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Doriana (Bode) XHULAJ*[1], Enea MALAJ[2], Adelajda HALILI[3]

BIODIVERSITY BENEATH THE CANOPY: UNDERSTANDING FOREST STRUCTURE INSIDE A PROTECTED AREA

SUMMARY

The purpose of this study was to evaluate the tree species' diversity, richness, and composition at the Gjeneruka forest habitat, part of Divjakë-Karavasta National Park. Twenty circular plots with a radius of 11.28 meters (0.1 hectares) were created from the study area. The heterogeneity in the composition of the communities under study was investigated by computing a number of tree species composition indices, such as the Shannon index (H'), Evenness index (J'), species richness (DMn), the Simpson index (D), the Berger-Parker index (d), and the Clark-Evans (R). The results suggest for the presence of the representatives of 10 families, consisting of 13 genera and a total of 22 species, and 1662 individuals. The overall research region's Shannon index value (H'=2.24) indicates that a small number of species have dominated the forest structure across all 20 locations. There is a good level of diversity among the forest trees across the entire test surface, as indicated by the Simpson index (D) value of 0.84. There is a significant degree of biological diversity in the areas being studied, as indicated by the research region's overall representative Berger-Parker Index value of 0.32. Data regarding forest structure and tree composition contributes to the conservation of endangered and economically significant species. To conserve tree species, it is crucial to promote awareness of the potential ecological benefits that tree stands on agricultural lands may offer to the local community both within and outside the study area.

Keywords: tree species, diversity, composition, forest structure, protected area

INTRODUCTION

Assessment of tree species richness, composition, and forest structure is essential for understanding ecosystem function and directing conservation

[1]Doriana (Bode) Xhulaj (corresponding author: dbode@ubt.edu.al), Department of Agronomic Sciences, Faculty of Environment and Agriculture, Agricultural University of Tirana, 1029 Tirana, ALBANIA;

[2]Enea Malaj, Forest Department, Faculty of Forest Sciences, Agricultural University of Tirana, 1029 Tirana, ALBANIA;

[3]Adelajda Halili, Department of Mineral Resources Engineering, Faculty of Geology and Mining, Polytechnic University of Tirana, Tirana, ALBANIA.

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management inside protected areas. Species diversity, often measured using indices like Shannon and Simpson, reflects both the number of species present and how evenly they are distributed, helping to understand ecosystem stability and resilience (Krebs, 1999; Magurran, 2004; Malaj *et al.,* 2025). Higher diversity is typically linked to greater functional redundancy and a stronger capacity to withstand environmental disturbances (Tilman, 1997). At the same time, forest composition, defined by the identity and distribution of species, is equally essential as it impacts habitat quality, the successional stage, and the availability of ecological niches for associated flora and fauna (Kent, 2012). Forest structure including tree density, size distribution, and vertical stratification: directly effects light availability, microclimatic conditions, and nutrient cycle processes (Oliver and Larson 1996), with greater structural complexity generally supporting higher biodiversity and ecosystem functioning. In protected areas, where conservation is a high priority, integrated assessment of diversity, composition, and structure provides a scientific basis for monitoring ecosystem health and detecting changes driven by natural dynamics or anthropogenic pressures (Lindenmayer *et al.,* 2000). Such evaluations promote evidence-based management plans, helping to conserve biodiversity, ecosystem services, and long-term ecological integrity.

The Divjakë–Karavasta National Park area represents the most important complex ecosystem in Albania in terms of biodiversity. It is known not only for its natural beauty and rich biodiversity, but also for traditional economic activities and tourism. Among its key natural values is the Karavasta Lagoon, endangered Mediterranean pine forest, riverbank forests along the Shkumbin and Seman, and forested hills in Divjakë (Gjenerukë). The area is rich in diverse endemic, sub-endemic, rare, threatened, and endangered plant species. Internationally, about 20,000 hectares of the Divjakë–Karavasta National Park are designated as a Ramsar site, recognizing it as a wetland of global importance. It is also considered one of the most important areas for bird conservation and a potential site for special protection status (VKM No. 59 and No. 60, 2022; BirdLife International, 2020). Furthermore, it has been identified as part of the Emerald Network under the Berne Convention for the Conservation of European Wildlife and Natural Habitats (Ramsar Convention Secretariat, 2013; Ministry of Tourism and Environment of Albania, 2018; Council of Europe, 2011).

