GSC Advanced Research and Reviews

eISSN: 2582-4597 CODEN (USA): GARRC2

Cross Ref DOI: 10.30574/gscarr

Journal homepage: https://gsconlinepress.com/journals/gscarr/

(Research Article)

Check for updates

The flora diversity and carbon stock of a disturbed tropical coastal National Park in the Littoral Region of Cameroon

Seraphine Ebenye Mokake [1, *], Elvis Njoh Mumu[1], Brenda Leaticia Nana Djomou [1], Jean Njoh Essombe [2], Michael Lyonga Ngoh [3], Jacques-Bruno Ngotta-Biyon [1] and Ndongo Din [1]

[1] *University of Douala, Faculty of Science, Department of Plant Biology, P.O Box 24157, Douala, Cameroon.*

[2] *Ministry of Forestry and Wildlife. P.O Box 34430, Cameroon.*

[3] *Tropical Plant Exploration Group (TROPEG), P.O Box 18 Mundemba, Cameroon.*

GSC Advanced Research and Reviews, 2026, 27(01), 062-083

Publication history: Received on 27 January 2026; revised on 16 March 2026; accepted on 19 March 2026

Article DOI: https://doi.org/10.30574/gscarr.2026.27.1.0063

Abstract

In Cameroon, forest ecosystems are undergoing degradation due to anthropogenic activities, thus the need to raise awareness and contribute to the conservation of its biodiversity. This study aimed to assess the flora diversity and carbon stock of a disturbed coastal tropical forest in the Douala-Edda National Park. Data was collected after delimitation, enumeration of the plots which made it possible to have an inventory of trees ≥ 2 cm in diameter. The study was carried out on three sites of different levels of disturbance of one hectare each: the Highly Disturbed Forests (HDF), Medium Disturbed Forests (MDF) and Low Disturbed Forests (LDF). Each hectare was divided into 25 quadrats of 20× 20 m and further to 400 subquadrate of 5 × 5 m to determine the composition, structure and the Carbon stock. There were 4,696 individuals classified into 160 species including 41 genera belonging to 86 families. The most important species were: *Klainedoxa gabonensis* Pierre. (27.19%) in the HDF; *Baphia capparidifolia* Baker. [41.36%] in the MDF; and *Mitragyna stipulosa* (DC.) Kuntze (41.05%) in the LDF. The most important families were: Oleaceae for HDF and Fabaceae for MDF and LDF. The Fischer α index indicated that the HDF was more diversified and the LDF was weakly diversified. Basal area was highest in the HDF and least in the MDF. The structure of these sites showed an inverted J curve. The above and below-ground biomasses were higher in the HDF and least in the MDF, but the reverse was true for the soil carbon stock. The litter carbon stock was almost equal to that of the Above ground biomass. The total carbon stock across all sites was estimated at 8,76 TC/ha of Carbon. The present results thus indicate the importance of forest management in maintaining and restoring plant cover in Coastal ecosystems.

Keywords: Above Ground; Abundance; Anthropogenic; Conservation; Douala-Edea National Park

1. Introduction

Forests cover almost a third of the world's land surface, that is 4.06 billion hectares, which corresponds to 31% of the total land area [1] and provide goods and services that enable us to meet a large proportion of our needs (energy, medicines and recreation) including air, rich soil, food, habitats for animals and people [2]. By virtue of the way they are populated and the diversity of the ecosystem services they provide to both mankind and the environment, forests are an essential asset in maintaining global equilibrium. It therefore requires knowledge, and coordination to manage them appropriately to ensure their viability and sustainability. However, many definitions are given by many organizations about forests, making existing data mixed and uncertain [3,4].

* Corresponding author: Seraphine Ebenye Mokake

One contemporary use of forest is its mitigation measures in climate change through its Carbon stock. In nature, forest ecosystems are the major terrestrial reservoirs of carbon in the form of plant biomass and soil organic matter [5,6] and are thus among the locally and globally recognized sources or sinks of carbon in the remaining or regenerating forests [7-9]. Also, it has been proposed that biodiversity plays an important role in ecosystem function, particularly in productivity [10] as several studies have found positive relationships between biodiversity and productivity, measured through biomass [11], and this relationship has been explained as a function of the complimentary between plant life strategies and use of resources [12,13]. Biomass is one of the most used predictors of productivity because it represents the stocks of organic matter in forests, and its quantification and monitoring are relevant to establish strategies against climate change [14]. Although tropical forest ecosystems typically persist on strongly weathered nutrient-poor soils, they comprise high species richness of over 50% of terrestrial biodiversity [15,16] and store large amounts of carbon in the form of carbon sequestration in trees from the atmosphere via plant carbon metabolism [17]. Knowledge of the terrestrial biodiversity and forest cover would depend on the composition and structure of the forests. Composition refers to the biodiversity of an ecological system, including the variety of genes, species, communities, and ecosystems, while structure refers to the physical arrangement of various physical and biological components of an ecological system. Thus, knowledge on the floristic diversity and Carbon stock of a tropical forest will provide information on the state of tropical coastal forest in the Congo basin.

The Congo basin tropical forests ecosystems in Central Africa also plays an important role in the global carbon cycle, especially in carbon sequestration [18]. Cameroon has the fourth most important forest reserves in the Congo Basin after the Democratic Republic of Congo, Gabon and Congo with a considerable diversity of flora and fauna [19]. This carbon results from global warming and is partly linked to anthropogenic activities such as loss in forest cover [2,20]. Environmental problems are further compounded by the fact that most of the knowledge on the ecology and diversity of the Congo Basin is descriptive and dated [21], furthermore large areas remain unexplored [21-23]. This lack of knowledge precludes proactive management, as it is impossible to predict the environmental impacts of development with any form of reliability [24]. Despite the size of the surface area of Cameroon's forest (19.09 million hectares , 40% of the country's territory and 11% of the Congo Basin's forests) [25,26], the richness of their biodiversity, forests are undergoing progressive destruction due to anthropogenic activities like population growth and agricultural expansion [27], which in Cameroon is estimated at a net deforestation rate of 0.14% and a net degradation rate of 0.01% [28], to support the increasing demands of global populations [29]. It has therefore become very imperative to assess the in situ biodiversity such as to better understand its natural regeneration [15] to continuously provide for its ecosystem goods and services.

Disturbance is considered as a factor affecting plant community structure, distribution, composition and functionality of most tropical forests [30,31]. Human disturbance on vegetation is nowadays an important concern in biodiversity conservation and current global change [32,33]. The loss of carbon is based on the fact that disturbances affect the structure of forests including the type, size, age, species stand and species diversity, the parameters, which are directly associated in the storage of carbon in forest ecosystems [34-36]. The effects of this disturbance could lead to high levels of species rarity [37,38], high occurrence of invasive species [39], and ecosystem loss of habitat fragmentation [40]. Moreover, human disturbance could completely change the species composition of the original plant communities, which in some cases can become irreversible [41,42].

Deforestation is due to several direct and indirect causes [19,43,44]; one of which the direct causes is urban growth [19]. This destroys natural areas [45] and is a major source of greenhouse gas emissions [46]. It also contributes to the disruption of forest ecosystems, leading to the loss of significant carbon stocks and forest biodiversity [45,47] which is a key element in the global carbon cycle [48]. Human activities cause land cover and land use changes that pose challenges on the capacity of forests to regenerate, function, and offer various ecological services including the capacity to function as carbon sources and sinks [49-51]. However, there is little information about the amount of carbon in regenerating forest ecosystems along the tropical coastal forests [in this study referred to as tropical coastal forests]. Therefore, it is important to estimate carbon stocks of the species in order to understand their contribution in the global carbon stock and in addressing climate change [52].

To reduce deforestation by agricultural activities and to protect its biodiversity, the Douala-Edéa National Park was created in 2018 as part of the permanent domain of the national forests. This therefore requires a management plan for its functioning taking into consideration its diversity in flora and fauna. Basic information is required for the implementation of management plans in forests in general and Parks in particular which will ensure the sustainable use of the forest resources. For the preparation and revision of these management plans, appropriate knowledge of the resource is of utmost importance to understand how these ecosystems function in order to derive and implement management plans that succeed in maintaining crucial ecosystem processes under projected future scenarios, while concomitantly providing ecosystem functions, such as continuous extraction of food and timber under realistic socioeconomic pathways. The knowledge of the vegetation would help in understanding the effects of disturbance on the composition and dynamics of the forest community. The present study thus aimed at assessing the tree diversity, the Carbon stock and the conservation status across different disturbance types in the Douala-Edéa National Park, thus bridging the information gap on the effect of disturbance on a coastal tropical forest. Specifically, the objectives of this study were a) to describe the species diversity, composition, and structure of a disturbed coastal forest for a sustainable forest management; b) to determine the carbon stock of a coastal disturbed forests as a climate change mitigation measure; and c) to assess the conservation status of woody plant species under human activities.

2. Material and Methods

2.1. Description of the study site

The study was carried out in the Douala-Edda National Park [DENP], located between latitudes 3°14 and 3°50 N and longitudes 9°34 and 10°03 E in the Cameroon coastal plain, precisely in the Douala-Kribi Basin [53]. It is bounded to the north by the Wouri estuary, to the east by the Sanaga, Dipombé and Kwa Kwa rivers, to the south by the Nyong and to the west by the Atlantic Ocean, with which it shares a boundary of around 100 km between the mouth of the Nyong and the Wouri estuary. The climate is equatorial, with two seasons [54] and usually experience 2,000 mm of rainfall or more in a year [55]. It belongs to the Littoral Atlantic forest domain with a variety of floristic species such as *Lophira alata* Banks ex Garten., and *Saccoglottis gaboneseis* (Bail.) Urb., with characteristic mangrove species (*Rhizophora* sp. and *Avicenia* sp.), wetland species such as Euphorbiaceae but also many commercial species: *Pterocarpus soyauxii* Taub., *Afzelia africana* Sm. ex Pers., *Guibourtia tessmannii* (Harms) Léonard., Staudtia stipitata warb., Afzelia pachyloba Harms., Milicia excelsa (Welw.) Bureau., *Entandrophragma cylindricum* (Sprague) Sprague., and especially *Sacoglottis gabonensis* (Baill.) Urb., and *Lophira alata* Banks ex Gaertn [54]. The choice of sites was marked by the diversity of species, its broad geographical spectrum, various anthropogenic activities such as the collection of NTFPs and the establishment of agro-industrial companies such as the Société Camerounaise de Palmeraies (SOCAPALM) (Figure 1)

