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# Structure and Composition of Woody Species in the Kpatawee Tropical Rainforest in Liberia

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***Authors' contributions***

*This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

Studying ecosystem structure and species composition is pivotal, offering critical insights into environmental health and biodiversity. It facilitates the evaluation of environmental changes, like deforestation and climate shifts, and their influence on species dynamics within ecosystems. Our study aimed to assess the woody species composition and structure within Liberia's Kpatawee tropical rainforest. We conducted transect walks, crossing the forest south-north and east-west, establishing six 20 m x 20 m sampling plots. Using the PlantNet plant species identifier tool, we cataloged surviving trees with a DBH ≥ 5 cm, including their scientific names. Results unveiled 71 tree species across 42 families, with Leguminosae displaying the highest diversity. Prominent species included Quararibea asterolepis, Hasseltia floribunda, and Castilla elastica. An intriguing inverted J-shaped pattern in diameter distribution linked to stem-stand shrubs, small-sized trees, and young large trees characterized the first class. The tree layer, mainly species like Garcinia benthamiana, Iramyan therasagotiana, and Eschweilera decolarans, contributed significantly to the total DBH (65.45%). Total basal area (BA) for trees DBH ≥ 5 cm was 16.39 m² $ha^{-1}$. Notably, eight

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species accounted for 93% of the basal area, reflecting a concentration of individuals in lower DBH classes in the first category. This trend suggests a gradual decline in numbers in higher DBH classes. Consequently, we recommend implementing sustainable forest management to mitigate the impacts of selective cutting on forest recruitment and regeneration processes. The inverted J-shaped pattern, indicating prolific regeneration but limited recruitment, possibly due to selective cutting, underscores the imperative for prudent forest management.

*Keywords: Tree species; tropical forest; species composition; forest structure; Kpatawee tropical forest.*

## 1. INTRODUCTION

Approximately 70% of all plant and animal species on Earth are found in tropical rainforests, which occupy just 7% of the planet's dry surface area but are incredibly biodiverse [1]. Numerous essential commodities and services are provided by these ecosystems to local and global societies. Tropical rainforests provide food, building materials, medicinal plants, and other necessities for indigenous populations (Ali et al., 2014). Furthermore, these forests are essential to maintaining the stability of the global environment because they help to regulate temperature, purify the air, and detoxify the soil (Bargali et al., 2015). Particularly, woody stands are significant carbon sinks [2], and studying them helps estimate their capacity to absorb and store carbon dioxide from the atmosphere. This knowledge is vital for climate change research and informed climate policy decisions.

Liberia is a perfect example of a nation rich in forest resources, with forests covering over 45% of its land area [3]. There are several tangible forest resources with market-determined values, including animals, inland fisheries, fuel wood, timber, and forage. Furthermore, Liberia's forests provide nonmarket-determined benefits like environmental protection, recreational opportunities, and amenities. Regretfully, massive deforestation has resulted in the demise of multiple species and the destruction of Liberia's lush environment. Deforestation and other environmental issues, however, pose a serious threat to Liberia's forests [4].

Within Liberia's forested landscape, the Kpatawee Rainforest is a prominent area that is renowned for its great richness and diversity of plant and animal species. It is home to numerous African vulnerable species that are extremely important for conservation, such as tree species like *Terminalia ivorensis, Pterocarpus soyauxii,* and *Milicia excelsa* [5]. But human activity has not spared this rainforest; the main one being the rapacious harvesting of forest resources, both timber and non-timber.

Amidst the challenges presented by deforestation and human disruptions, it is imperative to carry out thorough investigations on biodiversity and ecology. These investigations support conservation efforts by shedding light on the environmental benefits that this rare biodiversity offers. Developing fundamental scientific understanding of the composition and structure of woody species of the Kpatawee rainforest was the main goal of the study. It focuses on assessing the species composition and overall structure of woody stands. It provided some key recommendation from the outcome of this study.

