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Floristic Composition and Structure of Bimbia-Bonadikombo Community Forest, South West Region, Cameroon

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Abstract

Purpose: This study was conducted to assess forest structure and floral diversity in Bimbia-Bonadikombo Community Forest (Hereafter BBCF) after over two decades of conservation efforts. Three land use types were identified in BBCF. These include Primary Forest (PF), Secondary Forest (SF) and Agroforestry (AF).

Materials and Methods: Three line transects of 1 km long each were established in each of the land use types and plots of 20 X 20 meters were established at 100 meters' intervals alternately along each transect. A total of 90 plots were established and each live tree (≥ 5 cm DBH) was measured at 1.3 m and recorded.

Findings: A total of 1600 individual trees were identified belonging to 110 species and 36 families. The first three abundant families were Myristicaceae with 240 individuals (15%), followed by Fabaceae and Urticaceae with 183 (11.44%) and 143 (08.94%) individuals respectively. Families with highest number of tree species were Ebenaceae and Fabaceae with 8 species each. The most abundant species was *Musanga cecropioides.* Shannon diversity index (H') was highest in the PF (H' = 3.77) and least in AF (H' = 3.44). There was a significant relationship (X^2 = 1.801**;** p = 0.000) between trees DBH and land use types.

Implications to Theory, Practice and Policy: The 1994 forestry law of Cameroon (part III, section 34) guides creation of community forests with the responsibility of local communities to ensure protection of biodiversity and improve local livelihoods through forest management committees. Our study revealed that forest composition and structure of BBCF has been negatively affected due to unsustainable exploitation of resources by fringe communities. It is therefore recommended that to ensure significant forest reconstitution, appropriate conservation measures should be reinforced by BBCF management committee.

Keywords: *Cameroon, Diversity, Land Use, Tree Species, Tropical Rainforest*

1.0 INTRODUCTION

Tropical rainforests are generally recognized for their rich biodiversity, socio-economic importance, the ecosystem services they provide as well as their potential in buffering the impacts of climate change (Clark *et al.*, 2005). Also, they are a constant source of goods and services for most forest border communities who depend on the forests for their livelihoods (Acheampong *et al*., 2019; Hermans-Neumann *et al*., 2016). Over the last few decades, the rate of global forest loss has increased tremendously (FAO, 2012) while the amount of forest cover continues to decrease. The conversion of natural ecosystems to modified landscapes like agricultural lands is the major cause of species loss in many tropical forests (Dudley, 2005; Fahrig, 2013). Africa is presently experiencing the highest rate of deforestation globally; and it is estimated that 3.9 million hectares of forests are being cleared annually between 2010 and 2020, twice the global rate (FAO, 2020). Tropical lowland rainforests are undergoing enormous destruction due to human activities which have led to the dwindling of the tropical rainforest cover (Gogoi and Sahoo, 2018). Tropical forests are expected to experience even more pressures in the future principally due to agricultural expansion (Tilman *et al*., 2001; Dobrovolski *et al*., 2011) and also because the forestry sector represents a major source of income in developing countries (Sabogal *et al*., 2008; FAO, 2016, 2020, World Bank, 2021).

The lowland forest region of Cameroon is presently under enormous pressure from logging and commercial agriculture especially for cash crops like oil palms, cocoa and banana (Tchoumbou *et al*., 2020). The conversion of natural forests to modified landscapes produces different mosaics of habitats including farmlands, agroforests, old growth remnants, logged forests, secondary forests and tree plantations (Chezdon, 2014). This leads to the loss and fragmentation of natural forest habitats into smaller patches with negative effects on biodiversity (Laurance *et al*., 2014; Taubert *et al*., 2018). Although tropical rainforests continue to face anthropogenic disturbances, they are still rated high in terms of species richness and biodiversity compared to other terrestrial ecosystems (Gogoi and Sahoo, 2018).

Being the only remnant of lowland tropical rainforest along the Douala-Limbe coastline (Nuesiri, 2008), BBCF is host to abundant biodiversity amongst which are varied plant species. However, over the last two decades, BBCF has undergone some level of modification from human activities like artisanal logging, charcoal exploitation and opening of farms thereby altering habitat structure and species diversity. Hence, three habitat types can be clearly distinguished: primary forest, secondary forest and agroforestry. Anthropogenic disturbances cause habitat destruction leading to variation in plant species diversity among communities (Whitmore, 1984; Mligo, 2011). Disturbance is an ecological force that affects both the structure and functioning of tropical rainforests. Several studies assessing biodiversity and forest structure have been carried out in many parts of Cameroon but left out certain regions despite their richness in plant diversity (Ndenacho, 2005). Although some studies have been carried in BBCF like estimation of carbon stock (e.g. Longonje *et al.*, 2018), data on forest structure and species diversity was still to be documented. Thus the following research questions were raised:

What is the floral composition in BBCF?

How is the vegetation structure?

And finally what is the tree species diversity in BBCF?

It is from this premise that this study was carried out with specific objectives which were to:

i. Assess floral composition;

ii. Evaluate vegetation structure and;
iii. Ascertain tree species diversity in BBCF.

2.0 MATERIALS AND METHODS

Description of the Study Area

BBCF is found in Fako Division, South West Region of Cameroon. It is a coastal lowland tropical rainforest located between 3°58' N and 9°14' E. It covers a total surface area of 3,735 hectares. Climatically, there are two distinct seasons. The rainy season from March to November with August being the wettest month and the dry season from December to February. Annual rainfall ranges between 4000 and 5000 mm. Humidity in the area is usually between 75 – 80 % (Longonje *et al.*, 2018). The average annual temperatures range between 22 and 33°C (Fraser *et al.*, 1998). The relief slopes gently from the north at a maximum altitude of 540 m *asl* to the lowest point of 132 m *asl* southwards near the coast of the Atlantic Ocean. Four prominent rivers drain the area. The Bamukong and Mukuta Rivers that flow from north to east into the Atlantic Ocean. The Elephants and Jamstone Rivers flow southwards into the Atlantic Ocean.

