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

ABSTRACT

Studying the structure and species composition of ecosystems is important because it provides valuable insights into the health and biodiversity of the environment. One key reason for this is that it helps us assess the impact of environmental changes, such as deforestation or climate change, on the overall balance of species and their interactions within an ecosystem. The objective of this study was to evaluate the species composition and structure of Kpatawee, a tropical rainforest in Liberia.A transect walk that crossed the forest in both south-north and east-west directions was conducted. Along the transect, six sampling plots (20 m x 20 m) were established, and tree sampling was done inside of these plots. Using the PlantNet plant species identifier tool, every surviving tree with a diameter of ≥ 5 cm at breast height (DBH) was carefully categorized, along with their scientific names.The results showed that there were 76 different species of trees representing 42 families, with *Leguminosae* having the greatest species diversity. *Quararibea asterolepis, Hasseltia floribunda,* and *Castilla elastica* were among the prominent dominating trees. The presence of stem-stand shrubs, small-sized tree species, and younger individuals of larger trees in the first class were all linked to the inverted J-shaped pattern found in the diameter distribution analysis. The tree layer contributed significantly to the total DBH (65.45%), especially species like *Garcinia benthamiana, Iramyan therasagotiana*, and *Eschweilera decolarans*. The total basal area (BA) of tree species with a diameter of ≥ 5 cm was 16.39 m² ha^{-1}. This study identified eight species responsible for 93% of the basal area, indicating that there is a significant number of individuals in the lower diameter at breast height (DBH) classes within the first category. This suggests a gradual decrease in the number of individuals as we move into higher DBH classes. Therefore we recommended that implementing sustainable management practices to mitigate the effects of selective cutting on the forest's recruitment and regeneration processes.The inverted J-shaped pattern which implies a high rate of regeneration but limited recruitment, possibly as a result of selective cutting, highlights the necessity for cautious 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 (Elisabeth et al., 2015). 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 (Paul and Roxburgh, 2020) 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 (FAO, 2014). 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 (FAO, 2015).

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*(Kindt et al., 2021). 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 thestudy. 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. MATERIAL 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(Reed, 1951). 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 (Ahn et al., 2020).

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. (2018), 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*.* (2014). 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), π = 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^2ha^{-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 76 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. (2015). 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. (2004), 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 76 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) (Figure 1). The diameter distribution of the Kpatawee rainforest was found to be an inverted J-shaped distribution.

The reason for the J-shaped distribution might be due to a large number of stem-stand shrubs, small-sized tree species, and younger individuals of big-sized tree species, too(Picard, 2019; Rodrigo et al., 2022). Regarding the forest profiles, few tree species in the tree layer have contributed to most of the total DBH of Kpatawee forest. These are *Eschweilera decolarans, Garcinia benthamiana,* and *Iramyan therasagotiana* (65.45%). Similar results are also reported by Cirimwami et al. (2019), who studied on the effect of elevation on species richness in tropical forests depends on the considered lifeform: results from an East African mountain forest. The tree height value is also higher in the lower class and decreases in the higher class. This is also true for other forests too (Singh, 2018).

This revealed that the forest is also suffering from selective cutting, which results in smaller to medium-sized individuals attributed to a high rate of regeneration but low recruitment. The DBH distribution of Kpatawee rainforest is in line with some other forests in other countries (Juli & Mike, 2001). The reverse J-shaped population curve of trees suggests an evolving or expanding population, climax, or stable type of population in forest ecosystems, indicating that the forest harbors a growing and healthy population (Zeng et al., 2014).