## 2. MATERIALS AND METHODS

### 2.1 Study Site

The study was carried out in the Kpatawe rainforest, Liberia. It lies at an altitude of 270 m above sea level and is located at 7.0451° latitude and -9.5508° longitude. Climatic variables such as temperature and rainfall pattern are largely tropical, with an annual average temperature of 25 °C and an average annual rainfall of 2013 mm distributed from May to October. The main soil types in the district include latosols, lithosols, regosols, and alluvial or swamp soils [6]. The study area is home to many grasses, trees, and shrub species, which are said to be part of the remaining Upper Guinean rainforest. Cassava, rice, and maize farming are the dominant crops grown in the area [7].

### 2.2 Vegetation Data Collection

A transect walk was performed in the forest from east to west and from south to north. A representative sampling plot (20 m x 20 m, 100 m apart) was installed along the transect walk.

Tree sampling was performed on six selected sampling plots. Following the procedures by Hu et al [8], all living trees with a diameter ≥ 5 cm at breast height (DBH) were recorded by species using the latest botanical classification method. All tree species were assigned to their own families. A plant species identifier application (PlantNet) was used, and the scientific names of plants were identified.

#### 2.2.1 Tree basal area calculation

Tree diameter was measured at breast height for species more than 5 cm in diameter and over 3 m in height, according to Zeng et al. [9]. The diameter was measured using a diameter tape. Basal area (BA), which is the cross-sectional area of tree stems, was measured through the diameter at breast height, which is 1.3 m above ground level. It helped to measure the relative dominance (the degree of coverage of a species as an expression of the space it occupies) of a species in a forest. It was calculated as:

$$BA = \pi DBH^2/4$$

Where BA = basal area ($m^2$), DBH = diameter at breast height (cm), $\pi = 3.14$

#### 2.2.2 Dominance

Species dominance refers to the degree of coverage of a species as an expression of the space it occupies in a given area. Usually, dominance is expressed in terms of the basal area of the species. In this case, two types of dominance were calculated: dominance (the sum of basal areas of the individuals in $m^2$ $ha^{-1}$) and relative dominance, which is the percentage of the total basal area of a given species out of the total measured stem basal areas of all species.

Dominance = Total basal area/area sampled

Relative dominance = (Dominance of species A/total dominance of all species) * 100

### 2.3 Statistical Analysis

Descriptive statistics such as DBH, BA, and RD were performed to summarize the structure and composition of woody species in the study forest. JMP 14 Pro was used to perform all the statistical analyses.

## 3. RESULTS AND DISCUSSION

### 3.1 Tree Species Composition

The present study delves into the structure and composition of wood species within the Kpatawee rainforest. A comprehensive examination revealed the presence of 71 distinct tree species, distributed among 42 different families. In terms of species diversity, the Leguminosae family emerged as the most varied, followed closely by Sapotaceae, Chrysobalana, Burseraceae, and Myristicaceae. Moreover, when considering stand density, it becomes evident that *Dicorynia guianesis* stands out as the most dominant species in the study area. The observation of 20 individuals belonging to this family aligns with previous findings, as reported by Goulart et al. [10]. This information offers valuable insights into the prevalence and distribution of these significant tree species within the Kpatawee rainforest.

The Kpatawee rainforest boasts several dominant tree species, including *Quararibea asterolepis*, *Hasseltia floribunda*, *Castilla elastica*, *Hasseltia floribumda*, *Iryanthera sagotiana*, *Calophyllum tacanbhaca*, and *Licania bernoulli*. In contrast, species such as *Couma guianensis*, *Ceiba pentandra*, *Pouteria guianensis*, *Lecythis idatmon*, and *Dicorynia guianesis* are considered rare within the ecosystem. Kubota et al. [11], who studied the effects of topographic heterogeneity on tree species richness and stand dynamics in a subtropical forest on Okinawa Island, southern Japan, also corroborated the dominance of species like *Castilla elastica*, *Calophyllum tacanbhaca*, and *Hasseltia floribumda* in their research findings.

### 3.2 Diameter Class Distribution

A total of 71 individuals of tree species whose DBH was ≥ 5 cm were recorded from the Kpatawee rainforest. DBH was classified into ten classes of 10 cm intervals (Class 1 = 5–15, Class 2 = 16–25, Class 3 = 26–35, Class 4 = 36–45, Class 5 = 46–55, Class 6 = 56–65, Class 7 = 66–75, Class 8 = 76–85, Class 9 = 86–95, and Class 10 = ≥ 96) (Fig. 1). The diameter distribution of the Kpatawee rainforest was found to be an inverted J-shaped distribution.