The area has a high diversity of plant species amongst which are *Pterocarpus soyauxii, Lophira alata, Homalium longistylum, Coerocaryon preussii, Ceiba pentandra, Piptadeniastrum Africana*, etc. There also exist non-timber forest species like *Gnetum Africana, Piper guinensis, Irvingia garbonensis*, and *Ricinodendron heudelotii*. The loss of vegetation which is of a common occurrence has negatively affected large mammals like Drills and Chimpanzees which were said to have been almost extinct. Also present are animals like Brush-tailed porcupine, Bay duikers, Antelope, Squirrels, Alligators, Iguanas, Gabon vipers, Mona monkeys (*Circopithacus mona*) amongst others, although they are facing a lot of anthropogenic pressure (Nuesiri, 2008). However, BBCF is also a haven for numerous species of butterflies, bats and birds

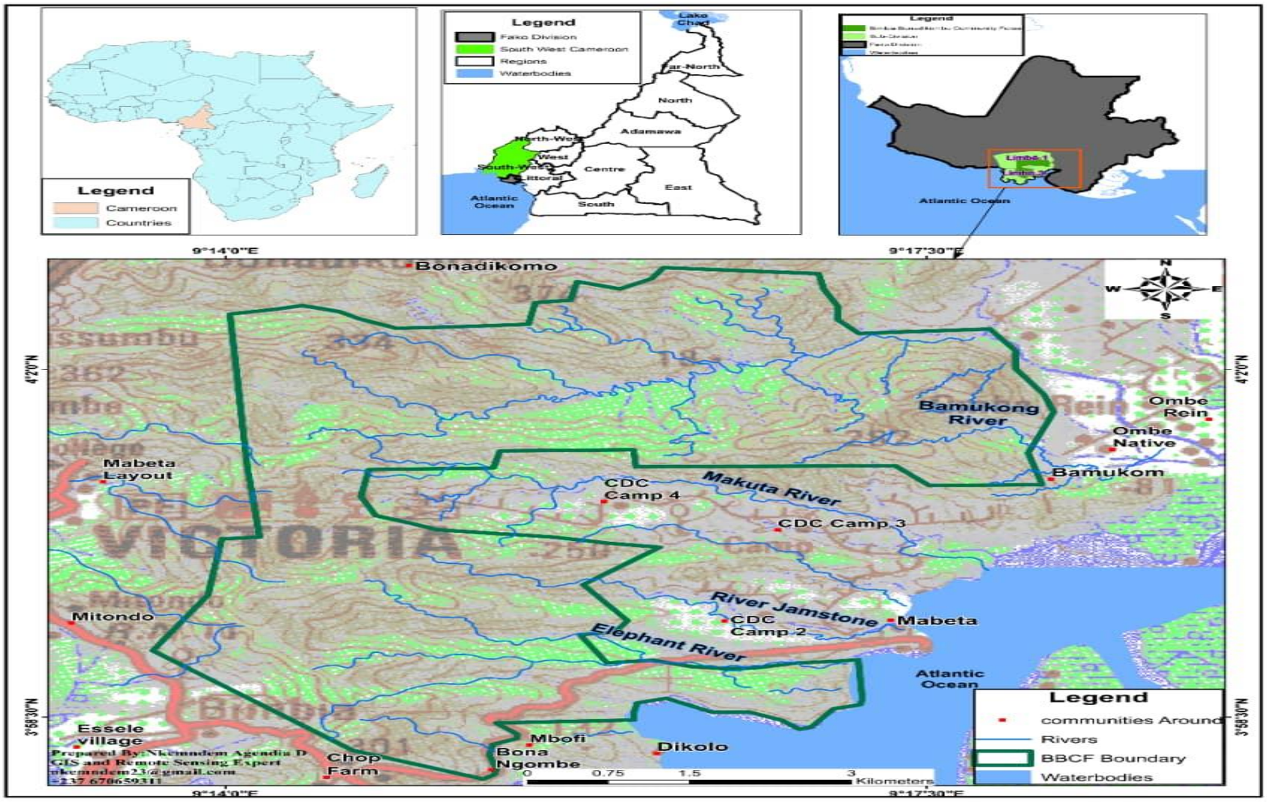

Figure 1: Map of the Study Area

Source: Adapted from US Geological Survey (UGS)

Botanical Inventory

Three transects of 1 km long each were established in each of the three habitat types of the study area using a 50-metres fiberglass tape. A compass bearing was used to ensure that transects were straight. Plots of 20 X 20 meters were established at 100 meters intervals alternately along each transect (Thomas *et al.,* 2003). Wooden stakes of 1.5 meters tall with ribbons were used to demarcate each plot. A total of 10 plots were created along each transect. In all, there were 90 plots created making up 3.6 ha. GPS coordinates were taken at start and end of each transect. GPS Garmin 60CSx was used which is very accurate in the forest, cheaper and works adequately under forest canopy (Condit, 2008). The trees were identified using standard botanical principles which are a combination of characters such as the general form of the tree (buttresses, roots systems, bark texture; slash colour, smell and exudates, leaf type and shape) as well as the flowers, and fruits of the trees. Species of vascular plants were recorded in each plot along the transects. Manuals and field books on tropical plants were used to help in the identification of the trees as in Thomas *et al.,* (2003).

Tree Measurement

Each live tree (≥ 5 cm DBH) was measured at 1.3 m in height using a stick (1.3 m long) placed against the trunk and the diameter gotten with the aid of a diameter metal tape. Where the ground was slopping, measurements were done on the upper side of the trunk. Multiple stems larger than or equal to 5 cm DBH at 1.3 m were measured individually. The data was recorded in data sheets. Trees with swollen stems at 1.3m were measured above the swelling while measurements for those with buttresses were taken at least 50 cm above the buttresses (Thomas *et al.*, 2003). The heights of trees were measured using the hypsometer (Vitax) and also by estimation i. e. average estimates of all field researchers (Zeh *et al*., 2019).

Data Analyses

Data was collected for three months from May to August 2022. Data from field data sheets was input into Microsoft Excel 2010 and later imported in to the statistical package R 4.1.2 software which was used in performing various statistical tests. PAST 3.0 software was used to compute biodiversity indices. Shannon diversity index (H') and Simpson's index of diversity (1-D) were used to do measures of species diversity since they have been shown to be more representative of diversity in larger areas.

