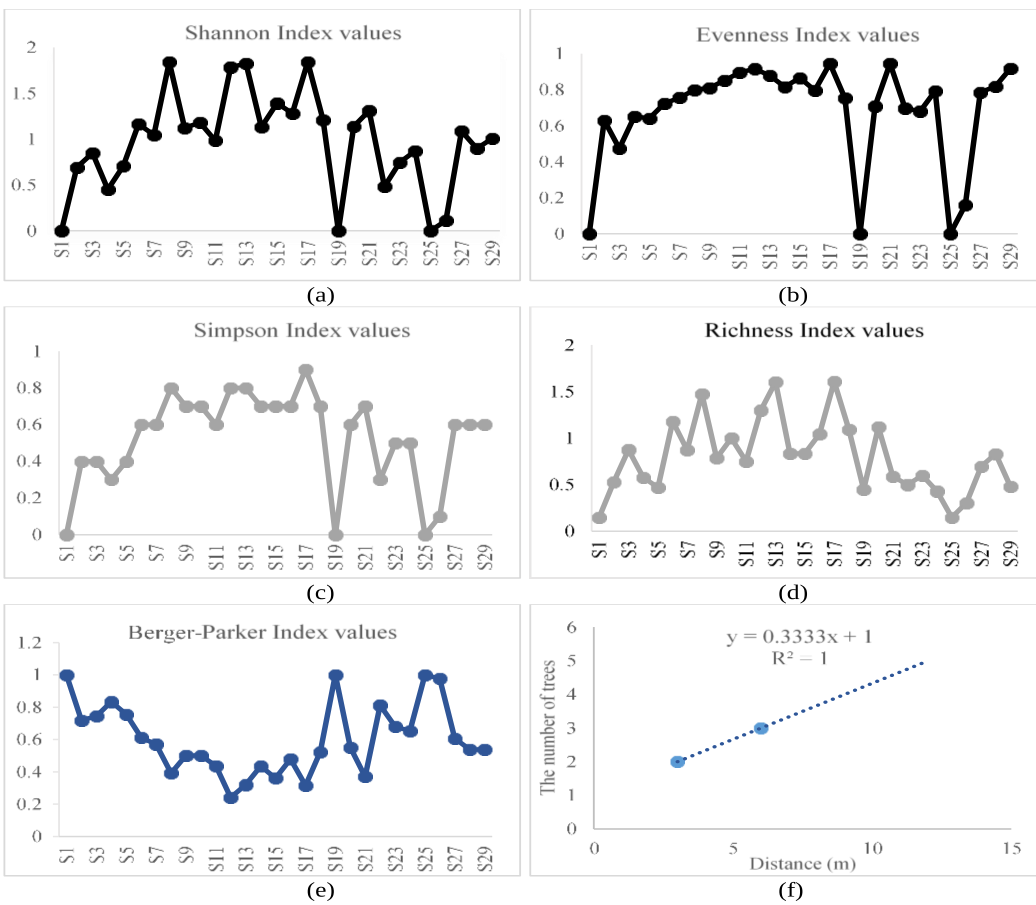

Figure 2. (a-f) Data of forest tree species diversity assessed by the six biological indices

The Clark & Evans (1952) aggregation index R is a crude measure of clustering or ordering of a point pattern. It is the ratio of the observed mean nearest neighbor distance in the pattern to that expected for a poison point process of the same intensity. A value of R >1 suggests ordering, while R < 1 suggests clustering. Our results indicate values higher than 1 of this index in 28 of the 29 plots observed, that is, with a regular distribution of forest species in these 28 plots. Between a distribution in groups of individuals in the population, it represents only the surface of the test S19 with values of R=0.683342. The Shannon-Weiner (H′) index for all 29 plots ranged from 0 to 1.84, falling within the range of 0.67 to 4.86 found in other woods (Panda et. al., 2013). The species diversity depends upon the adaption of species and rises with the stability of the community. These numbers show that the current Mediterranean woodland is a system with a wide variety of species.
The current study's concentration of dominance, or Simpson's index, falls between the previously reported range of 0.0–1.34 in other woods (Sahu et. al., 2012). The richness index in other research on forest diversity ranges from 4.54 to 23.41 (Zhao et. al., 2022). This analogy demonstrates how the effect of both ecological and anthropogenic factors has resulted in the loss of tree species in the research plots under investigation.