The assessment of tree species diversity, composition, and forest structure within the habitats of the Divjakë–Karavasta National Park is essential for understanding ecosystem functionality and enabling successful conservation management. Such evaluations provide essential insights into the ecological state, resilience, and successional processes of forest communities. By applying diversity indices and structural analyses, the objective of this study is to identify patterns of dominance, species distribution, and habitat complexity, which are key indicators of the ecosystem health. The study of the biodiversity of woody species in the Gjeneruka forest, as an area located near a populated center and threatened by anthropogenic pressure, will provide additional information about the presence of species diversity. The findings will support managers in evaluating the conservation measures applied within this forest ecosystem in the protected area.

MATERIAL AND METHODS

Study area:

The study was conducted at Gjeneruka forest of Divjakë-Karavasta National Park, which is one of the most important natural and environmentally protected sites in Albania's coastal area. The park's boundaries include latitudes 40° and 55° N, as well as longitudes 19° and 29°E.

Figure 1. Location map of the study area, Divjakë-Karavasta National Park, https://geoportal.asig.gov.al

Data collection:

Ecological parameters were collected in the Gjeneruka forest, a habitat of the Divjakë-Karavasta National Park, from spring 2025. Plots in the forest region with at least 70% tree canopy cover were selected to represent optimal stands using a GIS approach. A total of twenty circular plots, with an area of 200 m² (r=7.98 m), is used for measuring all the trees with a diameter at breast height ranging from 2 to 27 cm (Manual of Forest and Pasture Management Plans, 2019).

Data analysis:

Diversity of tree species. In this study, a variety of tree species composition indices, including Shannon index (H') (Shannon, 1948), species evenness (J') by index standardization Shannon (Elliot *et al.,* 1997), species richness (DMn) (Magurran, 2004), Simpson index (D) (Simpson, 1949), Berger-Parker index (d) (Berger and Parker 1970) and Clark-Evans (R) (Clark and Evans 1954), were computed to investigate the heterogeneity in the composition of the tree's communities.

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

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

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 and 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 and Evans, 1954) equation as below:

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

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 the number of trees per surface.

The forest structure: was defined using structural variables such as diameter size class distribution, basal area, and height. Trees in each sampling plot were divided into three diameter classes (<10, 10-20, and ≥ 20 cm DBH), and the percentage of trees in each class was examined for vegetation area. The total basal area of each tree species within each plot was computed, followed by the mean basal area for the entire vegetation area. Similarly, the height of each species inside the sampling plots was measured and then averaged across plots to provide an average height for the vegetation region.

RESULTS AND DISCUSSION

Family composition and tree dominance

Field data from the 20 plots in the Gjeneruka forest of the Divjakë-Karavasta National Park indicate the presence of 10 families, consisting of 13 genera and a total of 22 species (Table 1).

Table 1. Tree species composition and abundance in the Gjeneruka study area of Divjakë-Karavasta National Park

Species	Family	Frequency	RD %	Status
Pinus halepensis Mill.	Pinaceae	69	4.15	Frequent
Pinus pinea L.	Pinaceae	109	6.55	Abundant
Carpinus betulus L.	Corylaceae	82	4.93	Frequent
Carpinus orientalis Mill.	Corylaceae	544	32.7	Abundant
Quercus robur L.	Fagaceae	146	8.78	Abundant
Quercus cerris L.	Fagaceae	248	14.9	Abundant
Quercus frainetto Ten.	Fagaceae	147	8.84	Abundant
Quercus petraea (Matt.) Lieblein.	Fagaceae	3	0.18	Threatened
Quercus pubescens Willd.	Fagaceae	5	0.30	Threatened
Quercus trojana Webb.	Fagaceae	7	0.42	Threatened
Ulmus campestris L.	Ulmaceae	6	0.36	Threatened
Sorbus torminalis L.	Rosaceae	3	0.18	Threatened
Sorbus aucuparia L.	Rosaceae	1	0.06	Threatened
Crataegus monogyna Jacq.	Rosaceae	55	3.31	Occasional
Cercis siliquastrum L.	Leguminosae	31	1.86	Rare
Colutea arborescens L.	Leguminosae	1	0.06	Threatened
Spartium junceum L.	Leguminosae	2	0.12	Threatened
Paliurus spina-christi Mill.	Rhamnaceae	43	2.58	Rare
Cornus mas L.	Cornaceae	49	2.95	Rare
Fraxinus ornus L.	Oleaceae	89	5.35	Abundant
Acer monspessulanum L.	Aceraceae	16	0.96	Threatened
Acer tataricum L.	Aceraceae	6	0.36	Threatened