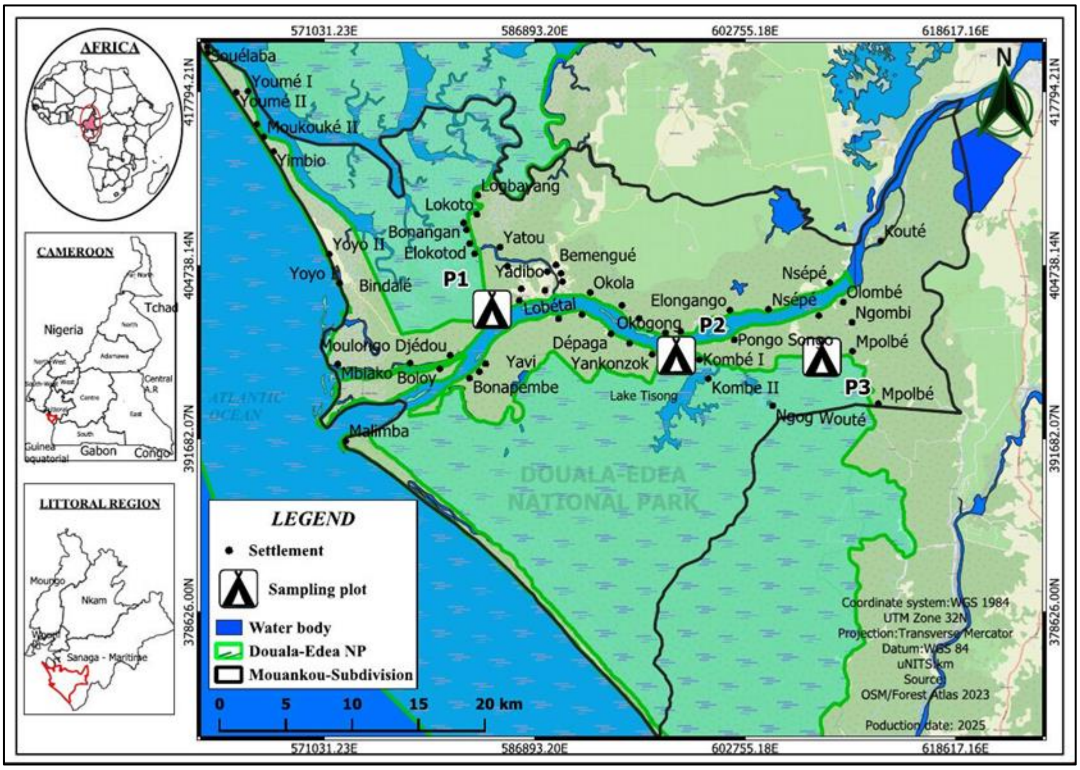

Figure 1 Map of the Douala-Edéa National Park (study site)

2.2. Establishment and demarcation of plots in the Douala-Edéa National Park

The study was carried out in three [3] sites of one [1] hectare each at different disturbance levels. These plots were located in two surrounding villages of Malimba and Yankonzok (Figure 1) and the delimitation of the plots for the inventory followed the standard protocols for permanent monitoring forest plots described by [56]. Each hectare was divided into 2, 100 × 100 m, subsequently into 25 plots or quadrats of 20 × 20 m and finally subquadrats of 5 × 5 m, giving a total of 400 quadrats (Figure 2).

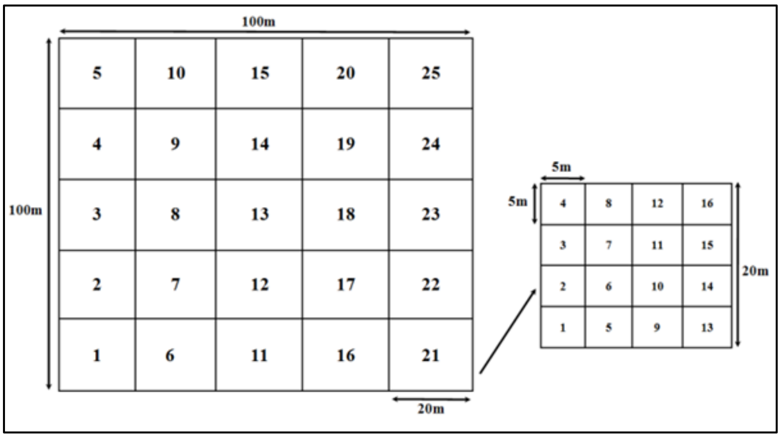

Figure 2 Demarcation of the study site of the Douala-Edéa National Park plots

2.3. Justification for the choice of sites

The sites were selected based on the tree species diversity and the level of disturbance found around the Douala-Edéa National Park. To this end, three [3] sites of one [1] hectare each indicating three levels of disturbance were maintained for our study:

- Highly Disturbed Forest (HDF): this forest is temporarily flooded at an altitude of about 12 m with slightly firm and sloping ground. It is located in the village of Malimba at the intersection of two unsealed roads and close to the local population, which is the reason for the increased and permanent anthropogenic activities (felling sites were observed and banana stems);
- Moderately Disturbed Forest (MDF): forest on sloping ground, partially flooded, at an altitude of around 16m with the bottom of the slope being inundated by water. It is located close to Lake Tissongo and far from the population, with natural tree fall on the ground;
- Low Disturbed Forest (LDF): forest with completely firm, almost level ground, at an average altitude of 13 m, close to the moderately disturbed forest. This site is far from the population and large-diameter dead wood is enormously present.

2.4. Enumeration

All tree species whose DBH was ≥2 cm were measured at 1.30 cm above the ground using a diameter tape measure for trees with a diameter ≥ 6 cm and a caliper for trees with a diameter ≤ 6 cm. To locate these species, X and Y coordinates were determined in each 5 x 5 cm subquadrate and pulled to the entire one-hectare plot. Trees with multiple stems ≥2 cm were taken into account i.e. a measurement was taken on each stem. Species identification was carried out by a villager to determine the common names and by a botanist for scientific or commercial names. Specimens (with or without flowers) were collected, pressed and dried, then matched with herbarium collections. Unidentified specimens were identified at the Yaoundé National Herbarium.

3. Data Analyses

3.1. Stand characteristics

3.1.1. Determination of the flora composition of the Douala-Edéa National Park (DENP)

To determine flora composition, species richness and absolute density [abundance] helped in the determination of other indices, such as the Important Value Index (IVI), and Family Important Value (FIV). The abundance of the species was determined as the total number of individuals of all the different species present in each plot [57]. Species richness (S) is the total number of species present in the population considered in a given ecosystem [58]. It is mainly expressed by the total number of species observed per unit area. The important Value Index (IVI) corresponds to the most important species according to[59]. It is calculated using the formula:

$$IVI = SRDe + SRDo + SRF \quad \text{......Eq1}$$

Where SRDe = Species Relative Density which is

$$RDe = \frac{\text{number of individuals of that species}}{\text{total number of individuals}} \text{ x } 100$$

SRDo= Species Relative Dominance which is

$$SRDo = \frac{\text{Basal area of that species}}{\text{total basal area}} \text{ x } 100$$

SRF= Species Relative Frequency which is

$$RF = \frac{\text{number of quadrats with that species}}{\text{total number of quadrats}} \text{ x}100$$

The Family Importance Value (FIV) corresponds to the most important family [60]. It is calculated by the formula:

$$FRDe + FRF + FRDo \quad \text{......Eq2}$$

Where FRDe = Family Relative Density which is

$$FRDe = \frac{\textit{Number of individuals of that family}}{\textit{total number of families}} \; x \; 100$$

FRDO = Family Relative Dominance which is

$$FRDo = \frac{\textit{Basal area of that family}}{\textit{total basal area}} \; x \; 100$$

FRF= Family Relative Frequency which is

$$FRF = \frac{\text{Number of quadrats with that family}}{\text{total number of quadrats}} \; x100$$

The species diversity was determined by the Fisher-alpha diversity and the Shannon diversity index. In calculating diversity only species that were identified to the species level were considered. Pielou's evenness for similarity was also calculated. Fisher's alpha diversity as described by [61] was determined as;

$$S = \alpha \times \ln(1+n/\alpha) \quad \text{......Eq3}$$

Where S is number of taxa, n is number of individuals and α is the Fisher's alpha.

Shannon diversity was determined as described by [62];

$$H = -1 \left(\sum pi * \ln pi\right) \quad \text{......Eq4}$$

Where pi is the proportion of individuals belonging to the i species in the dataset.

Species evenness was calculated using the Pielou's evenness index following the equation of [63];

$$J' = H/H'max \quad \text{......Eq5}$$

Where H is the observed shannon diversity and H'max is the maximum possible Shannon Index.

Determination of the floristic structure of the DENP

It was determined by the diameter size classes, density and basal area of a stand. Stems of a DBH range were grouped together in different diameter size classes for a better distribution of the species present at our different sites. These diameter size classes were distributed as follows: (<5 cm], [>5 - 10 cm], [>10 - 20 cm], [>20 - 30 cm], [>30 - 40 cm], [>40 - 50 cm], [>50 - 60 cm], [>60 - 70 cm], [>70 - 80 cm], [>80 cm]. The relative density [or otherwise known as density] corresponds to the number of individuals on a given surface area. Tree density was calculated by dividing the number of trees by the surface area of the sample. The basal area corresponds to the surface area of all the cross-sections of the trunks, at a height of 1.30 m, of the trees present in one hectare of forest. It is an excellent indicator of the weight of the stand. It depends on both the size and number of trees and is correlated with tree canopy cover, which makes it possible to quantify the degree of competition within the stand and the light conditions on the ground. It is expressed as:

$$BA= [\pi D^2]/4 \ldots\ldots\ldots\ldots Eq6$$

where: BA = basal area [m^2], D = diameter at breast height (cm) and π = pi (3.142).

3.2. Carbon stock assessment of the DENP

3.2.1. Estimation of the Above-ground Carbon Stock (ACS) of the DENP.

The diameters obtained during the floristic inventory were used to assess the above-ground biomass of the individuals surveyed. The allometric equation developed by [34] was used to assess above-ground biomass:

$$AGB = \rho s \times \exp[-1.499+ 2.148 \times \ln [DBH] + 0.207 X \ln (DBH)2 -0{,}0281 X \ln [DBH]3] \ldots\ldots Eq7$$

Where DBH= diameter at breast height in centimeter, ρs= specific wood density. For species without wood densities, an average for the genera or family was used.