Stand density and girth class distribution
The total stand density of trees for the 29 plots under study was 833 individuals. The mean stand density observed was 28.72 individuals ha^{-1}, with a maximum of 49 individuals found in plot 24, followed by two other plots S1 and S3, also with a moderate stand density (47 individuals each). The tested plot with the lower density of trees observed was S19 (5 individuals). The density of different tree species differs within 29 plots under study. The highest stand density observed was 256 individuals ha^{-1} of *Pinus pinea* L. and the basal area of 20.36 m^2 ha^{-1}, with its largest number (22) found in S25, followed by *Pinus halepensis* Mill. with 130 individuals ha^{-1} and a basal area of 20.31 m^2 ha^{-1} (Figure 3).
Two tree species presented the minimum number of individuals both in the same tested surface S8, *Carpinus betulus* L. with a basal diameter of 0.0028 m^2 ha^{-1} and *Crataegus monogyna* Jacq. with 0.00785 m^2 ha^{-1}. The tree species with the lowest basal area value among all other species are *Paliurus spina-christi* Mill. found only in S7 (0.000628 m^2 ha^{-1}) and *Rhamnus alaternus* L. was found in S18 and S20 (0.000628 m^2 ha^{-1}).

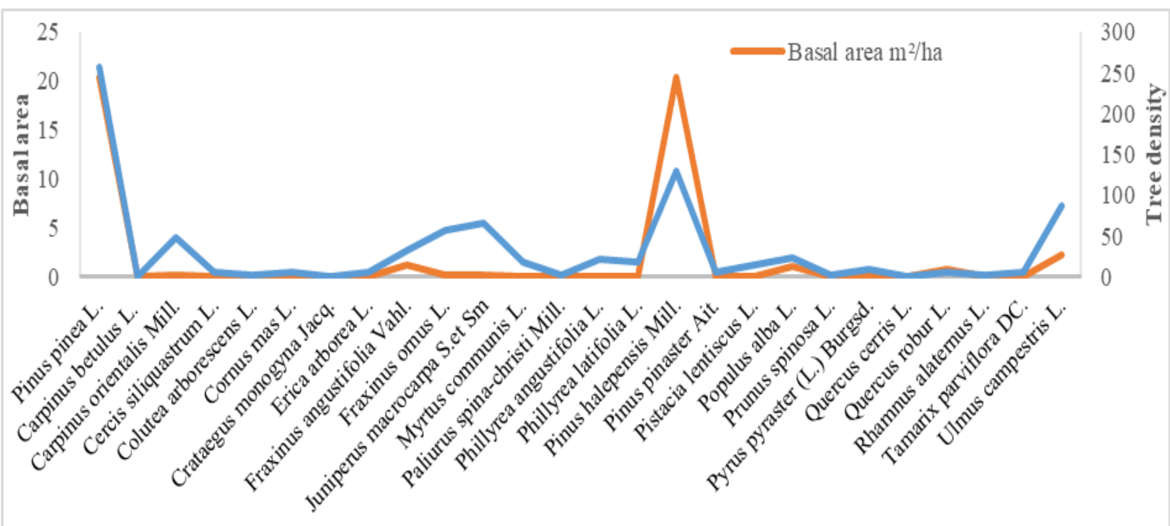

Figure 3. The density of trees and their basal surface, according to the main tree species throughout the study area

Tree species richness, as well as density, decreased with the increasing girth class in all 29 study plots, except in the first (2-22 class) and second girth class (26-46 class).

The girth class distribution has revealed the majority of the tree individuals represented in the 2-22 cm class with 66.02% followed by 26-46 cm (25.33%), from 46-62 cm with 5.52%, and less abundance we found in the tree other girth classes remained (from 66 cm to 122cm) with a total of 3.12% (Figure 4).