Species status (Edet et al. 2011): Abundant = RD ≥ 5.00, Frequent = 4.00 ≤ RD ≤ 4.99, Occasional = 3.00 ≤ RD ≤ 3.99, Rare = 1.00 ≤ RD ≤ 2.99 and Threatened/Endangered = RD < 1.00

The Fagaceae family presents the highest species richness, followed by the Leguminoseae and Rosaceae families. The plots are predominantly characterized by the three principal families Pinaceae, Corylaceae, and Fagaceae accounting for 81.82% of the total, with 1360 individuals. In the study region, 77.19% of tree species are abundant, 9.08% are frequent, 7.4% are rare, and 3% are classified as threatened due to their limited individual representation. In the plots taken in the study, the species presented with abundant status with a higher relative density at 33% was *Carpinus orientalis* Mill., followed by three species of the Fagaceae family (*Quercus cerris* L.; *Quercus frainetto* Ten. and *Quercus robur* L.). According to the Red List of the Flora and Fauna of Albania (2013) three of the species found in our study, *Pinus pinea* L., *Quercus robur* L. and *Ulmus campestris* L. belong to the vulnerable status.

The dominant species, *Carpinus orientalis* Mill., is present in nine examined plots, alongside *Fraxinus ornus* L., *Crataegus monogyna* Jacq., *Quercus robur* L., *Quercus cerris* L., *Cornus mas* L., *Paliurus spina-christi* Mill., *Quercus frainetto* Ten., *Hedera helix* L., *Acer monspessulanum* L., *Quercus pubescens* Willd., *Pteris aquilina* L., *Sorbus torminalis* L. and *Sorbus aucuparia* L.

Quercus frainetto Ten. is dominant in plots S7, S8, and S11, which includes 113 individuals or 6.79%. In plot S7, it constitutes 42%, accompanied by *Carpinus orientalis* L. at 22%, *Quercus cerris* L. at 18%, and various other species at 18%. Representatives of the Pinaceae family account for 10.7% of the woody species across the study plots, dominating four plots (S17, S16, S18, and S6) with proportions ranging from 32% *Pinus pinea* L. in S6 to 82% *Pinus halepensis* L. in S16. These species are primarily associated with *Quercus trojana* Webb., *Carpinus orientalis* Mill., *Quercus robur* L., *Acer monspessulanum* L., *Quercus frainetto* Ten., *Cercis siliquastrum* L. and *Fraxinus ornus* L.

Tree species richness and diversity

The findings from the 20 plots analyzed in the study reveal a total Shannon index value of *H′*=2.244 (Table 2), with values spanning from a low of 0 (at S10) to a maximum of 2.09 (S8).

Table 2. Data analyzing of the tree inventory of the Gjeneruka forest (Divjakë-Karavasta National Park)

Diversity index/20 plots	**Shannon H'**	**Evenness J'**	**Richness D_{Mn}**	**Simpson D**	**Berger-Parker d**	**Clark-Evans R**
Index value for the study area	2.244	0.726	0.539	0.841	0.327	5.957
Average	1.194	0.672	0.681	0.591	0.550	6.630
Min	0	0	0.132	0.017	0.202	3.650
Max	2.051	0.933	1.376	0.869	1	9.774
Variance	0.313	0.055	0.093	0.059	0.052	3.516
SD	0.559	0.235	0.306	0.243	0.228	1.875
CV	46.87	34.95	44.91	41.24	41.54	28.28