The Above ground Carbon stocks (ACS) in aerial biomass was estimated according to [64] :

$$\text{Carbon stock} =0{,}47 \times AGB \ldots\ldots\ldots\ldots Eq8$$

3.2.2. Estimation of the Below-ground Carbon Stock (BCS) of the DENP

It makes up a significant proportion of the total forest above-ground biomass. This was calculated using the formulae of [65].

$$BGB = 0.21 \times AGB \ldots\ldots\ldots\ldots Eq9$$

Where AGB = above-ground biomass;

Carbon stocks in underground biomass were estimated according to [64] as follows:

$$\text{Below-ground Carbon stock (BCS)} =0.47 \times BGB \ldots\ldots\ldots\ldots Eq10$$

3.2.3. Estimation of the Litter Carbon stock [LCS] of the DENP

Litter which consisted of leaves, tree barks, branches and woody roots was collected from ten random 1 m × 1 m quadrats per plot and for all three plots. The litter samples were bulked for each plot. Each collected sample was labeled, weighed (W field) and transported to the University of Douala Plant Biology Laboratory. Samples were then weighed (W sub sample fresh) using a scale to obtain their masses and oven-dried at 105°C to constant weight (W sub sample dry). Litter dry weight was determined as described by [66].

$$\frac{Wfield}{A} = \frac{Wsubsample\,(dry)}{Wsubsample\,(fresh)} = \frac{1}{10000}$$

where LB is leaf litter biomass in (ha), W field is weight of wet field sample of litter sampled within an area of size 1 m2 in (g), A is size of the area in which litter was collected (ha), W sub-sample (dry) is weight of the oven-dry sub-sample of litter taken to the laboratory to determine moisture content (g), and Wsub-sample (fresh) is weight of the fresh sub-sample of litter taken to the laboratory. Carbon stocks in leaf litter biomass was computed as follows:

$$LCS = LB \times \%C \ldots\ldots\ldots\ldots Eq12$$

where LCS is Litter Carbon Stock in ton/ha, %C is carbon fraction determined in the laboratory.

3.2.4. Estimation of the Soil Organic Carbon [SOC] of the DENP

Soil sampling was determined according to [67]. Nine quadrats of 1 m × 1 m were randomly selected in all the 3 plots and cored soil samples carefully collected and placed in polythene bags at 0 - 10 cm, 10 - 20 cm and 20 - 30 cm, giving a total of 27 samples/plot. The soil samples of the different soil depths for the different plots were labeled, bulked together, and representative samples taken. The soil samples were air-dried to prevent oxidation and sieved using a 2 mm sieve in order to separate the fine and coarse materials. Soil samples were weighed (W1) using a scale balance and oven-dried at 105˚C for 2 days to get the dry weight (W2). The samples were ashed at 500˚C for 5 hours to get the percentage of Carbon (%C) present in the sample (W3). The Soil organic Carbon was determined by the formula:

$$SOC = d \times \%C\ (W3) \times BD \quad \text{……Eq13}$$

where d = depth of soil, W1 is the weight of soil sample before drying, W2 is the weight of soil sample after drying, %C = percentage of carbon (W3) and BD = bulk density (kg/ha).

To determine the bulk density, a soil corer was used to collect soil samples with a known volume. The fresh weight (W1) was determined by weighing scale and this was oven dried at 105˚C for 48 hours to have the dry weight (W2). This was later used to determine the bulk density of the soil.

$$BD = W2/V\ (g.cm\text{-}3) \quad \text{……Eq14}$$

3.2.5. Estimation of the total Carbon Stock of the DENP

It was estimated on the basis of the different carbon pools studied and evaluated as described in measuring and calculating carbon stocks:

$$C(plot) = ACS + BCS + LCS + SOC \quad \text{……Eq15}$$

3.2.6. Where

- C(plot)= total carbon content in the plot (tonnes/ha)
- ACS= total carbon content of above-ground biomass per hectare in the plot (tonnes/ha)
- BCS=total carbon content of underground biomass per hectare in the plot (tonnes/ha)
- LCS= total carbon content of the litter biomass per hectare in the plot (tonnes/ha)
- SOC= total soil carbon content per hectare in the plot (tonnes/ha)

3.3. Determination of the conservation status of the woody species In DENP

The conservation status of the plant biodiversity in the DENP forest was assessed by determining the commercially exploitable species according to [68] and using the conservation status of plant species of the International Union for Conservation of Nature (IUCN). The conservation status has been assigned to each plant species based on information from the global threat assessments provided by IUCN [69-71]. The tree species statuses were obtained through the online consultation of the Red List of Threatened Species published by[72]. The IUCN Red List categories used in this study are: Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD) and Not Evaluated (NE). Critically Endangered (CR), Endangered (EN) and Vulnerable (VU) species are those listed as threatened in the IUCN Red List of Threatened Species [72].

4. Results

4.1. Floristic composition of the DENP

The floristic inventory recorded a total of 4,696 individuals/ha, 160 species/ha belonging to 86 families/ha and 41 genera/ha. The HDF had more individuals (1,734 stems/ha) with a higher number of species (58/ha), families (31/ha) and genera (49/ha) than the LDF, which had the least abundance (1,469 stems/ha); families (23/ha) and genera (39/ha).

Table 1 Floristic composition of the Douala-Edéa National Park

Sites/level of disturbance	Plant absolute density (stems/ha)	Number Species/ha	Number of families/ha	Number of genera/ha
Highly (HDF)	**1734**	**58**	**31**	**49**
Moderate (MDF)	1493	54	30	48
Low (LDF)	1469	48	23	39
Total	4696			

The most important species in the Douala-Edéa National Park was *Baphia capparidifolia* Baker., (41.36%) and the least important was *Funtumia africana* (Benth.) Stapf (0.05%). The most important species for the different sites were: *Klainedoxa gabonensis* Pierre., (27.19%) for HDF, *Baphia capparidifolia* Baker., (41, 36%) for MDF and *Mitragyna stipulosa* (DC.) Kuntze., (41.05%) for LDF. The least important species were the genus *Funtumia africana* in the HDF (0.05%) and LDF (0.72%) and *Heisteria parvifolia* Smith., (0.72%) in the MDF (Table 2).

Table 2 The floral species Importance Value Index (IVI) in the Douala-Edéa National Park

Sites	Levels of importance	Species	Family	IVI (%)
HDF	More Less	*Klainedoxa gabonensis* *Funtumia africana*	Irvingiaceae Apocynaceae	27.19 0.05
MDF	More Less	*Baphia capparidifolia* *Heisteria parvifolia*	Fabaceae Olacaceae	41.36 0.72
LDF	More Less	*Mitragyna stipulosa* *Funtumia elastica*	Rubiaceae Apocynaceae	41.05 0.72

The most important family in the Douala-Edéa National Park was Fabaceae (114.22%) and the least important was Gentianaceae (1.48%). The most important families were the Olacaceae (46.56%) for HDF, and Fabaceae for MDF (72.99%) and LDF (114.22%) while the least important families were Gentianaceae (1.48%) for HDF, Olacaceae (1.65%) for MDF and Lamiaceae (1.88%) for LDF (Table 3).

Table 3 The Most Important Family (FIV) in the Douala-Edéa National Park

Sites	Levels of importance	Family	FIV (%)
HDF	More Less	Olacaceae Gentianaceae	46.56 1.48
MDF	More Less	Fabaceae Olacaceae	72.99 1.65
LDF	More Less	Fabaceae Lamiaceae	114.22 1.88

These results showed an average of 10.7 Fisher index, 3,14 Shannon-weaver index and 0.44 Pielou equitability. The HDF was the most diverse with a 3.30 Shannon-Weaver index and 0.47 equitability, whereas the LDF was the least diverse with 2.96 and 0.4 equitability, as shown in Table 4 and Figure 3.

4.2. Plant community structure of the Douala-Edéa National Park

Figure 4 below follows an inverted 'J' curve with more individuals in the ≤ 5cm diameter size class. There were less individuals in the diameter classes between 60-80 cm. However, at diameter classes >80 cm, there were more individuals present especially in the HDF.

Table 4 Diversity and similarity indices of the Douala-Edéa National Park

Sites	Fisher α index	Shannon-Weaver Index	Equitability of Piélou
HDF	11.56	3.30	0.47
MDF	10.98	3.17	0.44
LDF	9.58	2.96	0.40
Average	10.7	3.14	0.44

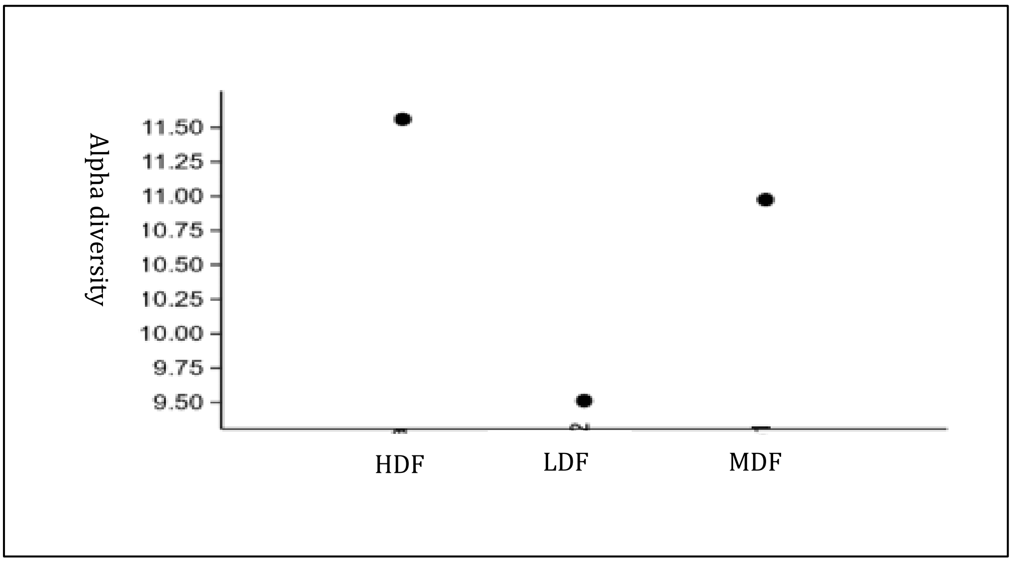

Figure 3 Species diversity of the Douala-Edéa National Park

The average basal area was 1.35±0.41 m^2/ha with 1565 individuals/ha in the Douala-Edéa National Park. The HDF contained more individuals (1734 individuals/ha) and had the highest basal area of 1.83 m^2/ha, whereas the MDF has the least density (1493 individuals/ha) and basal area (0.91 m^2/ha) (Table 5).