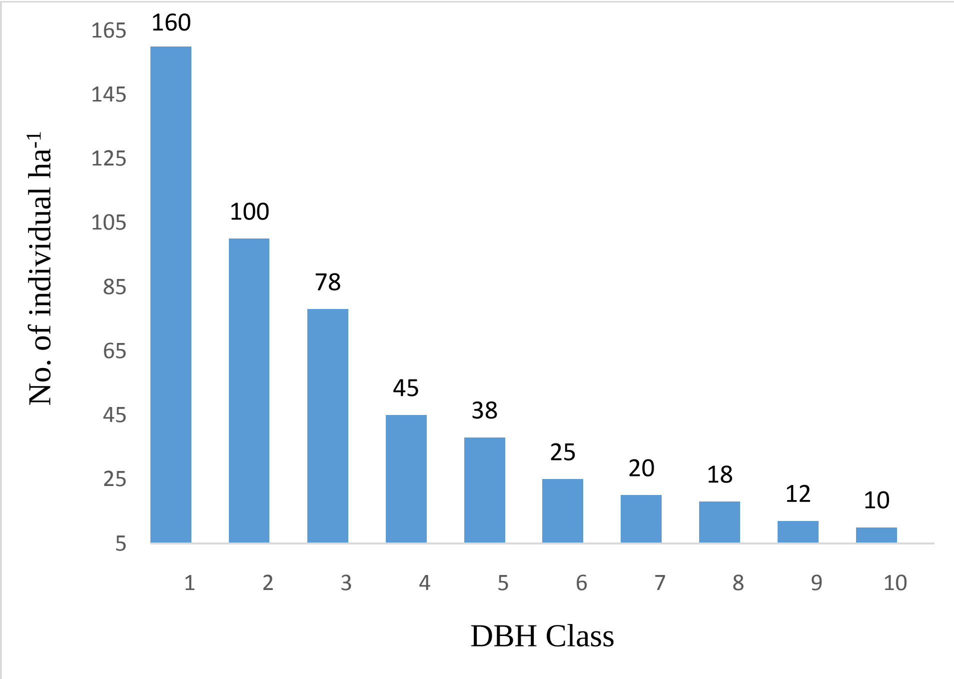

Figure 1. The diameter distribution of Kpatawee rainforest

3.3 Basal Area

Basal area (BA) is an important parameter for measuring the relative importance of tree species in a forest compared to stem counts (Mendez-Toribio et al., 2016). Hence, plant species with a larger basal area in a forest are considered to be the most important species in that forest. The sum total BA of tree species with DBH ≥ 5 cm was 16.39 m^2 ha^{-1}. In this particular study, eight species contributed 93% of the BA. However, according to Mi et al. (2012), the normal basal area of virgin tropical forest in Africa is 23–37 m^2 ha^{-1}.The low basal area (BA) in this study results from a combination of factors, including the composition of tree species with smaller basal areas, historical disturbances like logging, variations in growth rates and tree age, sampling methods, and environmental conditions within the study forest. These factors collectively contribute to a reduced basal area compared to reference data from other regions by Mi et al. (2012), highlighting the complex dynamics influencing forest ecosystems.

Dicorynia guianesis was the most important tree species in the forest, with a BA of 8.6 m^2 ha^{-1} which is about 44.15%. The second most important tree species was *Lecythis idatmon,* with a BA of 3.4 m^2 ha^{-1} which is 18.46%. Other plant species, such as *Pouteria guianensis*, *Ceiba pentandra,Couma guianensis,* and *Bocoa prouacensis,* had BAs of 0.403, 0.351, 0.294, and 0.204 m^2 ha^{-1}, respectively. This is due to the presence of relatively larger DBH-sized tree species in the study area (Table 1). On the other hand, *Licania heteromorpha* contributed the least amount of BA, about 0.001 m^2 ha^{-1} to the Kpatawee rainforest.

3.4 Forest Structure

In this study, tree species structure was determined considering their density at various DBH classes. As a result, species population patterns were determined as an inverted J-shape. This indicated that in the first class, there was a large number of individuals in lower DBH classes, with a gradual decreasing trend toward higher DBH classes. A few species, including *Dicorynia guianesis,* have shown this pattern, which suggests good recruitment and regeneration. A similar pattern was reported by Hu et al*.* (2018): 17 species at Gara-Ades and 18 species at Menagesha forests. The second pattern shows that individuals are more prevalent in lower DBH classes and less prevalent in intermediate and higher DBH classes (Figure 1).