The J-shaped distribution observed in this study may be attributed to a significant presence of stem-stand shrubs, small-sized tree species, and younger individuals of larger tree species [12, 13]. In terms of forest profiles, only a handful of tree species in the canopy layer contributed to the majority of the total DBH in the Kpatawee forest. These species include *Eschweilera decolarans, Garcinia benthamiana*, and *Iramyan therasagotiana*, accounting for 65.45% of the total DBH. Similar findings were reported by Cirimwami et al. [14] in their study on the impact of elevation on species richness in tropical forests, depending on the considered lifeform, in an East African mountain forest. Furthermore, tree height values were observed to be higher in the lower DBH class and decreased in the higher class. This pattern was consistent across other forests as well [15]. This distribution pattern reveals that the forest is also experiencing selective logging, resulting in the prevalence of smaller to medium-sized individuals. This suggests a high rate of regeneration but low recruitment.

The DBH distribution in the Kpatawee rainforest aligns with similar patterns observed in forests in other countries [16]. The reverse J-shaped population curve of trees indicates an evolving or expanding population, a climax, or a stable type of population within forest ecosystems, implying that the forest hosts a thriving and healthy population [9].

### 3.3 Basal Area

Basal area (BA) is a crucial parameter for assessing the relative importance of tree species in a forest, as opposed to relying solely on stem counts [17]. Plant species with a larger basal area in a forest are generally considered the most significant species within that ecosystem. In our study, the cumulative basal area of tree species with a diameter at breast height (DBH) ≥ 5 cm was 16.39 $m^2$ $ha^{-1}$. Remarkably, eight species accounted for 93% of this basal area. However, Mi et al. [18] reported that the typical basal area for virgin tropical forests in Africa ranges from 23 to 37 $m^2$ $ha^{-1}$. The lower basal area observed in our study is the result of various factors, including the presence of tree species with smaller basal areas, historical disturbances such as logging, variations in growth rates and tree age, differences in sampling methods, and variations in environmental conditions within the study forest. These factors collectively contribute to a reduced basal area compared to the reference data from other regions by Mi et al. [18], underscoring the intricate dynamics that influence forest ecosystems.

*Dicorynia guianesis* emerged as the most significant tree species in the forest, boasting a basal area of 8.6 $m^2$ ha-1, equivalent to 44.15% of the total. Following closely was *Lecythis idatmon*, with a basal area of 3.4 $m^2$ $ha^{-1}$, representing 18.46% of the total basal area. Other plant species, such as *Pouteria guianensis, Ceiba pentandra, Couma guianensis,* and *Bocoa prouacensis,* exhibited basal areas of 0.40, 0.35, 0.29, and 0.20 $m^2$ $ha^{-1}$, respectively. This variation can be attributed to the presence of tree species with relatively larger DBH sizes in the study area (Table 1). Conversely, *Licania heteromorpha* contributed the smallest basal area, approximately 0.001 $m^2$ $ha^{-1}$, to the Kpatawee tropical rainforest.