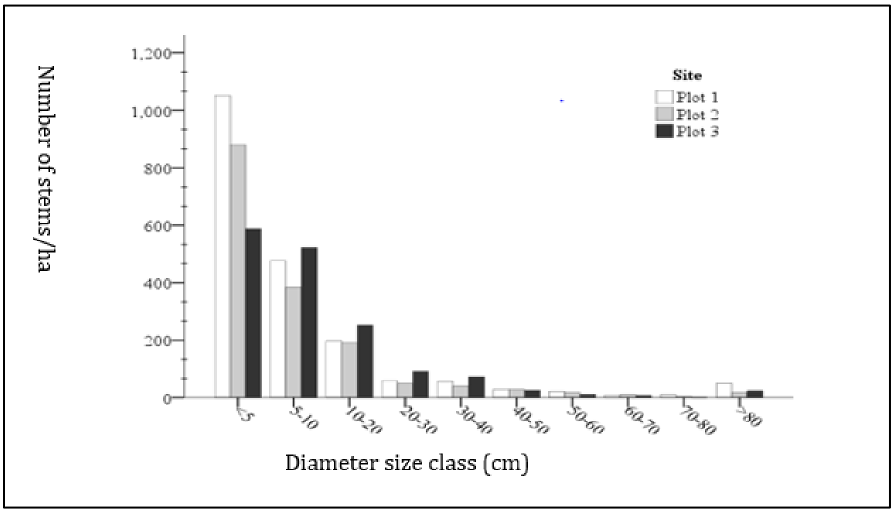

Figure 4 Distribution of stems in the Douala-Edéa National Park

Table 5 Proportion of the Basal area in the Douala-Edéa National Park

Sites	Number of individuals	Basal area (m^2/ha)
HDF	1734	1.83±0.45
MDF	1493	0.91±0.26
LDF	1469	1.32±0.51
Average	1565	1.35±0.41

4.3. Carbon stock of the Douala-Edéa National Park

4.3.1. Above-ground and Below-ground Carbon stocks

Above-ground biomass (AGB) and carbon stock were highly significant between the 3 sites ($P<0.05$). The results indicate an average AGB of 2.37±0.51 tC/ha and an average carbon stock of 1.17±0.25 t/ha. HDF had the highest above-ground biomass (4.39t/ha) and carbon stock (2.19 t/ha), while MDF had the lowest above-ground biomass (0.34t/ha) and carbon stock (0.17t/ha) (Table 6). On the other hand, the average below-ground biomass was 0.5±0.11 tC/ha and the average carbon stock was 0.22±0.04 t/ha. Similarly, HDF contains more below-ground biomass (0.92 t/ha) and carbon stock (0.43 t/ha), whereas MDF contains less: 0.07 tC/ha biomass and 0.003 tC/ha Carbon.

Table 6 Mean Above-ground, Below-ground biomass and Litter in the Douala-Edéa National Park

Sites	Above-ground biomass [t/ha]	Carbon stock (t/ha)	Below-ground biomass(t/ha)	Carbon Stock (t/ha)	Dry weight of litter (t/ha)	Carbon stock in litter (t/ha)
HDF	4.39±0.80	2.06±0.39	0.92±0.17	0.43±0.04	2.3±0.28	1.08±0.13
MDF	0.34±0.02	0.16±0.01	0.07±0.00	0.03±0.00	1.92±0.77	0.9±0.36
LDF	2.28±0.70	1.07±0.33	0.48±0.15	0.23±0.07	2.38±1.16	1.11±0.55
Average	2.37±0.51	1.11±0.24	0.5±0.11	0.22±0.04	2.2±0.74	1.03±0.35

4.3.2. Litter Carbon stock in the Douala-Edéa National Park

The average dry weight of the litter was 2,2±0.74 tC/ha and the average carbon stock was 1,03±0.35 tC/ha. The LDF contained more dry weight (2,38 t/ha) and carbon stock (1.11 tC/ha) while the MDF had the least (1.92 tC/ha) (Table 6).

4.3.3. Soil Carbon Stock in the Douala-Edéa National Park

The results indicated that the highest carbon was found in the soil of MDF (0.7 t/ha) and least in the soil of HDF (0.152 t/ha). Overall, the carbon stock increases with soil depth in the MDF and LDF, whereas in the HDF there is more carbon between 5-15 cm depth (0.33 t/ha) (Table 7).

4.3.4. Total Carbon Stock of the Douala-Edéa National Park

The total carbon stock was highest in the above ground Carbon stock (3.5 tC/ha) while the least was found in the Below ground carbon stock (0.7tC/ha) (Table 11). The total Carbon stock in the Douala-Edéa National Park was 8,76 tC/ha.

Table 7 Mean Carbon stock at the different soil depths in the Douala-Edéa National Park

Sites	Fresh weight of total sample (g)	fresh weight of sub-sample (g)	Ash soil sample (g)	Bulk density (g/cm^3)	Soil carbon stock (g/cm^3)	Soil carbon stock (tC/ha)
FTI						
0-5cm	263.7	134.4	10.0	0.9	45.0	0.05
5-15cm	216.9	155.2	21.1	1.04	329.2	0.33

15-30cm	225.8	158.0	2.6	1.06	82.68	0.08
Average	235.5	149.2	11.2	1.1	152.3	0.15
FPI						
0-5cm	208.7	193.0	35.3	1.29	227.7	0.23
5-15cm	218.8	192.5	35.3	1.29	683.1	0.68
15-30cm	242.0	211.0	28.2	1.42	1201.3	1.20
Average	223.2	198.8	3.9	1.33	704.0	0.70
FNI						
0-5cm	212.5	194.0	16.2	1.3	105.3	0.11
5-15cm	224.9	202.3	31.8	1.35	644.0	0.64
15-30cm	225.0	200.2	28.9	1.3	1127.1	1.13
Average	220.8	198.8	25.6	1.33	625.5	0.62

Table 8 Carbon stock of the Douala-Edéa National Park

Sites	**Above-ground Carbon stock (tC/ha)**	**Below-ground Carbon stock (tC/ha)**	**Soil Carbon stock (tC/ha)**	**Litter Carbon stock (tC/ha)**
HDF	2.19	0.43	0.15	1.08
MDF	0.17	0.003	0.70	0.90
LDF	1.14	0.23	0.62	1.11
TOTAL	3.50	0.70	1.47	3.09
Average	1.17	0.22	0.49	1.03

4.3.5. Total Carbon stock

The total carbon stock was calculated as follows

C(site) = C(AB) + C(BG) + C(Soil) +C(Litter)

=3,50 + 0,70 + 1,47 + 3,09 =8, 76 tC/ha

4.4. Conservation status of the woody species in DENP

4.4.1. Exploitable species

According to the list of 10 exploitable species in Cameroon, some tree species in the DENP are exploitable and commercial internationally [73]. In our different sites seven species were found: with 6 individuals in the HDF, 1 in the MDF and 3 in the LDF for a total of 10 individuals in our 3 sites (Table IV).

Table 9 Commercial and exploitable species in the Douala National Park-Edéa

	Common names	**Scientific names of species**	**Family**	**Presence of species by site**			
				HDF	MDF	LDF	Total
1	Dabema	*Piptadeniastrum africanum* [Hook.f.] Brenan	Fabaceae	1			1
2	Eveuss	*Klainedoxa gabonensis* Pierre.	Irvingiaceae	1			1

3	Frake	*Terminalia superba* Engl. et Diels.	Combretaceae	1		1	2
4	Iroko	*Milicia excelsa* (Welw.) C.C.Berg.	Moraceae	1		1	2
5	Kimba	*Ceiba pentandra* (L.) Gaertn.	Bombacaceae	1			1
6	Moabi blanc	*Baillonella toxisperma* Pierre.	Sapotaceae		1	1	2
7	Sapelli	*Entandrophragma cylindricum* (Sprague) Sprague.	Meliaceae	1			1
	TOTAL			6	1	3	10

Some species recorded in the Douala-Edéa National Park according to the red list of the International Union for Conservation of Nature (IUCN). In total there were 3 vulnerable species and 2 species of minor concern. There were in the great majority in the FTI (5 species); 2 species in the FPI and 2 species also in the FNI (Table V).

Table 10 Endangered species in Douala-Edéa National Park

No	Scientific names of species	Status	Presence of species by site			
			HDF	MDF	LDF	Total
1	*Annickia chlorantha* (Oliv.) Setten and Maas.	Least concern	1	1		2
2	*Baillonella toxisperma* Pierre.	Least concern	1	1	1	3
3	*Entandrophragma utile* (Dawe and Sprague) Sprague	Vulnerable	1			1
4	*Entandrophragma Cylindricum* (Sprague) Sprague	Vulnerable	1			1
5	*Ricinodendron heudelotii* (Baill.) Pierre ex Heckel	Vulnerable	1		1	2
Total			5	2	2	9

5. Discussion

5.1. Floristic composition of the Douala-Edéa National Park

The present study was carried out on 3 hectares in the Douala-Edéa National Park, and measurements were taken on all woody tree species with DBH ≥ 2 cm. The inventory of woody plants recorded a total of 4,696 individuals of 160 species belonging to 86 families and 41 genera. These results were similar to those of [74], who counted 4,717 individuals of 130 species belonging to 43 families and 110 genera with DBH ≥ 10 cm in the middle of the Biafran Rain Forest of Cameroon; [75] who had counted 10,205 individuals,103 species, 89 genera and 56 families of DBH ≥1 cm in the coastal line of the Douala-Edéa Wildlife Reserve; and [76] who counted 108 species, 37 families, 77 genera of DBH ≥10 cm in a humid semi-deciduous forest following anthropogenic disturbances and plant invasion in the Tinte Bepo Reserve in Ghana. The average densities of 1,545 individuals obtained in this study were quite low when compared to the mean values of 3,914, 3,068 and 3,600 stems/ha found in other understories of tropical rainforests reserves, by [77-79] respectively, indicating its level of disturbance as compared to these other undisturbed forests reserves stated above. This variation in recorded species number is best explained by the sampled area, the presence of fragmentation conditions caused by disturbance and the presence of communities of plants associated with different stages of secondary succession (e.g., pioneer species).

This high level of anthropogenic activities is the reason for the fact that the HDF had the highest plant density than in the others. This dynamics of forest regeneration and resilience after human disturbance, would favour the development of young individuals of different plant species in the understory. The high densities of small-diameter individuals (3–10 cm) indicates the renewal of seed-bearing trees and the replacement of cut down, felled or dead trees will be ensured in forest areas with farming activities. The HDF was closest to the population, which means that human activity is more frequent, as this will open up the canopy and allow light to enter easily and recurrently, enabling the germination of seeds in the soil seed bank. Also there might be an influx of seeds from neighboring primary forests, thus increasing the number of individuals. In fact, [80] indicated that when the ecosystem is more disturbed, the number of stems per hectare increases in a similar study in the East region of Cameroon. On the other hand, the other sites are close to lakes, restraining human intrusion thus reducing human activity in these areas. These results therefore highlight the human disturbance influence on plant communities' distribution and composition.