Diversity indices were calculated using the standard equations. We applied the Shannon diversity index as a measure of species abundance and richness to quantify diversity of the tree species. This index takes both species abundance and species richness into account:

$$\mathrm{H}' = -\sum_{i=1}^{s} Pi \ln Pi$$

where s equals the number of species and pi equals the ratio of individuals of species i divided by all individuals N of all species. The Shannon diversity index ranges typically from 1.5 to 3.5 and rarely reaches 4.5 (Gaines *et al*., 1999).

We have also considered the Simpson index (D), a measure of species dominance. The Simpson index is defined as:

$$D = \sum_{i=1}^{s} ni\,(\mathrm{n}i - 1)/\mathrm{N}(\mathrm{N} - 1)$$

where ni is the number of individuals in the ith species and N equals the total number of individuals. As biodiversity increases, the Simpson index decreases. Therefore to get a clear picture of species dominance, we used $D' = 1 - D$.

Initially, the Shapiro-Wilk tests were carried out to check the normality of the distribution of data on botanical inventory recorded during the study period. The Kruskal–Wallis tests followed by the multiple comparison rank test of Mann-Whitney pairwise tests were performed to verify significant differences in trees' DBH and height among land use types. Chi-Square tests were done to determine the significance of the relationship between tree's metrics (DBH and height) and land use types.

For ecological measurements, vegetation data was analyzed using standards relevant for the different ecological parameters which include relative abundance, basal area, relative density, relative frequency and relative dominance.

Basal area (m^2) = $\Pi(½\ \mathrm{DHB})^2$

Density = Total number of individual species in all plots / total number of plots studied

Relative density = Total number of individual species / total number of all species x 100

Relative abundance = number of individual tree species / total number of trees x 100

Relative frequency = frequency of a species / frequency of all species

3.0 FINDINGS

Species Composition and Richness

A total number of 1600 individual trees were identified and measured (DBH and Height), all belonging to 110 species and 36 families. The first three families of tree species with the highest abundance were Myristicaceae with 240 individuals (15%), followed by Fabaceae and Urticaceae with 183 (11.44%) and 143 (08.94%) individuals respectively, contributing primarily to the floristic composition of the canopy: many of their species were emergent or large canopy trees that accounted for much of the basal area recorded in the plots. The families with the least abundance were Arecaceae and Myrtaceae with only 1 individual each followed by Bignoniaceae and Polygalaceae with 2 individuals each (Figure 2).

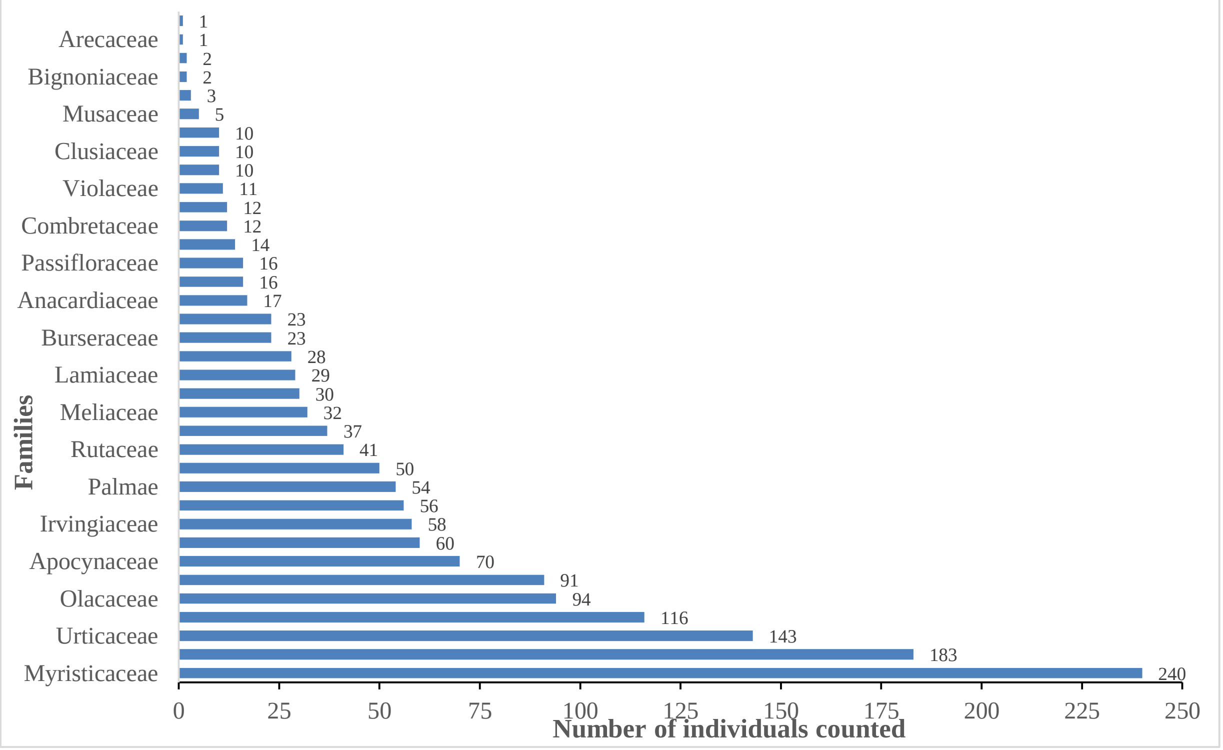

Figure 2: Abundance of Individuals Trees Per Family

The families that had the highest number of tree species were Ebenaceae and Fabaceae with 8 species each, followed by Moraceae with 7 species. The families Malvaceae, Moraceae and Olacaceae had 6 tree species each. The following families had the least number with only 1 species each: Arecaceae, Asteraceae, Bigniniaceae, Burseraceae, Combretaceae, Hypericaceae, Icacinaceae, Musaceae, Myrtaceae, Ochnaceae, Passifloraceae, Polygalaceae, Rutaceae and Salicaceae (Figure 3).