Plots S8 (143 individuals of 9 different tree species), S14 (135 individuals of 10 different tree species), and S15 (65 individuals of 10 different tree species) have the greatest values of this index and the richest species diversity. Twelve of the twenty plots in the study had low Shannon diversity index values; these surfaces are dominated by a few species and one dominating species with a large number of individuals relative to other species (Figure 3 (a)). Since *Pinus pinea* L. is the only species present, Plot S10 lacks diversity, with an index value of 0. A few species dominated the study region, and many of the species were represented by a limited number of individuals, according to data gathered from field observations. The Shannon index value for these national park economic units in this study falls within the same range as those found and reported in comparable studies carried out in other park ecosystems (Panda *et al.*, 2013; Lakićević, M. and Sredevic B., 2018; Malaj *et al.*, 2024, Stojanovski *et al.*, 2024; Malaj *et al.*, 2025).

The research area's Evenness index value, which ranges from 0 to 0.933, is J'=0.726. Plots with values near zero indicate the presence of a dominant species in terms of the number of individuals relative to other species (Figure 3 (b)). In particular, *Carpinus orientalis* L. dominates S1 and S4, with values of 0.32 and 0.36, respectively, while *Pinus halepensis* Mill. dominates S16. The index values for the other plots in the study range from 0.5 to 0.9, indicating that the species found on these sample surfaces are equally abundant. S6, S8, and S17 exhibit values near 1, indicating a high degree of evenness (very balanced).

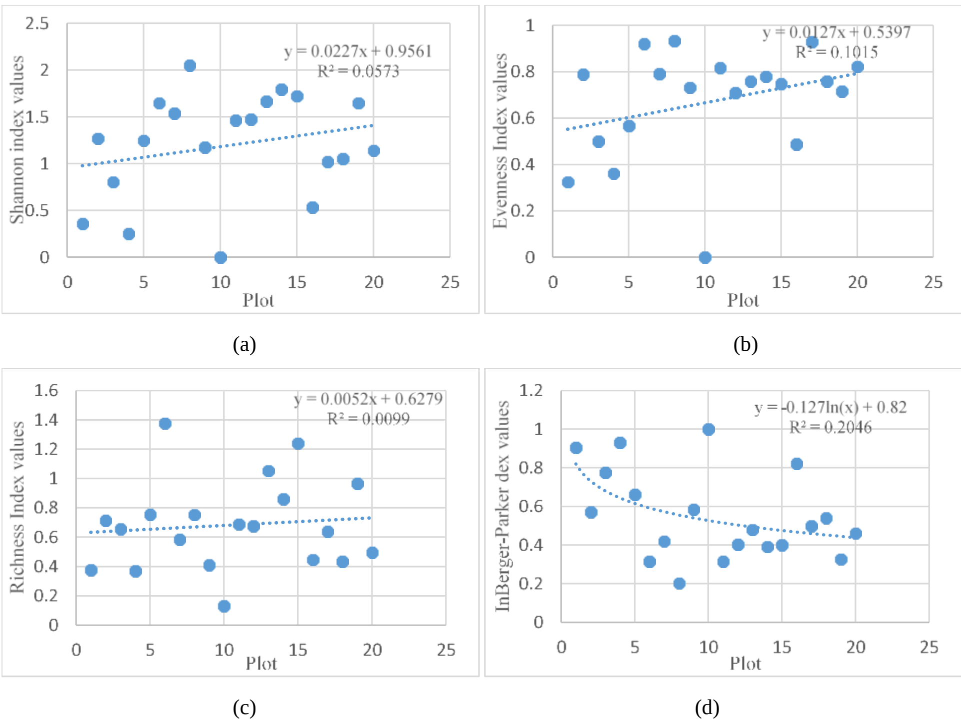
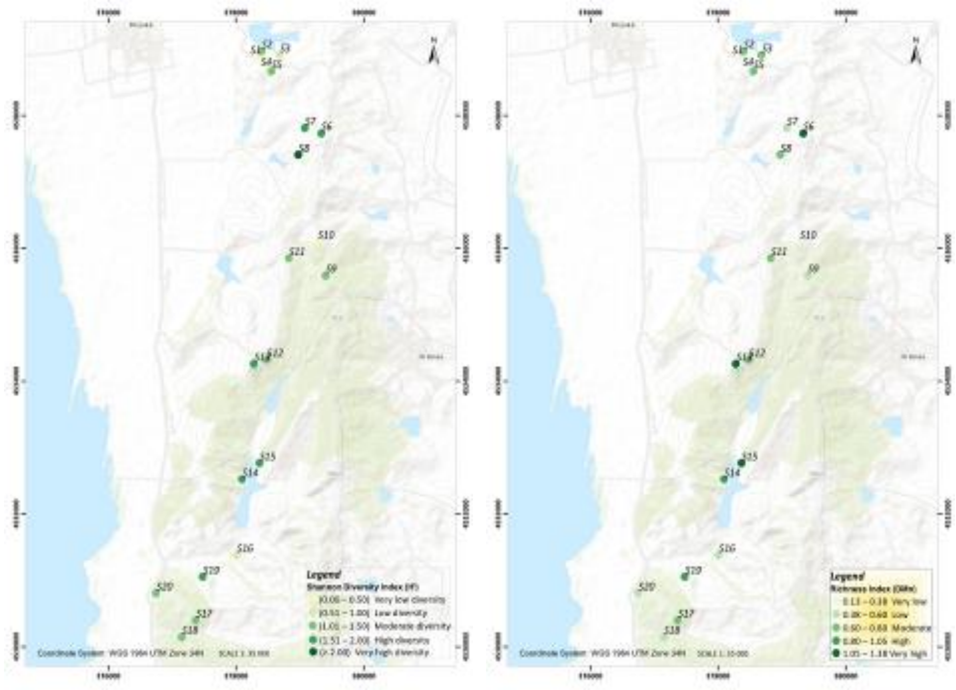