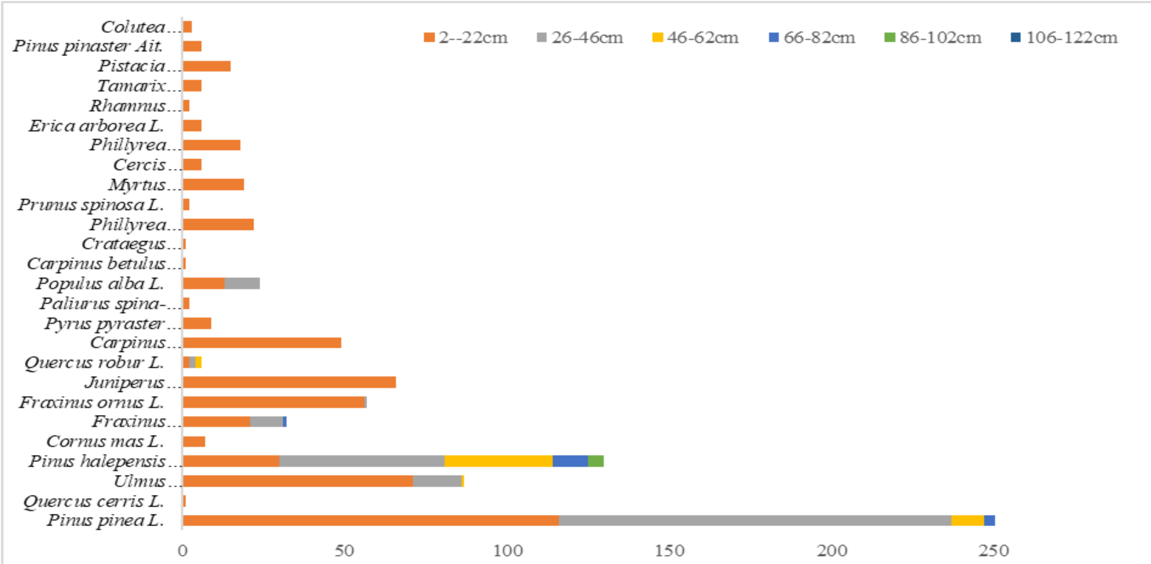

Figure 4. Tree species density according to the field measurement at the Mediterranean coniferous forest of Divjakë-Karavasta National Park.

A comparison was made of the relative distribution of the total number of individuals and their basal area in each diameter class. According to Suthari (2018), the basal area of a tree is the girth occupied at the breast height (gbh) and it is an important attribute to quantify the vegetation structure and site quality. In the present study, the basal area of tree species varied across the 29 plots, ranging between 1.09 m^2 ha^{-1} at the girth class 106-122cm to the17.52 m^2 ha^{-1} at the 26-46 cm girth class. The class with the highest density of wood is presented with a basal area surface of 6.20 m^2 ha^{-1} (Figure 5). Tree species richness, as well as density, decreased with the increasing girth class in all 29 study plots, except in the first (2-22 class) and second girth class (26-46 class). The girth class distribution has revealed the majority of the tree individuals represented in the 2-22 cm class with 66.02% followed by 26-46 cm (25.33%), from 46-62 cm with 5.52%, and less abundance we found in the tree other girth classes remained (from 66 cm to 122cm) with a total of 3.12%. Girth class frequency revealed that the tree population pattern seen in the research locations was consistent with that of other forest stands (Sahu, Dhal, & Mohanty, 2012). How successfully the expanding forest uses site resources is seen by the distribution of tree densities across various girth classes. A small number of medium-sized to large trees ha−1 could indicate that the tree crop is not using all of the area.