The IVI is a reliable measure to assess the relative importance of a species since it takes into account several properties of the species in the vegetation[59], thus highlighting the ecological importance of species and families. A species or family is ecologically dominant when its FIV or IVI > 10[81]. The most important species in the 3 sites were as follows: *Klainedoxa gabonensis* (27.19%) for HDF, *Baphia capparidifolia* (41.36%) for MDF and *Hallea stipulosa* (41.05%) for LDF. *Klainedoxa gabonensis* is a tree with seeds that germinate quickly and the tree is usually kept standing because of the hardness of its wood[82] which prevents the local population from exploiting it easily, which would explain why it is common in the most disturbed forest. *Baphia capparidifolia*, is a member of the Fabaceae family[83], which is widely distributed and found in almost all tribes, is characterized by its pod-like fruit and its large number of easily dispersed seeds[84]. The trees are often found in secondary tropical regions with non-climax character of forest areas with farmers' exploitation [85-87]. *Mitragyna stipulosa*, a species of the Rubiaceae family, found in marshes and wetlands, and requires a damp subsoil all year round, although not in swamps that are completely flooded twelve months out of the year. It is dominant in tropical forests and along lake shores. It is the wind that disperses a large quantity of seeds, causing dense seedlings to appear uncovered in the mud [82,88]. Padalia et al.[89] indicated that Euphorbiaceae and Rubiaceae were the most dominant families in all coastal forest types, except mangrove. The study sites were found around the lake Tisongo found in the Douala-Edéa National Park thus justifying the presence of the Rubiaceae. Similar studies were indicated by [90] who indicated that the Euphorbiaceae, Rubiaceae and Fabaceae were amongst the first 10 important families in the tropical deciduous forests of North Central Eastern Ghats, India. Kegne et al.[86] indicated that the Rubiaceae and the Fabaceae were amongst the eight most important species in the understory of the Essiengbot-Mbankoho rural tropical forests of Cameroon. The most important families at the various sites were: Olacaceae and Fabaceae. This result is similar to those obtained by [91] in the Dja reserve in Southern Cameroon; [86] in the two rural forests located in the Eastern and Southern agroforestry zones of Cameroon, which states that the tropical rainforest is mainly characterized by Fabaceae; [92] in the Lesio-louna protected forests in Southern Republic of Congo and [93] in a Protected Tropical Evergreen Forest of Belize.

The average Shannon index of 3.14 bits is similar to that of [78] with 3.56 bits in the Douala-Edéa National Park. The high Shannon value corresponds to environmental conditions favourable to the establishment of numerous species represented by a small number of individuals. This tendency towards high diversity associated with low density of each species is always observed in tropical forests [94,95]. The Piélou equitability index was 0.44 similar to that of [75] with 0.49 bits in the Douala-Edéa National Park. Sonke,[96] indicated that ecosystems that have reached a level of maturity have a high equitability between 0.6 and 0.8. This therefore means that these sites were not even and matured but rather disturbed by anthropogenic activities and thus most of the individuals inventoried belonged to just a few species. Spellerberg et al.[97] and Fedor et al.[98] indicated that an evenness index > 60% characterized an undisturbed ecosystem. The highest diversity in the HDF is similar to the results of[99] in forest communities in the Kouilou Département, Republic of Congo, who indicated that the highest diversity was closest to human infrastructure where the human pressure and disturbance was at its highest. This relationship could be interpreted in two ways:

- -Humans are selecting the most diverse plant communities for their activities or;
- -Human impacts are increasing plant diversity.

Previous reports of human impacts and disturbance on plant diversity in African rain forests have been contradictory. Von Gemerden et al.[100] reported a decrease in diversity after disturbance, whereas[101] reported that shifting cultivation could increase diversity on condition that the fields were small and embedded in a forest matrix. Cultivation lasted only a few years, remnant trees were preserved and fire was excluded. The present results support this hypothesis of an increase in diversity after disturbance. However, decrease in diversity usually occurs just immediately after the disturbance thus the long-term effects of disturbance should be taken into consideration.

5.2. Structure of the Douala-Edéa National Park

The stand structure of this park followed a reverse "J" curve, reflecting the presence of a tropical forest in full natural regeneration, since there were more young species with diameters < 10cm and the number of individuals decreased as the diameter increased. Djomo,[102], Mokake et al.[38], and Mokake et al.[42] indicated that when the ecosystem is more disturbed, the number of stems per hectare in the lower diameter size classes increases in a similar study in the East region of Cameroon. According to[103], the diversity and abundance of the small diameter trees suggest that the forest could have the ability to respond to disturbances in general. The same structure was observed by [104] in the Mondah natural forest and[105] in the Ituri province of the Democratic Republic of the Congo. According to[106], these curves are typical of tropical forests undergoing progressive dynamics. There were less individuals between the 60-

80cm diameter size class. This may be due to the illegal logging from the local population and tree fall activities which were greatly visible in the field. The increase in the number of trees in the >80cm may be due to certain tree individuals that are left in the forest as seed trees and most importantly due to the presence of trees species with hard wood like *Klainedoxa gabonensis* that is difficult to exploit by the local population due to lack of machines qualified to cut through the hardness of this wood and this result was most visible in the HDF.

The basal area provides a better measurement about the relative importance of tree species than simple stem count. The average basal area was 1.35±0.41 m^2/ha in the Douala-Edéa National Park. The HDF contained more individuals (1,734 individuals/ha) and a basal area of 1.83 m^2/ha, whereas the MDF contained the least of 0.91 m^2/ha. This could be explained by the fact that the HDF contained more small-diameter trees, compared to the MDF, which contained the lowest density of large-diameter trees. This result is low when compared to that found by [107] in the Mindourou community forest (3.919 m^2/ha) and by[108] in the dense semi-deciduous forests of East Cameroon (4.85 m^2/ha). Basal area is an excellent indicator of stand richness. It depends on both the size and the number of trees and is correlated with tree canopy cover, which makes it possible to quantify the degree of competition within the stand and the soil lighting conditions. The average density of this study which was 1,565 stems/ha differed from the forests of the Impfondo-Dongou axis from 144 stems/ha in primary forests to 868 stems/ha in degraded forests[109], from[91] who found an average density of 512 trees/ha in the forests of the Dja Reserve in south-east Cameroon, from [110] who obtained 532 trees/ha in the forest formations of southern Cameroon, and from [111] obtained 749 stems/ha in the Bangang forest in West Cameroon. This difference could be due to the reconstitution of the forest after anthropogenic activities and to the recruits that settle and develop after anthropogenic and natural disturbances. Disturbance has a direct influence on tree density, diversity and species composition [106]; like the felling of an individual tree of one of the species increases the distance between breeding individuals [112]. This makes it possible to assess the degree of disturbance or conservation of a biotope. In view of the results obtained, it should therefore be stated that the stands explored are not mature and constantly disturbed by human and natural activities, which confirms [113] assertions that the young vegetation of the reserve's coastline is constantly being renewed by the ebb and flow of the tide.

5.3. Carbon stock of the Douala-Edéa National Park

In tropical forest ecosystems, Carbon is stored at different levels: above ground, below ground, in the soil, in litter and in dead wood [114]. The total carbon stock of the various sites studied in the Douala-Edéa National Park stored was 8.76 tC/ha of Carbon. This result is far below the results of other studies. Njila, [115]acquired 210.42 tC/ha in the natural ecosystems of Kikot in Littoral-Cameroon; Mokake et al.[38] who indicated 278.75 t·C/ha in the Deng Deng forest reserve; Chimi et al.[108] in the semi-deciduous forest in the East region indicated that the biomass varied between 261 and 437 tC/ha; and Kabelong et al.[116] who indicated that the average total Carbon stock varied from 200.1 t ha^{-1} in forest residues to 439.1 t ha^{-1} in secondary forest. This reduction in the Carbon stock indicates the high level of disturbance in the Douala-Edéa National Park. One peculiarity of this National Park is the fact that the local population resides within the National Park who freely exploits it for their livelihood without them having any rights to artisanal and commercial logging. It is not surprising that forest owners have sought to start performing agricultural activities within the current National Park borders before the National Park establishment in 2018. This constant level of harvesting of forest resources, will make the forests to be in a state of constant regeneration and definitely reduce the Carbon stock. This therefore calls for the production of alternative sources of income for the local population which will prevent the over dependence on forest resources. However, as most of the Congo Basin countries are signatories to international conventions on biodiversity, the challenge is to develop sustainable projects to bring economic growth with minimal negative environmental impacts. Also, though a National Park has been created, more human and material resources from the Ministry of Forestry should be deployed for an effective control of the harvesting of the forest resources.

These differences can also be explained by the different allometric equations that have been used in the calculations of the Above ground biomass which is one of the greatest stores of the Carbon stock. Chimi et al.[108] used site specific equations while our study used the traditional pantropical equation of[34]. It has often been claimed that simply using stem diameter as a predictive variable of AGB is an effective approach [117]. In this study, one of the simplest models to estimate AGB for tropical forests around the world [34] was chosen in order to consider the principle of parsimony based on their mathematical simplicity as previous studies have already shown that species specific equations are unnecessary in estimating forest biomass [118]. This therefore calls for further analysis to investigate if there’s a significant difference in the use of site specific and pantropical allometric equations in the calculations of the above ground biomass. Also, most of the other studies studied trees from ≥10 cm indicating that they had large individuals and were undisturbed. Although our study carried out individuals ≥2 cm, the low AGB thus indicates a disturbed site particularly by wildfires and illegal tree cutting in the study area. These results are however similar to that found by[108], who obtained 10.81 tC/ha in the dense semi-deciduous forests of Eastern Cameroon and [116] who had a carbon stock of 5.02 tC/ha in old secondary forests in the periphery of Deng-Deng National Park in the East Region of Cameroon.

The Litter Organic Carbon was as high as that in the Above-ground biomass. This may be due to the high leaf fall caused by the wind coming from the waves of the sea which strongly adds to the fact that this site is highly disturbed. Ngo et al.[119] indicated that the contribution of the different compartments to total carbon stock varies markedly between primary and secondary forests. In primary forest, the dominant compartment is the aboveground biomass, and the soil contributes less due to a greater number of trees with larger diameters, while the opposite is true in secondary forest where the soil contributes a higher carbon stock than the above ground biomass. Also studies have shown that sediments characterized by high soil density are less porous and rich in mineral particles[120]. Such sediments restrict tree growth via their impact on soil aeration and water penetration. These sites are characterized by high litter fall and flooding in clay-sandy soils thus less porous. This increases the soil bulk density which reduces the growth of most trees. This is consistent with the general observation that soil C accounts for > 90% of total ecosystem Carbon in mangrove forests [121-123] which is a nearby vegetation to the coastal tropical forests. This is very close to the results of our study as the high Carbon stock of the Litter will be decomposed to the soil organic Carbon as leaf litter contributes to the soil organic Carbon. The LDF carbon stock was higher (2.38 t/ha) than the HDF carbon stock (1.92 t/ha) because of the absence of flooding and the presence of a forest canopy that will prevent erosion, leading to carbon accumulation in the LDF litter. Thus, the rainforest stored carbon in the leaves, the soil, above and below ground but at different proportions. Apparently, the bulk density and carbon stock generally increased with soil depth in the MDF and LDF which was the contrary in the HDF. This may be due to the fact that the HDF was constantly flooded leading to the erosion of the organic carbon from the top soil. Also, it could be due to leaching into the bottom layer, which is 15-30 cm deep.