Figure 2. (a-d) Data of forest tree species diversity assessed by the biological indices

The study's 20 plots had a species richness index ranging from a low of 0.132 (S10) to a high of 1.376 (S6). Five plots (S6, S13, S15, S14, and S19) had more species than the overall population, according to the variation in species richness across different locations. The Simpson index values displayed above for the same test surface are consistent with the low values found for this ecological indicator.

The Simpson index (D), which measures the variance of the distribution of species abundance, is one of the finest measures of variety. The results of the research indicate the forest trees in the entire test region have a good level of diversity, with an index value of 0.539 (Figure 2 (a)).

The 20 investigated plots, however, showed different outcomes for this ecological index; area S8 had a value of 0.869, while area S10 had the lowest value of 0.01. Both this test region and the other four (S6, S14, S15, and S11), which have the same score (D) of 0.7 to 0.8, have a great diversity of forest species. The fact that these measured values are similar to the Shannon index values gives validity to the hypothesis that plot S8 of the 20 regions analyzed contains the most diversity of forest species. The current study's dominance concentration, or Simpson index, falls between 0.0 and 1.34, which has been previously documented in different forest ecosystems studies (Sahu *et al.*, 2012; Malaj *et al.*, 2024; Stojanovski *et al.*, 2024).



(a) (b)

Figure 3. Data of forest tree species diversity assessed by (a) Shannon diversity index; (b) Richness index

According to the Berger-Parker index (Figure 2 (d)), at least four of the investigated locations had values that are close to 1, indicating that a single species dominates the community of tree species in these four places (S1, S4, S10, and S16). As previously noted, S10 had an absolute value of 1, which was dominated primarily by the species *Pinus pinea* L. The other areas all matched the Shannon index values, supporting the conclusions of minimal species diversity.

We used the Clark-Evans Index to learn more about the various forest structure levels and scales as well as their spatial features. This index yields values larger than 1 for each of the 20 plots in the research region, indicating a regular spatial distribution of trees. The results are similar to those of earlier research conducted in other Divjakë-Karavasta National Park Forest habitats (Malaj *et al.*, 2025).