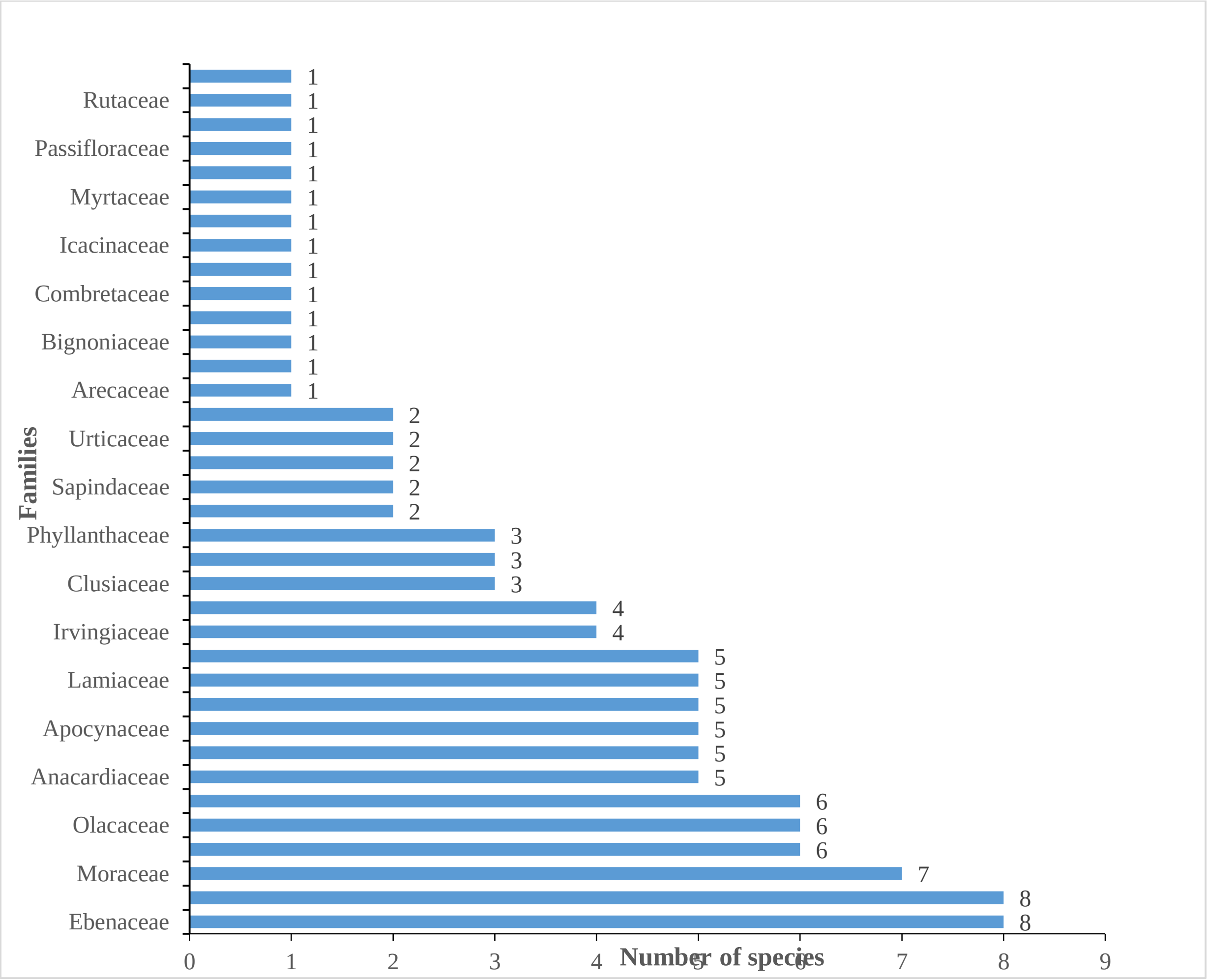

Figure 3: Tree Species Richness Per Family

Out of the 1600 individuals of tree species measured in the study area, 908 (56.75%) were found in the primary forest. This was followed by the secondary (regenerating) forest with 433 individuals (27.06) and agroforestry with 259 (16.19%) (Figure 4)

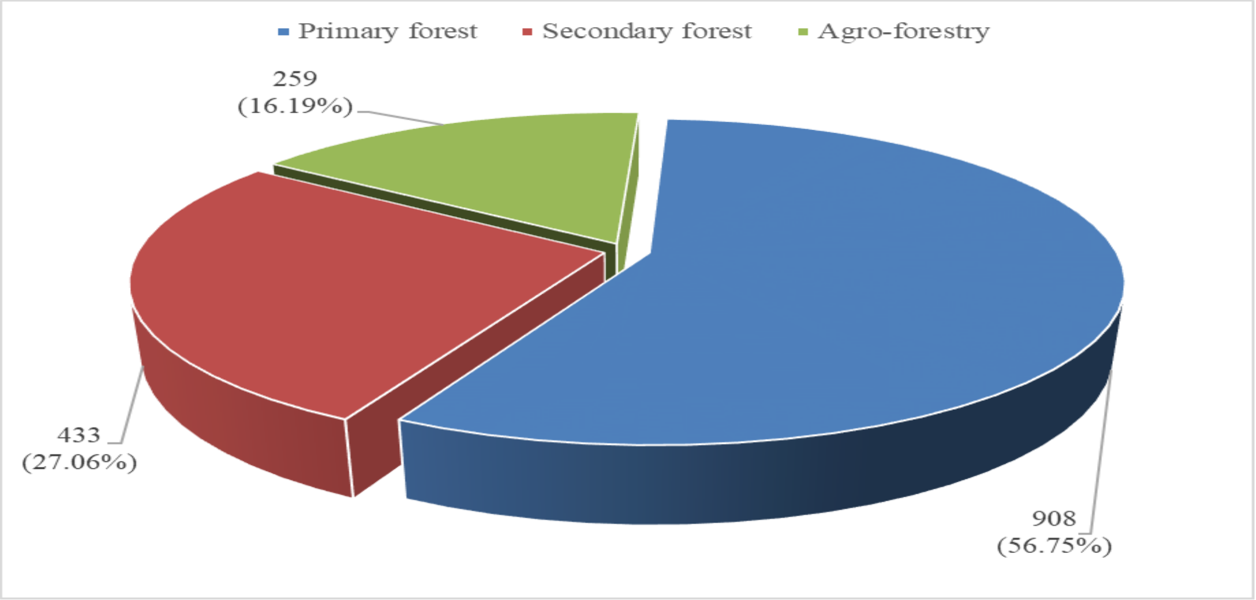

Figure 4: Total Number of Trees Measured Per Land Use Type

Out of a total of 110 species and 36 families recorded in the study area, the primary forest had the highest number of tree species (91) that belonged to 34 families. There were 57 species in the secondary forest that belonged to 28 families while the least number of tree species (49) that were distributed to 26 families were found in the agro-forestry land use type (Figure 5).