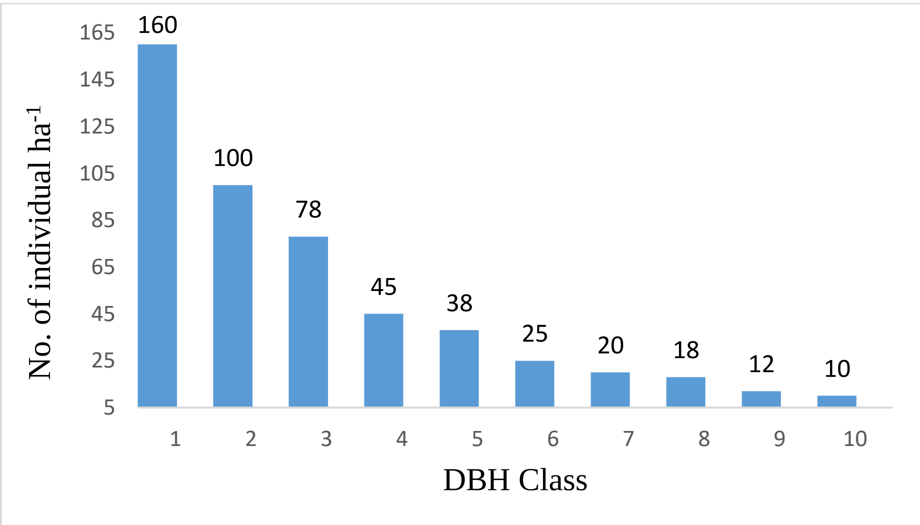


**Fig. 1. The diameter distribution of Kpatawee tropical rainforest**

### 3.4 Forest Structure

In this study, we analyzed the structure of tree species based on their density across various DBH (Diameter at Breast Height) classes. Our findings revealed a distinct population pattern resembling an inverted J-shape. This pattern indicated a high concentration of individuals in the lower DBH classes, with a gradual decrease in numbers as we moved to higher DBH classes. Notably, a few species, such as *Dicorynia guianensis*, exhibited this pattern, suggesting robust recruitment and regeneration within these species. Similar patterns were reported by Mi et al. [8] in their studies, with 17 species observed at Gara-Ades and 18 species at Menagesha forests. Furthermore, our analysis unveiled a second pattern where individuals were predominantly found in lower DBH classes, while their presence decreased in intermediate and higher DBH classes (Fig. 1).

Some species, such as *Quararibea asterolepis* and *Castilla elastica*, were classified within this category. This pattern signifies substantial human influence on higher DBH classes, leading to a scarcity of mature individuals capable of serving as seed sources. The third pattern revealed the presence of a significant number of individuals in both lower and higher DBH classes, with a notable absence of individuals in the intermediate DBH classes. Several species, including *Dicorynia guianensis* and *Lecythis idatmon*, exhibited this particular pattern. Similar findings were reported by Rai et al. [19] in their study on the impact of environmental factors on species richness and composition of vascular plants in the Manaslu conservation area and the Sagarmatha region of the Nepalese Himalaya. Their results corroborate the second and third population patterns. The fourth pattern depicted a predominance of individuals in the intermediate DBH classes, accompanied by a smaller number of individuals in both lower and higher DBH classes. A few species, including *Tabebuia rosea*, exemplified this pattern. This pattern suggests hindered regeneration, potentially attributable to inadequate recruitment coupled with the selective removal of individuals in the higher DBH classes [20].

**Table 1. Botanical name, Diameter at Breast Height (DBH), Basal Area (BA) and Relative Dominance (RD) and their family of the dominant species in the study area**