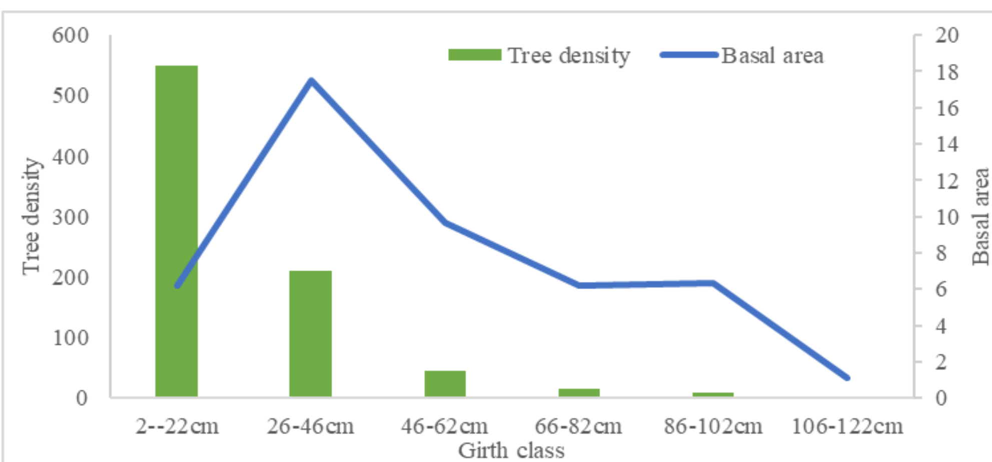

Figure 5. Contribution of tree species stands density and basal area based on girth class distribution in the area under study of the Divjake Karavasta park.

Family composition and tree dominance

In terms of main tree abundance, the Pinaceae family with 392 individuals (47%) dominated the coniferous forest, followed by Oleaceae (129 individuals; 15.5%), Ulmaceae (87 individuals; 10.4%), Cupressaceae (66 individuals; 7.9%), Corylaceae (50 individuals; 6%). These families also represented the top five tree families with an abundance of 724 individuals and 86.9% of the total importance value. Five families represented by single species with an abundance of 70 individuals accounted for a total of 8.3% of tree families' importance values. The primary accompanying tree species in eight of the *Pinus pinea* L.-dominated plots (S1, S2, S4, S5, S25, S26, S27, and S29) were *Fraxinus angustifolia, Fraxinus ornus, Pistacia lentiscus, Quercus robur, Ulmus campestris, Phillyrea latifolia, Ruscus aculeatus, Juniperus communis, Myrtus communis, Rubus ulmifolius, Pinus halepensis, Carpinus orientalis, Paliurus spina-christi, Phillyrea angustifolia, Cornus mas, Juniperus macrocarpa, Hedera helix, Colutea arborescens*.

In 4 of the plots (S6, S9, S14 and S15) with the dominant species *Ulmus campestris* L., the other co-dominant forest tree species were *Fraxinus ornus, Pinus pinea, Ruscus aculeatus, Rubus ulmifolius, Myrtus communis, Pyrus pyraster, Juniperus communis, Quercus robur, Phillyrea latifolia, Hedera helix, Cercis siliquastrum, Carpinus orientalis, Cornus sanguinea, Quercus petraea, Fraxinus angustifolia, Pinus halepensis, Crataegus monogyna*. Other companion forest tree species were discovered in four of the plots (S18, S20, S22, and S28) where *Pinus halepensis* was the main species. These species were *Erica arborea, Myrtus communis, Phillyrea latifolia, Rhamnus alaternus, Juniperus macrocarpa, Pinus pinea, Pistacia lentiscus, Colutea arborescens, Rubus ulmifolius, Crataegus monogyna, Colutea arborescens, Pyrus pyraster, Juniperus communis*. The tree species *Pinus halepensis* and *Ulmus campestris* are both found at the same levels of dominance in plot 11 (43.8%) while Myrtus communis with 12.5% of presence. In this plot, other accompanying tree species are *Fraxinus angustifolia*, *Phillyrea latifolia*, and *Ruscus aculeatus*. The species *Fraxinus ornus* appears dominant in 2 plots. Plot S3 is dominating at the level of 75% *Fraxinus ornus*, 17% *Ulmus campestris*, and 8% other companion species such as *Fraxinus angustifolia, Quercus robur, Cornus mas, Juniperus macrocarpa.* Meanwhile, in plot 10, the same species is present at the level of 50% *Fraxinus ornus*, 25% *Pinus pinea*, 19% *Ulmus campestris*, and 6% different ones such as *Fraxinus angustifolia, Carpinus orientalis, Rubus* ulmifolius. In plot S7, *Fraxinus angustifolia* is the dominant tree species at a level of 57%, *Populus alba* at 29%, and the level 14% other accompanying tree species such as *Cornus sanguinea, Rubus ulmifolius, Carpinus orientalis*.