6. Conclusion

This study assessed the diversity and carbon stock of the Douala-Edéa National Park which is a coastal tropical forest. It has contributed to the evaluation of the diversity of a coastal tropical forest and in the estimation of Carbon stock in the Central African Region in general and the Congo basin in particular. It confirms the Carbon storage of tropical forests found around the Mangrove ecosystem and highlights the impacts of the local population on the Carbon storage capacity of a coastal tropical forest in the Congo Basin. There is therefore an urgent need to consider the use of local traditional and governance approaches to improve on the conservation of the Douala-Edéa National Park. Conservation measures and research towards the sustainable use of coastal tropical forest resources must be prioritized in addition to sensitization and strengthening of local governance approaches to improve on the conservation of the Douala-Edéa Park. This therefore calls for both moral and physical resources to be allocated to the management of the Douala-Edéa National Park for a sustainable management of its forests.

Compliance with ethical standards

Acknowledgments

We are thankful to the Government of Cameroon through the conservator of the Douala-Edea National Park Mr Eboule Emmanuel for allowing us access to the park. We are also thankful to the Coordinator of CWCS Dr Ajonina Gordon for providing us with field work equipment. We thank all those who participated in this study that we may have forgotten. Special thank you to all the anonymous reviewers who provided valuable feedback towards the improvement of this manuscript.

Disclosure of conflict of interest

“The authors declare no conflict of interest.”

Statement of ethical approval

Data are available within the article and/or its supplementary materials.

References

[1] Food and Agriculture Organization [FAO] and United Nations Environment Programme [UNEP]. The State of the World's Forests 2020: Forests, biodiversity and people. 2020, Rome.

[2] Food and Agriculture Organization [FAO]. The State of the World's Forests 2018: Forests pathways to sustainable development. 2018, Rome.

[3] Panzou GJL, Doucet JL, Loumeto JJ, Biwole A, Bauwens S, Fayolle A. Biomass and carbon stocks of African tropical forests [bibliographic synthesis]. Biotechnol. Agron. Soc. Environ, 2016, 20[4]: 508-522. https://doi.org/10.25518/1780-4507.13232

[4] Bocko YE, Ifo SA, Loumeto JJ. Quantification of Carbon Stocks of Three Key Carbon Pools in Central Africa: Case of the Likouala Swamp Forest [Northern Congo]. European Scientific Journal, 2017, 13 [5]: 438 – 459. https://doi.org/10.19044/esj.2017.v13n5p438

[5] Potadar V, Patil S. Carbon storage and sequestration by trees in and around University Campus of Aurangabad City, Maharashtra. Int. J. Innov. Res. Sci. Eng. Technol. 2016, 5[4]:5459–5468.

[6] Heineman KD, Turner BL, Dalling JW. Variation in wood nutrients along a tropical soil fertility gradient. New Phytologist, 2016, 211 [2] 440-454. https://doi.org/10.1111/nph.13904.

[7] Suryawanshi MN, Pate LAR, Kale TS, Patil PR. Carbon sequestration potential of tree species in the environment of North Maharashtra University Campus, Jalgaon [MS] India. Biosci. Discov. 2014, 5[2]:175– 179.

[8] IPCC. Climate Change Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R. K. Pachauri and L. A. Meyer [Eds.]], Geneva, Switzerland. 2014, 169p.

[9] Mganga ND, Lyaruu HV, Banyikwa F. Above-ground carbon stock in a forest subjected to decadal frequent fires in western Tanzania. J. Biodivers. Environ. Sci. 2017, 10[2]:25–34.

[10] Cadotte MW. Experimental evidence that evolutionarily diverse assemblages result in higher productivity. Proceedings of the National Academy of Sciences of the United States of America, 2013, 110 [22], 8996–9000. https://doi.org/10.1073/pnas.1301685110.

[11] Coelho de Souza F, Dexter KG, Phillips OL, Pennington RT, Neves D, Sullivan MJP, Baker TR. Evolutionary diversity is associated with wood productivity in Amazonian forests. Nature Ecology and Evolution, 2019, 3[12], 1754–1761. https://doi.org/10.1038/s41559-019-1007-y

[12] Gross N, Suding KN, Lavorel S, Roumet C. Complementarity as a mechanism of coexistence between functional groups of grasses. Journal of Ecology, 2007, 95, 1296–1305. https://doi.org/10.1111/j.1365-2745.2007. 01303.x https://doi.org/10.1111/j.1365-2745.2007.01303.x

[13] Loreau M, Hector A. Partitioning selection and complementarity in biodiversity experiments. Nature, 2001, 412[6842], 72–76. https://doi.org/10.1038/35083573.

[14] Cifuentes BJG. Evaluation and monitoring of forest plantations in Guatemala. FODECYT Project No. 078-2007. National Council for Science and Technology [CONCYT, GT], National Secretariat for Science and Technology [SENACYT, GT], National Fund for Science and Technology [FONACYT, GT], National Institute of Forests [INAB, GT]. 2010, 135 p.

[15] Yoka J, Amiaud B, Epron D, Loumeto JJ, Vouidibio V. Analysis of the floristic diversity of the understory of the Mbobo palm grove in the Congolese Basin [Republic of the Congo]. Annals of Agronomic Sciences. 2013, 17. 161-178.

[16] Food and Agricultural Organisation [FAO]. The State of Food and Agriculture: Climate change, agriculture and food security, Rome, Italy 2016. https://www.fao.org/3/i6030e/i6030e.pdf

[17] Dusenge ME, André Galvao Duarte AG, Danielle A, Way DA. Plant carbon metabolism and climate change: elevated CO2 and temperature impacts on photosynthesis, photorespiration and respiration. New Phytol: 2018, 221 [1]: 32-49. https://doi.org/10.1111/nph.15283

[18] Ekoungoulou R, Liu X, Ifo SA, Loumeto JJ, Folega F. Carbon stock estimation in secondary forest and gallery forest of Congo using allometric equations. International Journal of Scientific and Technology Research 2014, 3[3]: 465-474.

[19] Tchatchou B, Sonwa DJ, Ifo SA, Tiana AM. Deforestation and forest degradation in the Congo Basin: State of play, current causes, and perspectives. Occasional Paper 2015, 120, Bogor, Indonesia, CIFOR. https://doi.org/10.17528/cifor/005457

[20] Ngomanda A, Lebamba J, Engone-Obiang NL, Lepengue N, M'Batchi B. Characterization of forest-savannah mosaics' dry biomass in Okouma and Bagombe plateaus, Southeastern Gabon. Journal of Applied Biosciences 2013, 68: 5417-5425. https://doi.org/10.4314/jab.v68i0.95067

[21] de Wasseige CP, de Marcken N, Bayol F, Hiol Hiol P, Mayaux B, Desclée R, Nasi A, Billand P, Defourny L, Eba'a Atyi R. The Forests of the Congo Basin—State of the Forest 2010. Luxembourg: Publications Office of the European Union. [2012]. https://doi.org/10.2788/47210

[22] Corlett RT, Primack RB. Tropical Rain Forests: An Ecological and Biogeographical Comparison [2nd Edition, 326 p]. Oxford: Wiley Blackwell 2011. https://doi.org/10.1002/9781444392296 .

[23] Vande Weghe J-P. Forêts d'Afrique centrale. La Nature et l'Homme. Ecofac, éditions Lannoo, Tielt, Belgique. 2004, 368 pg. ISBN 90-209-4783-4

[24] Willis KJ, Bennett KD, Burrough SL, Macias-Fauria M, Tovar C. Determining the Response of African Biota to Climate Change: Using the Past to Model the Future. Philosophical Transactions of the Royal Society B, 368, 2013 Article ID: 20120491. https://doi.org/10.1098/rstb.2012.0491.

[25] Central African Forests Commission [COMIFAC]. Reference manual for the installation of permanent plots in production forests in the Congo Basin. 2008, 78-81p.

[26] Ngomin A, Mvongo NMN. Second-generation silviculture in Cameroon: Conceptual bases, levers, and operationalization scheme. Cameroon, Yaoundé, 2015, 86p.

[27] Ernst C, Mayaux P, Verhegghen A, Bodart C., Musampa C, Defourny P. National forest cover change in Congo Basin: deforestation, reforestation, degradation and regeneration for the years 1990, 2000 and 2005. Glob Change Biol 2013, 19[4]:1173–1187. https://doi.org/10.1111/gcb.12092

[28] Central African Forests Commission [COMIFAC]. Reference manual for the installation of permanent plots in production forests in the Congo Basin. 2008, 78-81p.

[29] Barlow J, França F, Gardner TA, et al.. The future of hyperdiverse tropical ecosystems. Nature 2018, 559, 517–526. https://doi.org/10.1038/s41586-018-0301-1.

[30] Biswas SR, Mallik AU. Disturbance effects on species diversity and functional diversity in riparian and upland plant communities. Ecology, 2010, 91: 28-35.https://doi.org/10.1890/08-0887.1

[31] Nacoulma, B.M.I.; Schumann, K.; Traoré, S.; Bernhardt-Römermann, M.; Hahn, K.; Wittig R, Thiombiano A. Impacts of land-use on West African savanna vegetation: a comparison between protected and communal areas in Burkina Faso. Biodiversity and Conservation, 2011, 20: 3341-3362. https://doi.org/10.1007/s10531-011-0114-0

[32] O'Connor TG. Influence of land use on plant community composition and diversity in highland sourveld grassland in the southern Drakensburg, South Africa. Journal of Applied Ecology, 2005, 42: 975-988. https://doi.org/10.1111/j.1365-2664.2005.01065.x

[33] Southworth J, Zhu L, Bunting E, Ryan SJ, Herrero H, Waylen PR, Hill MJ. Changes in vegetation persistence across global savanna landscapes, 1982-2010. Journal of Land Use Science, 2016, 11: 7-32 https://doi.org/10.1080/1747423X.2015.1071439

[34] Chave J, Andalo C, Brown S, Cairns MA, Chambers JQ, Eamus D, Fölster H, Fromard F, Higuchi N, Kira T, Lescure J-P, Nelson BW, Ogawa H, Puig H, Riéra B, Yamakura T. Tree Allometry and Improved Estimation of Carbon Stocks and Balance in Tropical Forests. Oecologia, 2005, 145, 87-99. https://doi.org/10.1007/s00442-005-0100-x

[35] Karki S, Joshi NR, Udas E, Adhikari MD, Sherpa S, Kotru, R, Karky BS, Chettri N, Ning W. Assessment of forest carbon stock and carbon sequestration rates at the ICIMOD knowledge park in Godavari, Nepal. ICIMOD Working Paper 2016/6. Kathmandu: ICIMOD 2016, 6:52.

[36] Ruiz-Jaen MC Potvin C. Can we predict carbon stocks in tropical ecosystems from tree diversity? Comparing species and functional diversity in a plantation and a natural forest. The new phytologist. New Phytol. 2011, 189[4]: 978–87. https://doi.org/10.1111/j.1469-8137.2010.03501.x

[37] Adomou AC, Sinsin B, van Der Maesen LJG. Phytosociological and chorological approaches to phytogeography: a meso-scale study in Benin. Systematics and Geography of Plants, 2006, 76: 155-178.