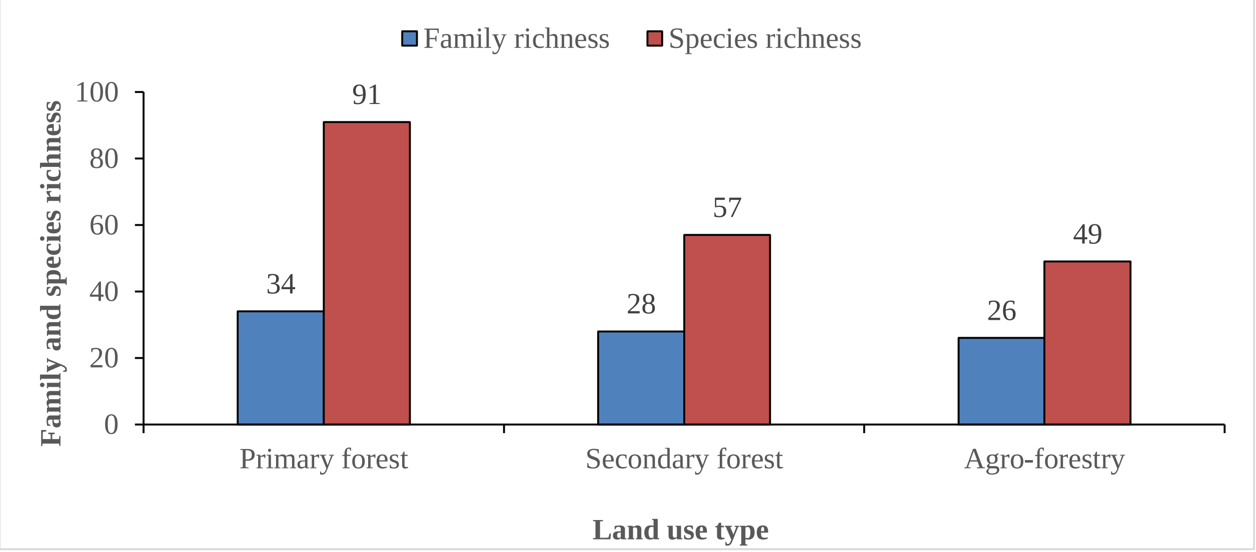

Figure 5: Families and Tree Species Richness Per Land Use Type

Figure 6 shows that in the primary forest, the first three families in terms of abundance of individual tree species were Myristicaceae, Urticaceae and Euphobiaceae with 142, 111, and 77 tree individuals respectiviely. For the secondary forest, Myristicaceae, Fabaceae and Moraceae families had 69, 55 and 41 tree individuals in the order. In the agro-forestry habitat type, they were Fabaceae, Myristicaeae and Phyllanthaceae with 56, 29 and 18 tree individauls respectively. Myrtaceae was the only family with just 1 tree individual in the primary forest. In the secondary forest, the families with the least abundance of just 1 tree individual each were Arecaceae, Clusiaceae, Ebenaceae and Sapidaceae. Families in the agro-forestry land use type with the least abundance of only 1 tree individual each were Anarcadiaceae, Clusiaceae, Ebenaceae, Icacinaceae, Melastomataceae and Sapotaceae.