| No | Botanical name | Family name | DBH (cm) | BA ($m^2$) | RD (%) |
|---|---|---|---|---|---|
| 1 | *Abies alba mill* | Pinaceae | 35.03 | 0.10 | 0.05 |
| 2 | *Abies nordmannian* | Pinaceae | 25.48 | 0.05 | 0.09 |
| 3 | *Acer opalus mill* | Sapindaceae | 25.48 | 0.05 | 0.09 |
| 4 | *Acioa guianensis* | Chrysobalana | 9.55 | 0.01 | 0.62 |
| 5 | *Aniba terminails duke* | Lauraceae | 27.07 | 0.06 | 0.08 |
| 6 | *Bocoa prouacensis* | Leguminosae | 50.96 | 0.20 | 0.02 |
| 7 | *Calophyllum tacamahaca* | Clusiaceae | 3.82 | 0.00 | 3.88 |
| 8 | *Canarium album* | Burseraceae | 12.74 | 0.01 | 0.35 |
| 9 | *Carya ovata Mill.* | Juglandaceae | 19.11 | 0.03 | 0.16 |
| 10 | *Castanea sativa* | Fagaceae | 19.11 | 0.03 | 0.16 |
| 11 | *Castilla elastica* | Moraceae | 1.59 | 0.03 | 22.32 |
| 12 | *Ceiba pentandra* | Malvaceae | 66.88 | 0.35 | 0.01 |
| 13 | *Celtis australis l.* | Cannabaceae | 44.59 | 0.16 | 0.03 |
| 14 | *Coffee arabica l.* | Rubiaceae | 19.11 | 0.00 | 0.16 |
| 15 | *Couepia bracteosa* | Chrysobalana | 27.07 | 0.06 | 0.08 |
| 16 | *Couepia guianesis* | Chrysobalanaceae | 15.92 | 0.02 | 0.22 |
| 17 | *Couma guianensis* | Apocynaceae | 61.15 | 0.29 | 0.02 |
| 18 | *Cupania hirsuta* | Sapidaceae | 36.62 | 0.11 | 0.04 |
| 19 | *Dacryodes nitens* | Burseraceae | 36.62 | 0.11 | 0.04 |
| 20 | *Dicorynia guianesis* | Leguminosae | 332.80 | 8.69 | 0.00 |
| 21 | *Diospyrus vestita* | Ebenaceae | 11.15 | 0.01 | 0.46 |
| 22 | *Douglas-fir* | Pinaceae | 15.92 | 0.02 | 0.22 |
| 23 | *Ecclinusa guianensis* | Sapotaceae | 7.96 | 0.01 | 0.89 |
| 24 | *Elephantopus madrium* | Lauraceae | 25.48 | 0.05 | 0.09 |
| 25 | *Eperna falcata* | Leguminosae | 4.78 | 0.00 | 2.48 |
| 26 | *Eschweilera decolarans* | Lecythidaceae | 23.89 | 0.05 | 0.10 |
| 27 | *Fagus sylvatica L.* | Fagaceae | 15.92 | 0.02 | 0.22 |

| No | Botanical name | Family name | DBH (cm) | BA ($m^2$) | RD (%) |
|---|---|---|---|---|---|
| 28 | *Fraxinus americana L.* | Oleaceae | 17.52 | 0.02 | 0.18 |
| 29 | *Garcinia benthamiana* | Clusiaceae | 4.78 | 0.00 | 2.48 |
| 30 | *Guapira eggersiana* | Nyctaginaceae | 25.48 | 0.05 | 0.09 |
| 31 | *Gustavia hexapetala* | Lecythidaceae | 12.74 | 0.01 | 0.35 |
| 32 | *Hasseltia floribunda* | Nyctaginaceae | 2.55 | 0.00 | 8.72 |
| 33 | *Hasseltia floribunda* | Salicaceae | 3.18 | 0.00 | 5.58 |
| 34 | *Humiriastrun subcrenatum* | Humiriaceae | 27.07 | 0.06 | 0.08 |
| 35 | *Hymenaea courbaril L.* | Leguminosae | 47.77 | 0.18 | 0.03 |
| 36 | *Hymenacea courbaril L.* | Leguminosae | 6.37 | 0.00 | 1.40 |
| 37 | *Iramyan therasagotiana* | Myristicaceae | 9.55 | 0.01 | 0.62 |
| 38 | *Iryanthera sagotiana* | Myristicaceae | 14.33 | 0.02 | 0.28 |
| 39 | *Juglans nigra* | Juglandaceae | 11.15 | 0.01 | 0.46 |
| 40 | *Lecythis idatmon* | Lecythidaceae | 208.60 | 3.42 | 0.00 |
| 41 | *Licania bernoulli* | Chrysobalana | 3.18 | 0.00 | 5.58 |
| 42 | *Licania berteroana* | Chrysobalanaceae | 49.36 | 0.19 | 0.02 |
| 43 | *Licania laxiflora* | Chrysobalana | 41.40 | 0.14 | 0.03 |
| 44 | *Licania nicranthia* | Chrysobalana | 35.03 | 0.10 | 0.05 |
| 45 | *Macrolobium bifolium* | Leguminosae | 38.22 | 0.12 | 0.04 |
| 46 | *Maquira guianensis* | Moraceae | 4.78 | 0.00 | 2.48 |
| 47 | *Morella cerifera* | Myricaceae | 19.11 | 0.03 | 0.16 |
| 48 | *Moronobea coccinea* | Clusiaceae | 9.55 | 0.01 | 0.62 |
| 49 | *Octrosia grandiflora* | Apocynaceae | 19.11 | 0.03 | 0.16 |
| 50 | *Chrysobalanaceae* | Leguminosae | 25.48 | 0.05 | 0.09 |
| 51 | *Oxandra asbeckii* | Annonaceae | 6.37 | 0.00 | 1.40 |
| 52 | *Picea abies* | Pinaceae | 46.18 | 0.17 | 0.03 |
| 53 | *Platymiscium trinitatis* | Leguminosae | 7.96 | 0.01 | 0.89 |
| 54 | *Pourouma villosa* | Urticaceae | 9.55 | 0.01 | 0.62 |
| 55 | *Pouteria brachyandra* | Sapotaceae | 36.62 | 0.11 | 0.04 |
| 56 | *Pouteria guianensis* | Sapotaceae | 71.66 | 0.40 | 0.01 |
| 57 | *Pradosia cochlearia* | Sapotaceae | 44.59 | 0.16 | 0.03 |
| 58 | *Pradosia ptychandra* | Sapotaceae | 27.07 | 0.06 | 0.08 |
| 59 | *Protium denerarense* | Burseraceae | 42.99 | 0.15 | 0.03 |
| 60 | *Protium sagotianum* | Burseraceae | 7.96 | 0.01 | 0.89 |
| 61 | *Protium subserratun* | Burserraceae | 15.92 | 0.02 | 0.22 |
| 62 | *Quararibea asterolepis* | Malvaceae | 1.59 | 0.00 | 22.32 |
| 63 | *Quercus iley* | Fagaceae | 7.96 | 0.01 | 0.89 |
| 64 | *Salix caprea l.* | Salicaceae | 14.33 | 0.02 | 0.28 |
| 65 | *Sandwithia caprea l.* | Salicaceae | 19.11 | 0.03 | 0.16 |
| 66 | *Sandwithia guyanensis* | Euphorbiaceae | 19.11 | 0.03 | 0.16 |
| 67 | *Simarouba amara* | Simaroubaceae | 25.48 | 0.05 | 0.09 |
| 68 | *Siparuna decipiens* | Siparunaceae | 25.48 | 0.05 | 0.09 |
| 69 | *Tabebuia rosea* | Bignoniaceae | 9.55 | 0.01 | 0.62 |
| 70 | *Terminalia catappa l.* | Conbretaceae | 19.11 | 0.03 | 0.16 |
| 71 | *Thyrsodium guianensis* | Anacardiaceae | 31.85 | 0.08 | 0.06 |