[38] Mokake SE, Weyi BK, Anyinkeng N, Lyonga LM, Obenarreyneke EB, Egbe EA. Stand Diversity and Carbon Stock of a Tropical Forest in the Deng Deng National Park, Cameroon Open Journal of Ecology, 2023, 13, 461-496.n https://doi.org/10.4236/oje.2023.137029.

[39] Aboh BA, Houinato M, Oumorou M, Sinsin B. Invasive capacities of two exotic species, *Chromolaena odorata* [Asteraceae] and *Hyptis suaveolens* [Lamiaceae], in relation to land use in the Bétécoucou region [Benin]. Belgian Journal of Botany, 2008, 141: 113-128.

[40] Thompson PL, Rayfield B, Gonzalez A. Loss of habitat and connectivity erodes species diversity, ecosystem functioning, and stability in metacommunity networks. Ecography, 2017, 40[1], 98-108. https://doi.org/10.1111/ecog.02558

[41] Lindenmayer D, Thorn S, Banks S. Please do not disturb ecosystems further. Nature Ecology and Evolution, 2017, 1: 1-3. https://doi.org/10.1038/s41559-016-0031

[42] Mokake SE, Chuyong GB, Egbe EA. Long-term impacts of selective logging in a tropical rainforest in the East Region of Cameroon. African Journal of Ecology, 2024, 62:e13341. https://doi.org/10.1111/aje.13341.

[43] Geist HJ, Lambin EF. What Drives Tropical Deforestation? A meta-analysis of proximate and underlying causes of deforestation based on subnational case study evidence. 2001, 116 pp. LUCC Report Series No. 4.

[44] Ifo SA, Mbemba M, Koubouana F, Binsangou S. Carbon stocks in coarse woody debris: the case of tropical rainforests in Likouala, Republic of the Congo. European Scientific Journal, 2017, 13 [12]: 384-399. https://doi.org/10.19044/esj.2017.v13n12p384

[45] Aguejdad R. Urban sprawl and assessment of its impact on biodiversity: from the reconstruction of trajectories to prospective modeling. Application to a medium-sized urban area: Rennes Métropole. Thesis for the degree of Doctor of the European University of Brittany. Doctoral School of Humanities and Social Sciences. University of Rennes 2 Upper Brittany under the seal of the European University of Brittany, 2009, 378p.

[46] IPCC. Good Practice Guidance for Land Use, Land-Use Change and Forestry. Penman, J., Gytarsky, M., Hiraishi, T., Krug, T., Kruger, D., Pipatti, R., Buendia, L., Miwa, K., Ngara, T., Tanabe, K. and Wagner, F., Eds., Institute for Global Environmental Strategies [IGES], 2003, Kanagawa.

[47] Seto K, Güneralp B, Hutyra L. Global Forecasts of Urban Expansion to 2030 and Direct Impacts on Biodiversity and Carbon Pools. Proceedings of the National Academy of Sciences. 2012, 109. 16083-8. 10.1073/pnas.1211658109. https://doi.org/10.1073/pnas.1211658109.

[48] Food and Agriculture Organization [FAO]. The Future of Food and Agriculture- Trends and Challenges. Food and Agriculture Organization of the United Nations, Rome, 2017, 163p.

[49] Thompson I, Mackey B, McNulty S, Mosseler A. Forest resilience, biodiversity, and climate change. A synthesis of the biodiversity/resilience/stability relationship in forest ecosystems. Montreal. 2009, 43. 28.

[50] Kimaro J, Lulandala L. Human influences on tree diversity and composition of a coastal forest ecosystem: The case of Ngumburuni Forest Reserve, Rufiji, Tanzania. Int. J. For. Res. 2013, 1–7. 29. http://dx.doi.org/10.1155/2013/305874

[51] Joyi O, Utanga MM, Dindi OO, Ynekulu JA, Ahman EAB. The effect of forest fragmentation on tree species abundance and diversity in the Eastern Arc Mountains of Tanzania. Appl. Ecol. Environ. Res. 2015, 13[2]:307–324. https://doi.org/10.15666/aeer/1302_307324

[52] del Río M, Barbeito I, Bravo-Oviedo A, Calama R, Cañellas I, Herrero C, Montero G, Moreno-Fernández D, Ruíz-Peinado R, Bravo F. Mediterranean pine forests: Management effects on carbon stocks. Managing Forest Ecosystems: The Challenge of Climate Change. 2017, 31p. Available:https://doi.org/10.1007/978-3- 319-28250-3/Pdf. https://doi.org/10.1007/978-3-319-28250-3_15

[53] Cameroon Wildlife Conservation Society [CWCS]. Rapport d'activités Mouanko. 2002, 44p.

[54] Itamouna RM. Rapport d'activités, premier semestre, Ministère des Forêts et de la Faune. Cameroun. 2014, 19p.

[55] Zepner L, Karrasch P, Wiemann F, Bernard L. ClimateCharts.net – an interactive climate analysis web platform, International Journal of Digital Earth, 2020 https://doi.org/10.1080/17538947.2020.1829112.

[56] Condit R. Tropical forest census plots: methods and results from Barro Colorado Island. Panama and a comparison with other plots. Springer, Berlin. 1998, 211 pp.

[57] Mueller-Dombois D, Ellenberg H. Aims and Methods in Vegetation Ecology. John Wiley and Sons, Inc, 1974, New York.

[58] Ramade F. Elements of Ecology: Fundamental Ecology. 3rd edition, Dunod, Paris, 2003, 690 p.

[59] Curtis JT, McIntosh RP. The interrelations of certain analytic and synthetic phytosociological characters. Ecology, 1950, 31[3]:434–455. https://doi.org/10.2307/1931497

[60] Mori SA, Rabelo BV, Tsou CH, Daly D. Composition and structure of an Eastern Amazonian forest at Camaipi, Amapa, Brazil. Boletim do Museu Paraense Emilio Goeldi, Serie Botanica, 1983, 5:3-18.

[61] Fischer RA, Corbet AS, Williams CB. The relation between the number of species and the number of individuals in a random sample of an animal population. Journal of Animal Ecology, 1943, 12: 42-58.https://doi.org/10.2307/1411

[62] Shannon WWCE. The Mathematical Theory of Communication, Urbana Illinois: University of Illinois. 1949, Pp 132.

[63] Pielou E. Association tests versus homogeneity tests: their use in subdividing subplots into groups. Vegetation, 1969, 18:4-18. https://doi.org/10.1007/BF00332826

[64] Zapfack L, Noiha V, Dziedjou P, Zemagho L, Fomete T. Deforestation and Carbon Stocks in the Surroundings of Lobéké National Park [Cameroon] in the Congo Basin. Environment and Natural Resources Research, 2013, 3[2]:1–10.

[65] Mokany K, Raison RJ, Prokushkin AS. Critical analysis of root: shoot ratios in terrestrial biomes. Global Change Biol. 2006, 12, 84–96. https://doi.org/10.1111/j.1365-2486.2005.001043.x

[66] Timothy P, Sandra B, Richard B. Measurement Guidelines for the Sequestration of Forest Carbon. USDA, General Technical Report NRS, 2007, 18, 24. https://doi.org/10.2737/NRS-GTR-18

[67] Food and Agricultural Organisation [FAO]. Measuring and Reporting Soil Organic Carbon, Western Australia. FAO Publications, 2019, Rome.

[68] Cerruti PO, Ingram V, Sonwa D. The forests of Cameroon in 2008. 2009, http://www.observatoirecomifac.net/docs/edf2008/EN/SOF_02_cameroon.pdf. https://doi.org/10.2788 /32456

[69] IUCN. Practical guide for the production of Regional Red Lists of threatened species. IUCN methodology and development process. IUCN, Paris, France, 2011, 56 p.

[70] IUCN. Guidelines for Application of IUCN Red List Criteria at Regional and National Levels: Version 4.0. IUCN, Gland, Switzerland and Cambridge, UK, 2012a, 41 p.

[71] IUCN. IUCN Red List Categories and Criteria: Version 3.1. Second edition. IUCN, Gland, Switzerland and Cambridge, UK, 2012b, 32 p.

[72] IUCN. The IUCN Red List of Threatened Species. Version 2021 [1–2]. Available: http://www.iucnredlist.org.

[73] International Tropical Timber Organization [ITTO]. ITTO guidelines for the restoration, management and rehabilitation of degraded and secondary tropical forests. ITTO Policy Development Series No 13, 2002, ITTO, Yokohama, Japan.

[74] Ngueguim J, Solefack M, Betti J. Floristic and structural traits of tree vegetation in three sites with different level of disturbance in dense humid forest of Cameroon. 10.5897/JENE2018.0685. 2018,Vol. 10[9], pp. 239-249. https://doi.org/10.5897/JENE2018.0685

[75] Angoni H, Ngodo Melingui JP, Zinga EA. “The floristic diversity and the carbon stock evaluation in some periphery sites of the Douala-Edéa wildlife reserve in Cameroon”, International Journal of Development Research, 2018, 8, [06], 20991-20998.

[76] Addo-Fordjour P, Obeng S, Anning A, Addo M. Floristic composition, structure and natural regeneration in a moist semi-deciduous forest following anthropogenic disturbances and plant invasion. International Journal of Biodiversity and Conservation, 2009, 1. 21-37. 3341-3362.

[77] Tchouto MGP, De Boer WF, De Wilde J, Van der Maesen LJG. Diversity patterns in the fora of the Campo-Ma’an rain forest, Cameroon: do tree species tell it all? Biodivers Conserv 2006, 15:1353–1374. https://doi.org/10.1007/s10531-005-5394-9

[78] Lü XT, Yin JX, Tang JW. Diversity and composition of understory vegetation in the tropical seasonal rainforest of Xishuangbanna, SW China. Rev Biol Trop 2011, 59:455–463.

[79] Sainge MN. Vegetation Patterns in Tropical Forests of the Rumpi Hills and Kimbi-Fungom National Park, Cameroon, West-Central Africa. Ph.D. Thesis, Cape Peninsula University of Technology, South Africa, 2017, 210 p.

[80] Djomo NA, Knohl A, Gravenhorst G. Estimations of Total Ecosystem Carbon Pools Distribution and Carbon Biomass Current Annual Increment of a Moist Tropical Forest. Forest Ecology and Management, 2011, 261, 1448-1459. https://doi.org/10.1016/j.foreco.2011.01.031

[81] Kabore E, Sambare O, Ouedraogo A, Thiombiano A. Diversité et structure des cordons ripicoles le long de la sirba [Nord-Est du Burkina Faso]. International Journal of Biological and Chemical Sciences, 2013, 7, 1929-1950. https://doi.org/10.4314/ijbcs.v7i5.13.

[82] Oteng-Amoako AA. Tropical African Timber Trees from Ghana: Tree Description and Wood Identification with Notes on Silviculture, Ethonobotany and Uses 2006, 304 p. Accra: Graphic Packaging.