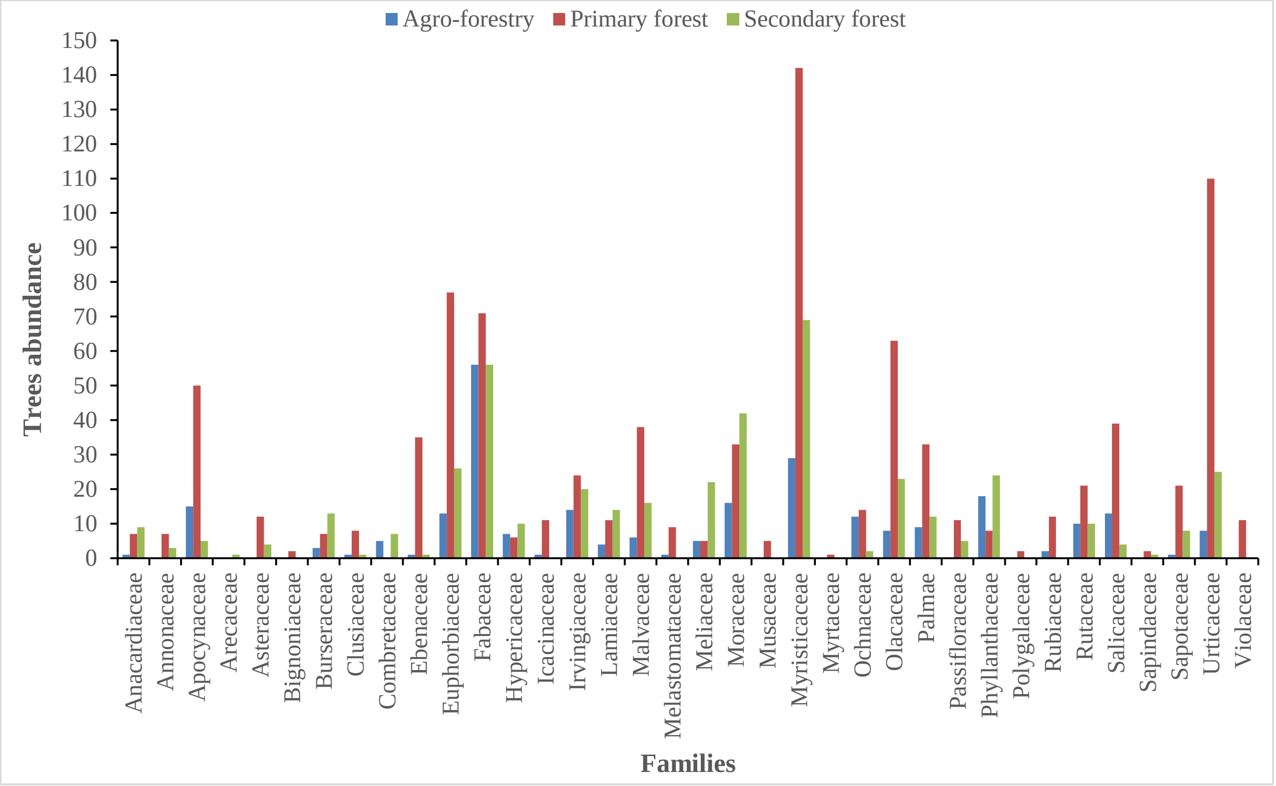

Figure 6: Abundance of Trees in Each Family Per Land Use Type

The most dominant species in the primary forest was *Musanga cecropioides*, followed by *Coelocaryon preussii* and *Strombosia pustulata* with 109, 82 and 45 individual tree species respectively. In the secondary forest, the 1st, 2nd and 3rd dominant tree species were *Coelocaryon preussii, Ficus mucuso* and *Musanga cecropioides* with 40, 27 and 20 individual tree species respectively. In the agro-forestry land use type, *Albizia zygia*, *Hylodendron gabunense* and *Coelocaryon preussii* were the first three dominant species with 26, 21 and 18 individuals of tree species respectively (Table 1). Four tree species which were dominant in all three land use types with varied abundances were *Coelocaryon preussii*, *Hylodendron gabunense*, *Zanthoxylum gilletii* and *Albizia zygia*. Ten plant species were dominant in more than one land use type. They were *Musanga cecropioides, Strombosia pustulata, Homalium longistylum, Macaranga monandra*, *Pycnanthus angolensis, Elaeis guineensis*, *Ficus mucuso, Lophira alata, Scyphacephalium mannii* and *Bridelia micrantha.*

Table 1: Summary List of the First Five Dominant Species in Each Land Use Type with Their Total and Relative (%) Abundances Given in Bracket; Dominant Species Here Are Those with Total Abundance Greater Than or Equal to 10 Individuals Per Land Use Type

Dominant species (total and relative abundances)		
Primary forest	**Secondary forest**	**Agro-forestry**
Musanga cecropioides (109; 12%) *Coelocaryon preussii* (82; 9.03%) *Strombosia pustulata* (45; 4.96%) *Funtumia elastica* (39; 4.30%) *Homalium longistylum* (39; 4.30%)	*Coelocaryon preussii* (40; 9.24%) *Ficus mucuso* (27; 6.24%) *Musanga cecropioides* (25; 5.77%) *Strombosia pustulata* (20; 4.62%) *Albizia zygia* (16; 3.70%)	*Albizia zygia* (26; 10.04%) *Hylodendron gabunense* (21; 8.11%) *Coelocaryon preussii* (18; 6.95%) *Bridelia micrantha* (16; 6.18%) *Homalium longistylum* (13; 5.02%)

NB: Red colour stands for cosmopolitan species which are abundant in all the land use types, while green colour for frequent species abundant in at least two land use types.

Table 2 shows diversity of tree species in the study area. The highest value of Shannon's Index (H') on diversity of tree species was recorded in the primary forest (3.767) while the secondary forest and the agro-forestry had 3.616 and 3.441 (least) respectively. On the other hand, the secondary forest had the highest evenness of 0.641, followed by agro-forestry with 0.624 and primary forest with 0.471. Mean tree DBH was highest in the agro-forestry (31.05), secondary forest second (26.13) and lowest in the primary forest (22.94). Trees density (individuals per hectare) was highest in the primary forest (757) followed by secondary forest (361) and least in the agro-forestry (216). Equitability was highest in the SF and least PF while dominance was highest in the AF land use (0.043) though very slight difference compared to PF. There was a wide disparity in tree stand basal area as that of the primary forest was more than double (96.950) those of the secondary forest and the agro-forestry with values of 40.355 and 36.151 respectively.

Table 2: Tree Species Diversity Across the Different Land Use Types

Trees Metrics	Primary forest	Secondary forest	Agro-forestry
Surface area (ha)	1.2	1.2	1.2
Total abundance of trees	908	433	259
Number of tree Species	91	57	49
Trees density (ind./ha)	757	361	216
Shannon's Index (H')	3.767	3.616	3.441
Evenness (E)	0.471	0.641	0.624
Pielou's Equitability (J)	0.833	0.891	0.879
Dominance index (D)	0.041	0.035	0.043
Simpson's Index of diversity (1-D)	0.961	0.965	0.957
Mean diameter of trees (DBH)	22.94	26.13	31.05
Stand basal area- G (m^2)	96.950	40.355	36.151
Lorey's mean height (H)	28.344	25.864	28.894

Structure

The distribution of plants according to DBH classes in Table 3 shows that DBH class [11-20 cm] was the most represented with 522 individuals followed by the classes ≤10 cm, [21-30 cm] and [31-40 cm] with 383, 349 and 216 individuals respectively. The Chi-Square test revealed that there was a significant relationship (X^2 = 1.801; p = 0.000) between trees DBH and land use types.

Table 3: Descriptive Statistics of Tree Species According to DBH Classes and Land Use Types

DBH classes (cm)	Primary forest	Secondary forest	Agro-forestry	Total	Chi-square tests
≤10	298	61	24	**383**	X^2 = 1.801 p-value = 0.000
[11-20]	309	130	83	**522**	
[21-30]	146	148	55	**349**	
[31-40]	82	74	60	**216**	
[41-50]	33	12	19	**64**	
[51-60]	10	1	5	**16**	
[61-70]	5	0	5	**10**	
[71-80]	5	0	3	**8**	
>80	20	7	5	**32**	
Total	**908**	**433**	**259**	**1600**	

The distribution of tree species according to height classes (Table 4) shows that height class [6-10 m] was the most represented with 589 individuals followed by the classes [11-15 m], ≤10 m, [16-20 m] and [21-25 m] with 297, 297, 225 and 112 individuals respectively. The Chi-Square test revealed that there was a significant relationship (X^2 = 1.084; p = 0.000) between trees height and land use types.