Some species, such as *Quararibea asterolepis,* and *Castilla elastica,* were in this category. This pattern indicated heavy human pressure on higher DBH classes, leading to a scarcity of mature individuals that can serve as seed sources. The third pattern revealed the presence of a large number of individuals in the lower and higher DBH classes and the absence of individuals at the intermediate DBH classes. Some species, such as *Dicorynia guianesis* and *Lecythis idatmon,* have shown this pattern. Similar results were reported by Rai et al*.* (2012),who did a study on the effects of the environment on species richness and composition of vascular plants in Manaslu conservation area and Sagarmatha region of Nepalese Himalaya, and his results were in agreement with the second and third population patterns. The fourth pattern depicted the presence of a large number of individuals in the intermediate DBH classes and a small number of individuals in the lower and higher DBH classes. A few species, including *Tabebuia rosea,* exhibited this pattern. This pattern shows hampered regeneration, which could be attributed to poor recruitment coupled with selective cutting of individuals in the higher DBH classes.

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 (m2)	RD (%)
1	*Abies alba mill*	Pinaceae	35.03	0.096	0.046
2	*Abies nordmannian*	Pinaceae	25.48	0.051	0.087
3	*Acer opalus mill*	Sapindaceae	25.48	0.051	0.087
4	*Acioa guianensis*	Chrysobalana	9.55	0.007	0.62
5	*Aniba terminails duke*	Lauraceae	27.07	0.058	0.077
6	*Bocoa prouacensis*	Leguminosae	50.96	0.204	0.022
7	*Calophyllum tacanbhaca*	Clusiaceae	3.82	0.001	3.875
8	*Canarium album*	Burseraceae	12.74	0.013	0.349
9	*Carya ovata mill*	Juglandaceae	19.11	0.029	0.155
10	*Castanea sativa*	Fagaceae	19.11	0.029	0.155
11	*Castilla elastica*	Moraceae	1.59	0.029	22.32
12	*Ceiba pentandra*	Malvaceae	66.88	0.351	0.013
13	*Celtis australis l.*	Cannabaceae	44.59	0.156	0.028
14	*Coffee arabica l.*	Rubiaceae	19.11	0	0.155
15	*Couepia bracteosa*	Chrysobalana	27.07	0.058	0.077
16	*Couepia guianesis*	Chrysobalanaceae	15.92	0.02	0.223
17	*Couma guianensis*	Apocynaceae	61.15	0.294	0.015
18	*Cupania hirsuta*	Sapidaceae	36.62	0.105	0.042
19	*Dacryodes nitens*	Burseraceae	36.62	0.105	0.042
20	*Dicorynia guianesis*	Leguminosae	332.8	8.694	0.001
21	*Diospyrus vestita*	Ebenaceae	11.15	0.01	0.456
22	*Douglas fir*	Pinaceae	15.92	0.02	0.223
23	*Ecclinusa guianensis*	Sapotaceae	7.96	0.005	0.893
24	*Elephantopus madrium*	Lauraceae	25.48	0.051	0.087
25	*Eperna falcata*	Leguminosae	4.78	0.002	2.48
26	*Eperua falcata*	Leguminosae	20.7	0.034	0.132

