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ECOLOGICAL STUDY OF THE VEGETATION OF THE DOUALA EDEA WILDLIFE RESERVE IN CAMEROON

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ABSTRACT

The Douala-Edea Wildlife reserve is situated in the Littoral region, specifically in the Sanaga Maritime Department. The study aims to characterize the plant diversity of the reserve. This study was conducted in three phases, the rapid botanic survey, a botanical inventory of the reserve; and species identification in the herabarium. The methodology used combined the quadrants to achieve the botanical inventories, as well as surveys and field visits. The forest of the Douala-Edea reserve is rich and diverse, 435 species and 76 families were identified. This potential varies with facies. Four facies were identified, the coastal facies, the disturbed forest, the undisturbed environment and marshy environment. The coastal facies with the least species abundance is dominated by Fabaceae and Rubiaceae. Diversity is average and plant regeneration in the under "canopy" is dominated by 47.3 % of plants with a diameter less than or equal to 10 cm. The average recovery is 82 m2 / ha, Confirming that the forest reserve is a mature forest.

INTRODUCTION

Cameroon has an open coastline on the Atlantic Ocean on a length of about 402 kilometers Sayer *et al*., (1992) in Anonymous (1999b). Geomorphologic ally this coast line is divided into three parts, the West Coast, North Coast and South Coast Anonymous (1999b). This open coast line gives a gate way for the importation and exportation of products in Central Africa countries. Thus the Cameroonian coasts are increasingly solicited for industrial development which leads to a strong industrialization and urbanization, which may cause significant adverse consequences on the physical and biological environment Angoni, (2014). Thus the landscapes which were originally known have not yet revealed all their biological characteristics to the scientific community and their benefits to local residents as they are subjected daily to various forms of degradation. Habitat modification resulting from this degradation cause problems whose consequence are climate change Angoni and Ayissi (2009). This study takes place in a context marked by a high demand of the Cameroonian Atlantic coast; in Kribi, by the installation of major development projects such as the deep-water port of Kribi, the iron ore terminal in Lolabé which will result to the construction of a railway that leads to the ocean and Kribigas construction site.

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Research and the discovery of new oil deposits in the Douala Edea Wildlife Reserve cause the Opening of the linear tailboards to create access roads and the installation of living accommodation for personnel in the exploitation of crude oil at the Mviasite. All these human activities are likely to fragment the ecosystem, cause an erosion of biodiversity with a risk of species extinction in the absence of an appropriate legal framework for the protection of coastal forests and mangroves.

Yet many studies are known in coastal forests among which Tchouto *et al.,* (2006 (2008), and Angoni, (2014) in the Campo Ma'an UTO. These authors describe all coastal forests as intertidal areas in the Campo Ma'an UTO. It appears from various studies that coastal forests are rich and diverse, 1500 speciese valuated of which 700are found in off shore bars in the periphery of Campo Ma'an Park. These forests_contain114 end emic species Tchouto *et al.,* (2006). Two species characterize and areas in the forests of Cameroon's coast; Lophiraalata and Saccoglottisgabonens is Letouzey (1968). According to Tchouto *et al.,* (2008) the Campo Ma'an forest by its density in endemic species and its rich diversity, is probably one of the major plant Pleistocene refuges as indicated by many authors. In the estuary of Cameroon, many studies have been carried out on mangroves including Ndongo (1993) in the Wouri estuary and Ajonina, (2008) in the Atlantic coasts of the Douala-Edea wildlife reserve. These

specific studies describe the dynamics of mangroves through biometric data on different species of Rhizophora and their role in stabilizing ecosystems and food for coastal wildlife. These studies also raise many concerns about the uncontrolled use of these coastal protected areas especially the management of mangrove forests (smoking of fish, construction, manufacturing canoes) Ajonina and Toung (1999); Ajonina and Usongo (2001). These studies reveal several illegal wildlife poaching and forest exploitation practices. To contribute to improving the conservation status of the Douala-Edea wildlife reserve, we propose as part of the main objective of this study, to study the vegetation of the Douala-Edea wildlife reserve.