Table 4: Descriptive Statistics of Tree Species According to Height Classes and Land Use Types

Height classes (m)	Primary forest	Secondary forest	Agro-forestry	Total	Chi-square tests
≤5	210	70	17	**297**	X^2 = 1.084 p-value = 0.000
[6-10]	335	166	88	**589**	
[11-15]	144	108	45	**297**	
[16-20]	98	66	61	**225**	
[21-25]	72	14	26	**112**	
[26-30]	24	4	14	**42**	
[31-35]	18	0	4	**22**	
[36-40]	6	3	4	**13**	
>40	1	2	0	**3**	
Total	**908**	**433**	**259**	**1600**	

Trees DBH ranged between 5 and 350 cm with mean values of 22.94±28.89 cm, 26.13±22.48 cm and 31.05±28.59 cm for primary forest, secondary forest and agro-forestry, respectively (Table 4). Concerning trees height, values recorded during the study period ranged from 2 to 77 m with the highest mean value (14.76±7.98 m SE) being observed in agro-forestry land use type. In primary and secondary forest, trees height mean values were respectively 11.68±8.15 m and 11.58±10.61 m. The non-parametric Kruskal-Wallis test showed that there were significant differences (H= 118.28; p = 0.000) and (H= 46.77; p = 0.000) of trees DBH and height with respect to land use types respectively (Table 5).

Table 5: Descriptive Statistics on Trees DBH and Height

Trees Metrics	Land Use Type	Mean	Std. Deviation	Minimum	Maximum	Kruskal-Wallis Test (H)
Trees DBH (cm)	Primary forest	22.94	28.89	5	350	H = 118.28
	Secondary forest	26.13	22.48	5	280	
	Agro-forestry	31.05	28.59	5	250	p = 0.000
Trees Height (m)	Primary forest	11.68	8.15	2	77	H = 46.77
	Secondary forest	11.58	10.61	2	45	
	Agro-forestry	14.76	7.98	3	40	p = 0.000

Discussion

Myristicaceae, Fabaceae, Urticaceae, and Euphorbiaceae were the most abundant families in the study area. Ebenaceae and Fabaceae were the most dominant families with 8 species each. This result is similar with those of most authors who have worked in the Guineo – Congolian Region who showed that Fabaceae was the most dominant family in primary forests (Latouzey, 1968). This also corroborates with Lebrun (1936) whose study revealed that the vegetation of the Korup forest was dominated by Fabaceae. It was also reported same of Fabaceae being the most dominant plant family in the Kimbi-Fungom National Park, in the North West Region of Cameroon (Zeh *et al.*, 2019). This confirmed the fact that Fabaceae is always amongst the three most dominant families in the world. It is considered the third largest family of angiosperms in terms of species after Asteraceae and Orchidaceae in the global context (Beech *et al*., 2017; Azani *et al.*, 2017). Fabaceae has been reported to always be among the three most abundant families in the Amazon both in old and recent forest fragments, as well as various types of forests (Rankin-de-Merona *et al*., 1992). However, Myristicaceae being the most abundant family (with *Musanga cecropioides* being the most abundant species) is very often associated with secondary vegetation. This is partly due to the fact that gaps created by selective artisanal logging and charcoal exploitation are currently undergoing reconstitution. Tchoumbou *et al*., (2020) reported that the lowland forest region of Cameroon is currently under severe pressure from logging and commercial agriculture (mainly cash crops like oil palms, banana, rubber, and cocoa). This is what BBCF has been experiencing in some parts for the past two decades resulting to its fragmentation and degradation. Forest fragmentation results in three noticeable changes: reduced forest area, increased isolation among fragments and creation of edges where forest adjoins non-forested habitats (Sekerçioglu, 2006).

Different species expressed their dominance in the three sites. The PF was dominated by *Musanga cecropioides*. Though a pioneer colonizer it can also be abundant in swamp forest and riversides (Orwa *et al.*, 2009). This species was thus luxuriant in quasi-monospecific stands in the southern part of the PF which is constantly inundated during high tides in the rainy season (especially from July to October) by the Atlantic Ocean as well as the Elephant and Jamstone Rivers. *Coelocaryon preussii* was dominant in the SF and was also the first species amongst four others which occurred in all the three land use types. Gonmadje *et al*., (2011) also reported of highest dominance of *C. preussii* in Ngovayang's lowland forests in Cameroon. *Albizia zygia* was dominant in the AF land use type which confirms its ecological adaptation of being a pioneer light demanding species common in coastal lowland rainforest and can grow up to 30 m tall with a spreading crown (Orwa *et al.*, 2009). The species has thus been retained in the farms where it provides shade and for future use in the construction of houses.

Forest communities considered rich are characterized by a Shannon diversity value of about 3.5 or higher (Kent and Coker, 1992). In this study, the Primary and Secondary forests out of the three sites had Shannon-Weiner index values greater than 3.5 (table 2). BBCF can therefore be considered rich in plant species. All tropical forests have many rare species, which generally present high risk of at least local extinction (Kenfack *et al*., 2006). A progressive reduction in species richness and diversity in the present study is indicative of anthropogenic disturbances which are in the form of farming, tree felling for charcoal, building and roofing of houses. Similar results were reported by Esther *et al*., (2014) in Kakamega forest in western Kenya and Eshaghi *et al*., (2018) in an oak forest in Iran. Evenness (E) varied between land use types with the highest value recorded in the Secondary forest and the least in the Primary forest (table 2). Similar results were recorded by Mounmemi *et al*., (2023) in eastern Cameroon. This could be due to more forest gaps in the secondary forest allowing more light to reach the forest floor, thus promoting growth of light-demanding secondary forest species.

DBH class of 11 – 20 cm had the highest number of tree species in the study area which was characteristic of tropical forest vegetation. These results corroborate with those of Newberry and Gartlan (1996) in the Korup forest of Cameroon. This indicates a high number of small trees and a higher contribution of shrub species which developed small circumferences. There were fewer trees which belonged in DBH classes of 60 cm and above. Similar results were recorded by Zeh *et al*., (2019). This may be attributed to continuous degradation of the forests due to dominance and falling of bigger trees in addition to other factors like decrease in soil nutrients that limited the sustainability of tree species (Saunders *et al.*, 1991). Contrarily, Ngueguim *et al*., (2017) suggested that the higher number of tree species recorded in the DBH classes of less than 30 cm was an indication of vigorous regeneration, while the presence of large trees with high DBH values revealed that the forest was an old one.