27	*Eschweilera decolarans*	Lecythidaceae	23.89	0.045	0.099
28	*Fagus sylvatica l.*	Fagaceae	15.92	0.02	0.223
29	*Fraxinus americena l.*	Oleaceae	17.52	0.024	0.184
30	*Garcinia benthamiana*	Clusiaceae	4.78	0.002	2.48
31	*Guapira eggersiana*	Nyctaginaceae	25.48	0.051	0.087
32	*Gustavia hexapetala*	Lecythidaceae	12.74	0.013	0.349
33	*Hasseltia floribumda*	Nyristicaceae	2.55	0.001	8.719
34	*Hasseltia floribunda*	Salicaceae	3.18	0.001	5.58
35	*Humiriastrun subcrenatum*	Humiriaceae	27.07	0.058	0.077
36	*Hymenaca courbaril l.*	Leguminosae	47.77	0.179	0.025
37	*Hymenacea courbaril l.*	Leguminosae	6.37	0.003	1.395
38	*Hymenaceae courbaril*	Leguminosae	15.92	0.02	0.223
39	*Iramyan therasagotiana*	Myristicaceae	9.55	0.007	0.62
40	*Iryanthera sagotiana*	Myristicaceae	3.18	0.001	5.58
41	*Irynathera sagotiana*	Myristicaceae	14.33	0.016	0.276
42	*Juglans nigra*	Juglandaceae	11.15	0.01	0.456
43	*Lecythis idatmon*	Lecythidaceae	208.6	3.416	0.001
44	*Licania bernoulli*	Chrysobalana	3.18	0.001	5.58
45	*Licania heteromorpha*	Chrysobalanaceae	49.36	0.191	0.023
46	*Licania laxiflora*	Chrysobalana	41.4	0.135	0.033
47	*Licania nicranthia*	Chrysobalana	35.03	0.096	0.046
48	*Macrolobium bifolium*	Leguminosae	38.22	0.115	0.039
49	*Maquira guianensis*	Moraceae	4.78	0.002	2.48
50	*Morella cerifera*	Myricaceae	19.11	0.029	0.155
51	*Moronobea coccinea*	Clusiaceae	9.55	0.007	0.62
52	*Octrosia grandiflora*	Apocynaceae	19.11	0.029	0.155
53	*Ormosia nelanocarpa*	Leguminosae	25.48	0.051	0.087
54	*Oxandra asbecki*	Annonaceae	6.37	0.003	1.395
55	*Picea abies*	Pinaceae	46.18	0.167	0.027
56	*Platymicium trinitatis*	Legumimosae	7.96	0.005	0.893
57	*Platyniscium trinitatis*	Legumisosae	4.78	0.002	2.48
58	*Pourouma villosa*	Urticaceae	9.55	0.007	0.62
59	*Pourouna villosa*	Urticaceae	15.92	0.02	0.223
60	*Pouteria brachyandra*	Sapotaceae	36.62	0.105	0.042
61	*Pouteria guianensis*	Sapotaceae	71.66	0.403	0.011
62	*Pradosia cochlearia*	Sapotaceae	44.59	0.156	0.028
63	*Pradosia ptychandra*	Sapotaceae	27.07	0.058	0.077
64	*Protium denerarense*	Burseraceae	42.99	0.145	0.031
65	*Protium sagotianum*	Burseraceae	7.96	0.005	0.893
66	*Protium subserratun*	Burserraceae	15.92	0.02	0.223
67	*Quararibea asterolepis*	Malvaceae	1.59	0	22.32
68	*Quercus iley*	Fagaceae	7.96	0.005	0.893
69	*Salix caprea l.*	Salicaceae	14.33	0.016	0.276

70	*Sandwithia caprea l.*	Salicaceae	19.11	0.029	0.155
71	*Sandwithia guyanensis*	Euphorbiaceae	19.11	0.029	0.155
72	*Simarouba amara*	Simaroubaceae	25.48	0.051	0.087
73	*Siparuna decipiens*	Siparunaceae	25.48	0.051	0.087
74	*Tabebuia rosea*	Bignoniaceae	9.55	0.007	0.62
75	*Terminalia catappa l.*	Conbretaceae	19.11	0.029	0.155
76	*Thyrsodium guianensis*	Anacardiaceae	31.85	0.08	0.056

4. CONCLUSION

In this particular study, we explored the structure and species composition of the Kpatawee 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 76 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.

AUTHORS' CONTRIBUTIONS

All authors involved in the design of the study, performed the statistical analysis, wrote the protocol, and wrote the manuscript. All authors read and approved the final manuscript.

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