The dominant species in plot 8 at the level of 39% was *Populus alba*, *Carpinus orientalis* at 20%, 11% *Ulmus campestris,* and at a high level of 30% they are represented by different accompanying species such as *Fraxinus angustifolia, Cornus mas, Fraxinus ornus, Crataegus monogyna, Prunus spinosa, Carpinus betulus*. The *Carpinus orientalis* tree species dominates plot 13 at a level of 32%, where 24% is accompanied by *Fraxinus angustifolia*, 12% by *Ulmus campestris* and 32% of the plot has different forest species such as *Pinus pinea, Pinus halepensis, Cornus mas, Rubus ulmifolius, Ruscus aculeatus, Myrtus communis, Fraxinus ornus and Ulmus campestris*. The surface of the test P12 is co-dominant with 24% *Carpinus orientalis* and 24% *Fraxinus ornus*, while at close levels we find 21% *Pinus halepensis*, 10% *Ulmus campestris*, 10% *Phillyrea angustifolia* and 11% different such as *Pinus halepensis, Fraxinus angustifolia, Ruscus aculeatus, Phillyrea latifolia, Crataegus monogyna, Cercis siliquastrum, Cornus mas*. Plot 16 is dominated at a level of 48% by *Myrtus communis*, 26% by *Pinus halepensis*, 18% by *Cercis siliquastrum*, and 8% by various species such as *Cornus mas, Phillyrea angustifolia*. Meanwhile, plot 19 is the third dominated by a single forest species 100% *Tamarix parviflora*. The species *Phillyrea angustifolia* is dominant only in plot 21 at the level of 37%, together with the same values of 26% *Pinus halepensis* 26% *Phillyrea latifolia* and 11% of *Pistacia lentiscus*.

CONCLUSION

- The baseline data on the distribution richness and relative abundance of taxa needed to make conservation decisions is provided by biodiversity measures. The current investigation suggested that there are more species diversity and average stand density, as well as the study plots highlight the potential and distinctiveness of to preserve the ecology as a whole. The overall research region's Shannon index value (H'=2.35) indicates that a limited number of species have dominated the forest structure in all 29 plots, and many species have fewer individuals. The Simpson index (D) data of the entire test surface in the study, which displays a value of 0.8 on this index, suggests that the forest trees seen on this area have a good degree of variation.

- The Evenness Index has values ranging from 0 (S1, S19, and S25) at the lowest to 0.94 (S17) at the highest. The Berger-Parker Index total representative value for Pisha e Divjaka is 0.3, which indicates a high level of variety throughout the areas looked at. In addition to providing baseline data for the management of protected areas in developing countries such as Albania, the study highlights the potential of the *in situ* method in the conservation of natural regions.