## 4. CONCLUSION

In this particular study, we explored the structure and composition of woody species in the Kpatawee tropical rainforest, in order to see its ecological dynamics. Our research provides important new information about the biodiversity and overall health of this special ecosystem. A total of 71 species of trees identified, categorized into 42 groups, the most diverse of which is *Leguminosae*. It was discovered that the prominent tree species in the forest were *Quararibea asterolepis, Hasseltia floribunda, Castilla elastica, Hasseltia floribumda, Iryanthera sagotiana, Calophyllum tacanbhaca,* and *Licania bernoulli*. This finding highlights the significance of these tree species in the structure of the forest.

An inverted J-shaped pattern was found in the diameter class distribution study, which was explained by a mix of stem-stand shrubs, small-sized tree species, and juvenile individuals of large-sized trees. This distribution pattern, which implies a high rate of regeneration but limited recruitment, possibly as a result of selective cutting, highlights the necessity for cautious management. The importance of specific tree species was reaffirmed by basal area analysis, with *Dicorynia guianesis* and *Lecythis idatmon* emerging as major contributors. Determining the relative importance of various species within the forest ecosystem requires an understanding of their basal areas.

Therefore, we recommended that implementing sustainable management practices to mitigate the effects of selective cutting on the forest's recruitment and regeneration processes. As the forest faces challenges related to its regeneration and long-term health, it is crucial to adopt careful and responsible management strategies that prioritize the conservation of important tree species and support the overall biodiversity of the ecosystem. This could involve controlled logging practices, reforestation efforts, and the protection of vital tree species like *Dicorynia guianesis* and *Lecythis idatmon* to ensure the sustainability of the Kpatawee rainforest.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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