Forest Structure

Important forest structure indicators, including tree diameter, width, density, and basal area, were collected for our study. The study's 20 plot results for these characteristics are significant for biodiversity protection, timber production planning, and supporting the unit's long-term growth as a forest economy within the National Park. The overall density value of the 20 plots that were the subject of our research (1662 tree individuals), indicates that the study area is reasonably populated with trees, though density is not uniform throughout. There is a clear variation between plots. Plot 9 had the highest number of individuals (147), suggesting it is a denser and possibly more productive or less disturbed area, followed by S8 and S7, both of which had a high number of tree species (143), indicating that certain parts of the forest support greater tree abundance and possibly more favorable growing conditions. The average stand density was 75.54 trees per hectare, indicating a moderately stocked forest, neither sparse nor overly crowded. This level of density can reflect a balance where trees have sufficient space to grow while still competing for resources such as light, water, and nutrients.

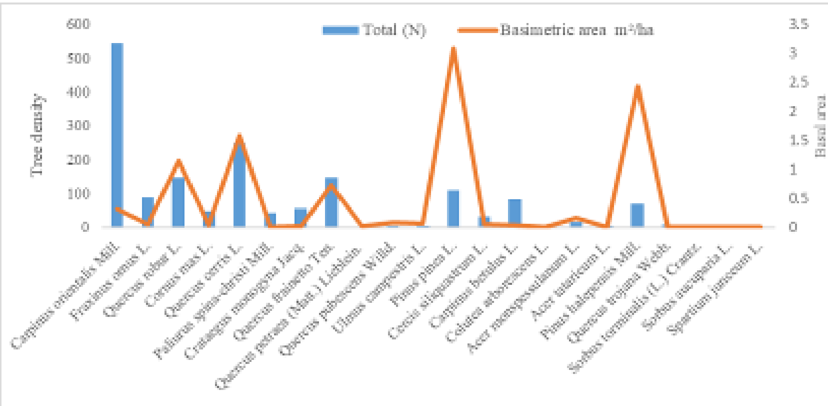


Figure 4. The density of trees and their basal surface, according to the main tree species found in the study

The density of different tree species varies across the 20 study plots. *Carpinus orientalis* Mill. had the maximum stand density (544 individuals ha^{-1}) and a basal area of 0.324 m² ha^{-1}. This species has the highest density, meaning it is the most numerous species in the study area; however, its basal area is relatively low (0.324 m² ha^{-1}), which suggests that although there are many individuals, they are generally small in size. The plot S5 had the most (94 individuals ha^{-1}) of these plants, indicating that this species is particularly concentrated in certain locations, followed by *Quercus cerris* L. with 248 individuals ha-1 and a basal area of 1.5901 m² ha^{-1}, and *Quercus frainetto* Ten. with 147 individuals ha-1 and a basal area of 0.729 m² ha^{-1} (Figure 4). *Quercus cerris* L. shows a lower density (248 individual's ha^{-1}) but a much higher basal area (1.5901 m² ha^{-1}), indicating that fewer individuals occupy more space, meaning these trees are larger and more developed, contributing significantly to the overall stand structure. Similarly, *Quercus frainetto* Ten. has moderate density and basal area, suggesting it also plays an important structural role, though less dominant than *Quercus cerris* L. *Sorbus aucuparia* L. (0.000314 m^2 ha^{-1}) and *Spartium junceum* L. (0.000628 m² ha^{-1}) are the tree species with the lowest basal area values, indicating that they are either very rare, very small, or both within the study area. Their contribution to the forest structure is therefore minimal. These results suggest a forest where some species dominate in number (high density), while others dominate in size (high basal area). This reflects a mixed and structurally diverse stand, where species differ in their ecological roles, growth patterns, and levels of dominance.

Tree diameter at breast height (DBH) is a widely used metric in forest ecology and management. It is used to evaluate tree size and age, as well as to compute biomass, wood volume, and carbon stock in a forest. The evaluation of size class distribution of tree stems inventoried in the complete 20 sampling plots showed that the majority of trees (78.88% or 1311 individuals) were in the <10 cm DBH range. In contrast, the minimal percentages (4.15% or 69 individuals) of trees were recorded in the ≥20 cm DBH range, while 16.97% or 282 individuals were documented in the 10-20 cm DBH range (Figure 5).