REFERENCES

1. Berger Wh, Parker Fl, (1970). Diversity of planktonic foraminifera in deep sea sediments. Science, 168, 1345-1347;
2. Clark PJ, Evans FC, (1954). Distance to nearest neighbor as a measure of spatial relationships in populations Ecology 35, 445-453;
3. Díaz S, Settle J, Brondízio ES, Ngo HT, Guèze M, Agard J et. al., (2019). The global assessment report on biodiversity and ecosystem services of the intergovernmental science-policy platform on biodiversity and ecosystem services: summary for policy makers. Bonn, Germany: IPBES Secretariat. 56;
4. Elliot AJ, Church MA, (1997). A hierarchical model of approach and avoidance achievement motivation. Journal of Personality and Social Psychology, 72(1), 218-232. https://doi.org/10.1037/0022-3514.72.1.218;
5. Freer-Smith Ph, Webber JF, (2015). Tree pests and diseases: the threat to biodiversity and the delivery of ecosystem services. Biodiversity Conservation, 1-15;
6. Giseppe SM, Helfried O, Pietro P, Kalliopi R, (2000). Forests of the Mediterranean region: gaps in knowledge and research needs, Forest Ecology and Management, Volume 132, Issue 1, Pages 97-109, ISSN 0378-1127, https://doi.org/10.1016/S0378-1127(00)00383-2;
7. Gross M, (2016). How can we save forest biodiversity? Current Biology, 26(22)1167-1170;
8. Hansen AJ, Noble BP, Veneros J, East A, Goetz SJ, Supples C et. al., (2021). Towards monitoring forest ecosystem integrity within the post-2020 global biodiversity framework. Conserv. Lett. 14: e12822. doi: 10.1111/conl.12822;
9. Huang W, Pohjonen V, Johansson V, Nashanda M, Katigula MIL, Luukkanen O, (2003). Species diversity, forest structure and species composition in Tanzanian tropical forests. Forest Ecology and Management, 173, 111-124;
10. Hurlbert SH, (1971). The non-concept of species diversity: a critique and alternative parameters. Ecology 52, 577-586. doi: 10.2307/1934145;
11. "Karavasta Lagoon". Ramsar Sites Information Service. Retrieved 25 February 2024;
12. Magurran AE, (2004). Measuring Biological Diversity. Oxford, UK: Blackwell.Margalef R: Information theory in ecology. General Systems, 3, 36-71, 1958;
13. Médail F, Monnet AC, Pavon D et. al., (2019). What is a tree in the Mediterranean Basin hotspot? A critical analysis. For. Ecosyst. 6, 17. https://doi.org/10.1186/s40663-019-0170-6;
14. Naidu MT, Kumar OA, (2015). Tree species diversity in the Eastern Ghats of northern Andhra Pradesh, India. Journal of Threatened Taxa, 7(8), 7443-7459;
15. Panda PC, Mahapatra AK, Acharya PK, Debata AK, (2013). Plant diversity in tropical deciduous forests of Eastern Ghats, India: A landscape level assessment. International Journal of Biodiversity Conservation, 5, 625-639;
16. Premavani D, Naidu MT, Venkaiah M, (2014). Tree species diversity and population structure in the tropical forests of north central Eastern Ghats, India. Notulae Scientia Biologicae, 6(4), 448-453;
17. Rennolls K, Laumonier Y, (2000). Species diversity structure analysis at two sites in the tropical rain forest of Sumatra. Journal of Tropical Ecology, 16, 253-270;
18. Sahu SC, Dhal NK, Mohanty RC, (2012). Tree species diversity and soil nutrient status in a tropical sacred forest ecosystem on Niyamgiri hill range, Eastern Ghats, India. Tropical Ecology, 53, 163-168;
19. Stirling G, Wilsey B, (2001). Empirical relationships between species richness, evenness and proportional diversity. The American Naturalist,158(3)286-299;
20. Simpson EH, (1949). Measurement of diversity. Nature, 163, pp. 688. doi:10.1038/163688a0;
21. Suthari S, Raju VS, (2018). Tree species composition and forest stratification along the gradients in the dry deciduous forests of Godavari valley, Telangana, India. Indian Forester;

22. Swingland IW, (2001). Biodiversity, definition of. In: Encyclopedia of Biodiversity. Volume I (S.A Levin, ed.), Academic Press, San Diego, pp. 377-391;
23. Shannon CE, (1948). A mathematical theory of communication. The Bell System Technical Journal, 27, pp. 379-423. https://doi.org/10.1002/j.1538-7305.1948.tb01338.x;
24. Watson JE, Evans T, Venter O, Williams B, Tulloch A, Stewart C et. al., (2018). The exceptional value of intact forest ecosystems. Nat. Ecol. Evolut. 2, 599-610. doi: 10.1038/s41559-018-0490-x;
25. VKM No. 60, Date 26.1.2022. For the Declaration of Natural Ecosystems, Managed Natural Reserves/Natural Park (Category Iv), as well as the Approval of the Change of Status of Existing Surfaces of Environmentally Protected Areas, Belonging to this Category. https://akzm.gov.al;
26. Zhao Z, Hui G, Yang A, Zhang G, Hu Y, (2022). Assessing tree species diversity in forest ecosystems: A new approach. Front. Ecol. Evol. 10:971585. doi: 10.3389/fevo.2022.971585;