The trend in the distribution of tree species according to DBH classes was slightly different in the three land use types. These result agree with those of Mounmemi *et al*., (2023). This may be due to anthropogenic activities of the communities around the forest. There was a significant relationship (X^2=1.801, p=0.000) between trees DBH and land use types (table 3). Tree diameters are commonly thought to be indicative of the ages of trees; hence trees with small diameters are younger while larger diameters indicate older trees (Hall, 1991). This may be the reason for the decrease in the number of trees in the DBH class of greater than or equal to 80 cm ($\geq$ 80 cm) from primary forest to the agroforestry land use type. Anthropogenic activities like artisanal logging and charcoal production are some of the causes of this trend in the distribution of trees in DBH classes in BBCF. The highest mean DBH (31.05 ± 28.59) was recorded in the agroforestry land use type. Similar results were recorded by Gogoi and Sahoo (2018). This was probably due to the fact that some of the species like *Irvingia gabonensis*, *Terminalia superba, Ceiba pentandra* and *Ricinodendron heudelotti* which had large DBH values (> 250 cm) had been retained for their economic values.

The highest number of trees (526) in the study area belonged to the height class of 6 – 10 m. The number of trees in their respective height classes varied in the different land use types. There was thus a significant relationship (X^2=1.084, p=0.000) between tree heights and land use types (table 4). This may be attributed to the extraction of some of these tree species like *Terminalia superba, Aningeria robusta, Piptadeniastrum africana*, *Albizia zygia,* etc. for use in roofing of buildings and other for the production of charcoal e.g. *Lophira alata*, *Homalium longistylum*, etc. There were significant differences (H = 118.28; p = 0.000) and (H = 46.77; p = 0.000) in trees DBH and height with respect to land use types respectively (table 5). The increase in the intensity of disturbance from primary forest to agroforestry land use type may be the cause for the gradual decrease in basal area from the primary forest to the agroforestry land use type (Singh and Singh, 1992). Tree density (individuals hectare^{-1}) also decreased from primary forest (D= 757 individuals hectare^{-1}) to agroforestry (D = 216 individuals hectare^{-1}). This result agrees with Momo *et al.*, (2016) who reported of a decrease in tree density from primary to secondary tropical forests of Mount Oku, Cameroon. Previous studies in tropical forests have also reported on the negative effects of forest loss and habitat fragmentation on plant biodiversity especially late-successional, shade tolerant and zoochoric tree species (Rocha-Santos *et al.*, 2017). Changes in floral composition and vegetation structure are the most noticeable changes in tropical rainforests because edges become dominated by ruderal and light-demanding pioneer species (Gascon *et al.*, 2000; Tabarelli *et al.*, 2008).

4.0 CONCLUSION AND RECOMMENDATIONS

Conclusion

Disturbance is an ecological force that affects both the structure and functioning of tropical rainforests (Gogoi and Sahoo, 2018). Anthropogenic disturbances cause habitat destruction leading to variation in plant species diversity among communities (Whitmore, 1984; Mligo, 2011). BBCF has been modified due to the activities of the surrounding villages resulting to three distinct land use types: primary forest, secondary forest and agroforestry. Despite the fact that most tropical forest ecosystems have been modified by human activities, they still continue to provide conducive habitat for the rainforest biodiversity (Whitworth *et al.*, 2016). Botanical inventory revealed a total of 1600 individual trees which were identified and measured (DBH and Height), all belonging to 110 species and 36 families. Myristicaceae, Fabaceae, Urticaceae, and Euphorbiaceae were the most abundant families in the study area. Ebenaceae and Fabaceae were the most dominant families with 8 species each. The most abundant species was *Musanga cecropioides*. The Primary Forest had the highest tree species diversity (H' = 3.767), followed by Secondary Forest, and Agroforestry with values of 3.616 and 3.441 respectively (table 5). Hence, diversity of plant species in BBCF was high in the Primary and Secondary forests sites since according to Kent and Coker (1992), forest communities considered rich in tree species are characterized by Shannon diversity index values of about 3.5 or higher. Tree density (individuals hectare^{-1}) decreased from Primary Forest (D= 757 individuals hectare^{-1}) to Agroforestry (D = 216 individuals hectare^{-1}). The vegetation structure of BBCF had been modified due to human disturbances.

Recommendations

The study revealed the state of floral composition and vegetation structure in the lone lowland tropical rainforest along the Douala – Limbe coastline. The conversion of natural forests to modified landscapes produces different mosaics of habitats including farmlands, agroforests, old growth remnants, logged forests, secondary forests and tree plantations (Chezdon, 2014). BBCF has been modified to three distinct land use types: Primary forest, Secondary forest and Agroforestry due to human disturbances. The 1994 forestry law of Cameroon which guides the creation of community forests to protect biodiversity and improve on the livelihoods of indigenous populations puts the responsibility of the sustainable management of these forests in the hands of local communities through the community forest management committee put in place by the supervisory Ministry of Forestry and Wildlife. The management committee of BBCF seems not to have done enough in her responsibility of ensuring the sustainable exploitation of forest resources. This was evident from the unsustainable activities like artisanal logging and charcoal exploitation of some targeted tree species and opening of farms. This has resulted to differences in tree species diversity between the land use types. Being a protected area, there is need to redress this trend of activities in BBCF. It is therefore recommended that the management committee of BBCF should embark on campaigns for raising awareness of local communities living in neighbourhoods of the forest on the importance of sustainable exploitation of forest resources. Also, strict control measures should be reinforced to stop wanton cutting of trees and agricultural activities. There should also be reforestation in the forest gaps with diverse indigenous key species to enhance regeneration of the forest. Although tropical rainforests continue to face anthropogenic disturbances, they are still rated high in terms of species richness and biodiversity compared to other terrestrial ecosystems (Gogoi and Sahoo, 2018).

Conflict of Interests

The authors have not declared any conflict of interests.

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