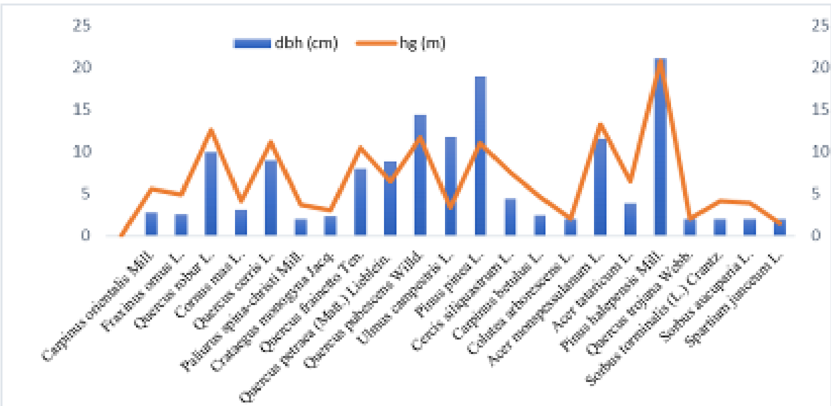


Figure 5. Tree species average height and diameter by field measurement at the Gjeneruka forest of Divjakë-Karavasta National Park

The results obtained for the distribution of trees by diameter classes (Diameter at Breast Height – DBH) indicate pronounced variation ranges, which represent a characteristic feature of forests in protected areas, as also confirmed by findings from similar studies. (Szmyt, 2017; Curovic *et al.*, 2025).

Tree height is a key measure of forest growth and productivity. It contributes in the assessment of site quality, competition among trees for light, and the formation of vertical forest layers, all of which are vital for many other organisms. The characteristic is important in forest management especially when determining the intensity of selective felling. The average height of trees in the group of average diameters smaller than 10 cm is 5.12 m, while this parameter in the category ≥20 cm DBH results in a mean value of 10.41 m. The observed increase in tree height with diameter indicates a typical growth pattern in which larger diameter trees are also taller, reflecting more advanced developmental stages. This relationship suggests that trees with greater DBH are likely older and have experienced prolonged growth. Additionally, the variation in height and diameter classes points to a heterogeneous stand structure, characterized by the presence of multiple size and age classes. Smaller trees are likely younger or suppressed individuals growing under canopy shade, while larger trees are more dominant and have greater access to light resources. This pattern highlights competition for light, where taller and thicker trees occupy the upper canopy and outcompete smaller individuals, which may exhibit reduced growth due to shading. These characteristics suggest a developing or uneven-aged stand, potentially undergoing continuous regeneration rather than representing a uniform, even-aged plantation.

CONCLUSIONS

The study reveals a forest community composed of 22 species from 13 genera and 10 families, with a total of 1662 individuals. The Shannon diversity index indicates moderate diversity, with a limited number of species dominating the forest structure. Families such as Corylaceae and Fagaceae contribute the majority of individuals, highlighting their ecological importance in the area. Structural analysis shows a strong dominance of small-diameter trees (<10 cm DBH), which make up nearly 79% of all individuals, suggesting a young or regenerating forest. This is further supported by the relatively low average tree height in smaller diameter classes compared to larger ones. These findings suggest that the forest is in an early successional stage or is experiencing continuous regeneration, possibly influenced by environmental or anthropogenic factors. The high density of species such as *Carpinus orientalis* L. indicates competitive dominance, which may limit the development of other species and reduce structural complexity over time. For future forest management, it is recommended to promote structural diversification by supporting the growth of larger diameter classes and maintaining species balance. Selective thinning could be applied to reduce excessive competition in dense stands and encourage the development of underrepresented species. Additionally, long-term monitoring should be implemented to track changes in species composition, diversity, and structure.

Conservation strategies should focus on protecting dominant but ecologically valuable families while enhancing habitat conditions to support greater biodiversity and ecosystem stability.

REFERENCES

Berger, W.H. & Parker, F.L. (1970). Diversity of planktonic foraminifera in deep sea sediments. Science, 168: 1345–1347.