[83] Neuwinger, H.D. African Traditional Medicine. Mepharm Scientific Publisher, 2000, Stuttgart.

[84] Christenhusz MJM, Byng JW. "The number of known plant species in the world and its annual increase". Phytotaxa. 2016, 261 [3]: 201–217. https://doi.org/10.11646/phytotaxa.261.3.1

[85] Kengne OC, Zapfack L, Garcia C, Noiha NV, Nkongmeneck B-A. Floristic and structural diversity of two community forests under exploitation in Cameroon: case of Kompia and Nkolenyeng. Eur Sci J, 2018, 14[24]:245–271. https://doi.org/10.19044/esj.2018.v14n24p245

[86] Kengne OC, Feukeng SSK, Ngansop ET, Meyan-ya RGD; Zapfack L. Floristic composition, growth temperament and conservation status of woody plant species in the Cameroonian tropical rainforests. Ecological Processes 2022,11:50 https://doi.org/10.1186/s13717-022-00387-9.

[87] Watson L, Dallwitz MJ. The families of flowering plants: descriptions, illustrations, identification, and nformation retrieval. 1992, Version: 25th Archived from the original on 8 October 2017.

[88] Pragasan LA, Parthasarathy N. Landscape-level tree diversity assessment in tropical forests of southern Eastern Ghats, India. Flora - Morphology, Distribution, Functional Ecology of Plants, 2010, 205, 728–737. https://doi.org/10.1016/j.flora.2010.04.011

[89] Padalia H, Chauhan N, Porwal MC, Roy PS. Phytosociological observations on tree species density of Andaman Islands, India. Current Science, 2004, 87[6], 799– 806.

[90] Tarakeswara Naidu D, Premavani S.S,Venkaiah M. Assessment of tree diversity in tropical deciduous forests of Northcentral Eastern Ghats, India, Geology, Ecology, and Landscapes, 2018, 2:3, 216-227. https://doi.org/10.1080/24749508.2018.1452479.

[91] Sonké B. Forests of the Dja Reserve. Floristic and structural studies. National Botanical Garden of Belgium. Scripta Botan. Belg. 2004, vol. 32. 144p.

[92] Ekoungoulou R, Folega F, Mukete B, Ifo SA, Loumeto JJ, Liu XD, Niu SD. Assessing the effectiveness of protected areas on floristic diversity in tropical forests. Applied Ecology and Environmental Research 2018, 16[1]:837-853. https://doi.org/10.15666/aeer/1601_837853

[93] Luna-Kamyshev NM, López-Martínez JO, Vargas-Larreta B, Islebe G, Villalobos-Guerrero T, Vázquez de la Rosa A, Reyes O, Garza E. Floristic Composition, Diversity, and Biomass of a Protected Tropical Evergreen Forest Belize. Tropical Conservation Science. 2020, 13. https://doi.org/10.1177/1940082920915433

[94] Swaine MD, Whitmore TC. On the definition of ecological species groups in tropical rainforests. Plant Ecol. 1988, 75[1]:81-86. https://doi.org/10.1007/BF00044629

[95] Peters CM. Sustainable exploitation of non-timber forest products in humid tropical forests: An ecological primer. 1997, BSP, Washington DC.

[96] Sonke B. Floristic and structural studies of the forests of the Dja Faunal Reserve [Cameroon]. 1998, Doctoral thesis: Université Libre de Bruxelles [Belgium].

[97] Spellerberg IF, Fedor PJ. A tribute to Claude Shannon [1916-2001] and a plea for more rigorous use of species richness, species diversity and the Shannon-Wiener Index. – Global Ecology and Biogeography 2003, 12[3]: 177-179. https://doi.org/10.1046/j.1466-822X.2003.00015.x

[98] Fedor PJ, Spellerberg IF. Shannon-Wiener Index. Reference Module. Earth Systems Environmental Sciences, 2013, 1: 1-4. ecology. New York: Wiley. https://doi.org/10.1016/B978-0-12-409548-9.00602-3.

[99] Rooyen MV, Rooyen NV, Orban B, Nsongola G, Miabangana ES, Gaugris J. Floristic composition, diversity and structure of the forest communities in the Kouilou Département, Republic of Congo. Tropical Ecology 2016, 57[4]: 805-824, 2016. ISSN 0564-3295

[100] Von Gemerden BS, Olff H, Parren MPE, Bongers F. The pristine rainforest? Remnants of historical human impacts on current tree species composition and diversity. Journal of Biogeography 2003, 30: 1381-1390. https://doi.org/10.1046/j.1365-2699.2003.00937.x

[101] N'Dja JKK, Decocq G. Successional patterns of plant species and community diversity in a semi-deciduous tropical forest under shifting cultivation J. Veg. Sci. 2008, 19 809–20. https://doi.org/10.3170/2008-8-18453

[102] Djomo NA. A Structure Analysis for Ecological Management of Moist Tropical Forests. International Journal of Forestry Research, 2015, Article ID: 161645. https://doi.org/10.1155/2015/161645

[103] Memiaghe HR, Lutz JA, Korte L, Alonso A, Kenfack D. Ecological importance of small-diameter trees to the structure, diversity and biomass of a tropical evergreen forest at Rabi, Gabon. PloS One 2016, 11 [5], e0154988. https://doi.org/10.1371/journal.pone.0154988.

[104] Ndjomba CD, Koubouana F, Kimbatsa IM, Cécile M, Mabaka JM, Mbela FD. Floristic Diversity, Structure and Estimation of Carbon Stocks in Woody Stands of the Mondah Natural Forest. European Scientific Journal, ESJ, 2022, 18[33], 75-100. https://doi.org/10.19044/esj.2022.v18n33p75

[105] Nsangua MB, Nshimba NH, Boyemba F, Katusi R, Mbayo F, Mbuyu L. Study of the structural and floristic variability of terra firma forests in the Bahema-Boga Chiefdom [Ituri Province, DRC]. European Scientific Journal, 2018, 14:30, 500. https://doi.org/10.19044/esj.2018.v14n30p500

[106] Hitimana J, Kiyiapi JL, Njunge JT. Forest structure characteristics in disturbed and undisturbed sites of Mt Elgon Moist Lower Montane Forest western Kenya Forest. Ecology and Management, 2004, 194:269-291. https://doi.org/10.1016/j.foreco.2004.02.025

[107] Tsopmejio JP, Momeni J, Tsopjio FN, Tedjon VS, Mkounga P, Nuzhat SM, Choudhary I, Nkengfack AE. Bioactive secondary metabolites from Plectranthus glandulosus Hook. [Lamiaceae], Phytochemistry Letters [2019]: [30] 133-137. ISSN 1874-3900.https://doi.org/10.1016/j.phytol.2019.01.029.

[108] Chimi DC, Zapfack L, Djomo NA. Diversity, structure and biomasse [above and below] in a semi-deciduous moist forest of the East Region of Cameroon. Journal of Biology and Environment Sciences, 2018, 12 [3]: 60-72.

[109] Koubouana F. Congo Basin. Rev. Sci. Tech. For. Environ. 2018, Volume 11. PP. 11-25.

[110] Gonmadje CF, Doumenge C, Doyle M, Tchouto GPM, Sunderland, TCH, Balinga PB, Sonke B. Tree diversity and conservation value of Ngovayang's lowland forests, Cameroon. Biodivers. Conserv. 2011, 20[12]:2627-2648. https://doi.org/10.1007/s10531-011-0095-z

[111] Tiokeng B, Mapongmetsem P-M, Nguetsop V, Tacham W. Floristic biodiversity and natural regeneration in the Lebialem Highlands [Western Cameroon]. Int. J. Biol. Chem. Sci. 2015, 9[1]: 56-68. https://doi.org/10.4314/ijbcs.v9i1.6

[112] Gartlan S. The conservation of forest ecosystems in Cameroon. Tropical Forest Programme. 1989, IUCN, Gland, Switzerland.

[113] Letouzey R. Note on the phytogeographic map of Cameroon at 1/500,000. Toulouse, France: Institute of the International Map of Vegetation, 1985.

[114] Vogt K, Honea J, Vogt D, Edmonds R, Patel-Weynand T, Sigurdardottir R, Andreu M. Forests and Society: Sustainability and 188 Life Cycles of Forests in Human Landscapes.CAB International. 2006, https://doi.org/10.1079/9781845930981.0188

[115] Njila NEN. Influence of agroforestry activities on woody resources and carbon stocks in a forest-savanna transition zone: the case of Kikot. Professional Master's Thesis, University of Yaoundé 1. 2017, 88 p.

[116] Kabelong B, Roger LP, Zapfack L, Weladji RB, Chimi DC, Nyako MC, Bocko, YE, Essono DM, Nasang JM, Madountsap TN, Abessolo CIM, Sakouma KR, Souahibou FM, Palla FJS, Ketchatang PT, Jiagho RE, Kenmou TL, Jumo UACK, Andjik BAA, Mbobda RB. Floristic Diversity and Carbon Stocks in the Periphery of Deng-Deng National Park, Eastern Cameroon. Journal of Forestry Research, 2018, 31, 989-1003. https://doi.org/10.1007/s11676-018-0839-7.

[117] Wirth C, Schumacher J, Schulze ED. Generic biomass functions for Norway spruce in Central Europe— A meta-analysis approach toward prediction and uncertainty estimation. Tree Physiology, 2004, 24, 121–139. https://doi.org/10.1093/treephys/24.2.121

[118] Gibbs H, Brown S, Niles J, Foley J. Monitoring and measuring tropical forest carbon stocks: Making REDD a reality. Environmental Research Letters, 2007, 2[4], 045023.http://doi.org/10.1088/1748-9326/2/4/045023

[119] Ngo KM, Turner BL, Muller-Landau HC, Davies SJ, Larjavaara M, Nik Hassan NF. Carbon Stocks in Primary and Secondary Tropical Forests in Singapore. Forest Ecology and Management, 2013, 296, 81-89. https://doi.org/10.1016/j.foreco.2013.02.004.

[120] USDA. USDA National Nutrient Database for Standard Reference, 2008, Release 21. NDB 09209.

[121] Kauffman BJ, Bhomia RK. Ecosystem carbon stocks of mangroves across broad environmental gradients in West-Central Africa: Global and regional comparisons. PLoS ONE 2017, 12, e0187749. https://doi.org/10.1371/journal.pone.0187749

[122] Donato DC, Kauffman JB, Murdiyarso D, Kurnianto S, Stidham M, Kanninen M. Mangroves among the most carbon-rich forests in the tropics. Nat. Geosci. 2011, 4, 293–297. https://doi.org/10.1038/ngeo1123

[123] Scharlemann JP, Tanner EV, Hiederer R, Kapos V. Global soil carbon: understanding and managing the largest terrestrial carbon pool. Carbon Management, 2014, 5[1], 81–91. https://doi.org/10.4155/cmt.13.77