Bird Life International (2020). Important Bird Areas factsheet: Divjakë–Karavasta.

Clark, P.J. & Evans, F.C. (1954). Distance to nearest neighbor as a measure of spatial relationships in populations. Ecology, 35: 445–453.

Council of Europe (2011). The Emerald Network and the Conservation of European Wildlife and Natural Habitats.

Curovic, M., & Bugarin, D., Motta, Renzo., Gazdić, M., & Medarević, M. (2025). Structural characteristics of old-growth forest of silver fir and beech at Biogradska Gora. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 53: 14807. 10.15835/nbha53414807.

Edet, D.I., Ijeomah, H.M. & Ogogo, A.U. (2011). Preliminary assessment of tree species diversity in Afi Mountain Wildlife Sanctuary, Southern Nigeria. Agriculture and Biology Journal of North America, 3(12): 486–492.

Krebs, C.J. (1999). Ecological Methodology (2nd ed.). Menlo Park, CA, Benjamin Cummings.

Lakićević, M. & Sredevic B. (2018). Measuring biodiversity in forest communities a role of biodiversity indices. Contemporary Agriculture, 67: 65–70.

Lindenmayer, D.B., Margules, C.R. & Botkin, D.B. (2000). Indicators of biodiversity for ecologically sustainable forest management. Conservation Biology, 14(4): 941–950.

Magurran, A.E. (2004): Measuring Biological Diversity. Oxford, UK, Blackwell.

Malaj, E. & Xhulaj (Bode), D. (2024). Assessing biodiversity in forest ecosystems using ecological indices. Case study of the Mediterranean coniferous forest at Divjakë-Karavasta National Park. International Journal of Ecosystems and Ecology Science (IJEES), 14(4): 129–138. https://doi.org/10.31407/ijees14.417

Malaj, E., Bode, D. & Halili, A. (2025). Ecological assessment of tree species diversity, richness and composition in the deciduous forest ecosystem of Divjakë-Karavasta National Park. International Journal of Ecosystems and Ecology Science (IJEES), 15(4): 195–204. https://doi.org/10.31407/ijees

Manual of Forest and Pasture Management Plans (2019). (https://qeverisjavendore.gov.al/Manuali-i-planeve-te-mbareshtimit-te-pyjeve-dhe-kullotave-2019.pdf)

Ministry of Environment, Albania (2013). Red List of the Flora and Fauna of Albania (Ministerial Order No. 1280, 20 Nov. 2013). Tirana, Albania. Retrieved from archive.nationalredlist.org.

Ministry of Tourism and Environment of Albania (2018). Management Plan of Divjakë–Karavasta National Park.

Oliver, C.D. & Larson, B.C. (1996). Forest Stand Dynamics (Updated ed.). New York, Wiley.

Panda, P.C., Mahapatra, A.K., Acharya, P.K. & Debata, A.K. (2013). Plant diversity in tropical deciduous forests of Eastern Ghats, India: A landscape level assessment. International Journal of Biodiversity Conservation, 5: 625–639.

Ramsar Convention Secretariat (2013). The Ramsar Convention Manual: A Guide to the Convention on Wetlands (Ramsar, Iran, 1971) (6th ed.). Gland: Ramsar Convention Secretariat.

Sahu, S.C., Dhal, N.K. & Mohanty, R.C. (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.

Shannon, C.E. (1948). A mathematical theory of communication. The Bell System Technical Journal, 27: 379–423. https://doi.org/10.1002/j.1538-7305.1948.tb01338.x

Simpson, E.H. (1949). Measurement of diversity. Nature, 163: 688. https://doi.org/10.1038/163688a0

Stojanovski, V., Andonovski, V. & Orlović S. (2024). Diversity of woody plants in urban parks. Šumarski list 149(9-10): 431-442. https://doi.org/10.31298/sl.149.9-10.3

Szmyt, J. (2017). Structural diversity of selected oak stands (*Quercus robur* L.) on the Krotoszyn Plateau in Poland. Forest Research Paper, 78 (1): 14-27.

Tilman, D. (1997). Biodiversity and ecosystem functioning. Nature, 277: 1300–1302.

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