It is specifically to:

1) Describe the types of vegetation facies
2) Make a botanical inventory

MATERIALS AND METHODS

Tree methods were used to characterize the biodiversity of the Douala-Edea wildlife reserve. They include:

1) Identification of types of plant formation;
2) Data collection to enable the study of vegetation;
3) Plant identification in the herbarium.

Data collection to enable the study of vegetation

A preliminary inventory long the main axis andoil exploration paths of the reserve (Mviaarea), the Atlantic Ocean (beaches from Yoyo to Badangue and Suélaba, Gabon, Mombo), the banks of the Sanaga (Mombo, Yavi, Yatou, Yakonzok) and the banks of the Nyong permitted the identification of vegetation types. The description of the vegetation has taken into account the physiognomy of the vegetation, tree size, the number of strata and species.

Dendro metric measures

Experimental device for dendrometric data collection

Quadrants were used as the basis to study vegetation parameters White and Edwards, (2000), drawing inspirations from Mbolo, Mbolo, (2004), Ndongo (1993) and Angoni, (2005). The quadrant as sampling unit was recommended by Weaver and Frederick (1929) to study the structure and composition of vegetation. This method permits seasonal and yearly changes on the vegetation to be saved. In a bit to better sample the forest, the identified vegetation types in the reserve were divided into quadrants. Quadrant sizes of 50 m x 20 m, 10 m x 10 and x 11 m were selected for the inventory of the vegetation. Two consecutive quadrants were separated bya 100 m transect line on the ground. Thus, in a quadrant of 50 x 20m Camp bell (2006) in Alonso *et al.* (2006), we surveyed and measured at breast height with a tape measure, all trees greater than 10cm in diameter or a circumference of 31.4 cm. Trees which were measured were slightly wounded with a cutlass to avoid repeating measurements on the same species. In subquadrants all shrubs less than 10 cm or a circumference of 31.4cm were measured using calipers and other biological types were surveyed. In densely vegetated sites, the transect increased from 2000 m. A total of 13 transects of 2000 m run through different types of facies, on which 24 quadrats of 50 m x 20 m were made, with 21 quadrants in the interior of the forest and 3 quadrantsin the coastal zone. During the vegetation survey, 40 sub-quadrants of 10 m x 10 m were made in the interior of the forest and 12 sub-quadrants of 1 m x 1m in the coastal zone.

Collection and identification of herbarium specimens

During the preliminary studies and inventories on quadrants along our forest trails on the Atlantic coast, the Sanaga and Nyong rivers, samples of flowers, fruits and fragments of stems or branches were collected, pressed directly in the field and subjected to drying using fire wood. Some samples were identified directly in the field or at the Botanical-ecology laboratory with the documents of Vivien and Faure (2011); Duncan and Wilbur (1990) were deposited for identification in collaboration with the National Herbariumin Yaounde. Internet sites from the Google engine (IPNI Red List of IUCN database) were consulted as well as and researchers specialized in forest plants in Cameroon.

Data analysis

Analysis of data on vegetation

The analysis of data collected will determine the following parameters: The vegetation density, the basal area of a tree, the dominance, the absolute and relative frequency.

Species diversity index of Shannon-Weaver

$$Ish \text{ ou } H = -\sum_{i=1}^{s} \frac{Ni}{N} \log_2 \frac{Ni}{N}$$

Where:

H =diversity index, s= the number of taxonomic group, Ni =the number of individuals in the first taxonomic group, N = the number of individuals at the station

Evenness varies from0 to 1: it tends to 0 when almost all of the actual is focused on the same species; it is 1when all the species have the same abundance.

Species diversity

The importance of the various indices, H and EorIs and Es, is to allow global comparison of different populations or the state of the same settlement seize dat different times. One of the simplest and also the most interesting is the index of proportional similarity which takes into account the availability of resources Barbault (1992); Ramade (1992).

RESULTS

Study of the vegetation of the forest reserve

The forests of the forest reserve are presented differently. In some cases, we find undisturbed forest types (natural formations) and disturbed forests types (open formations).

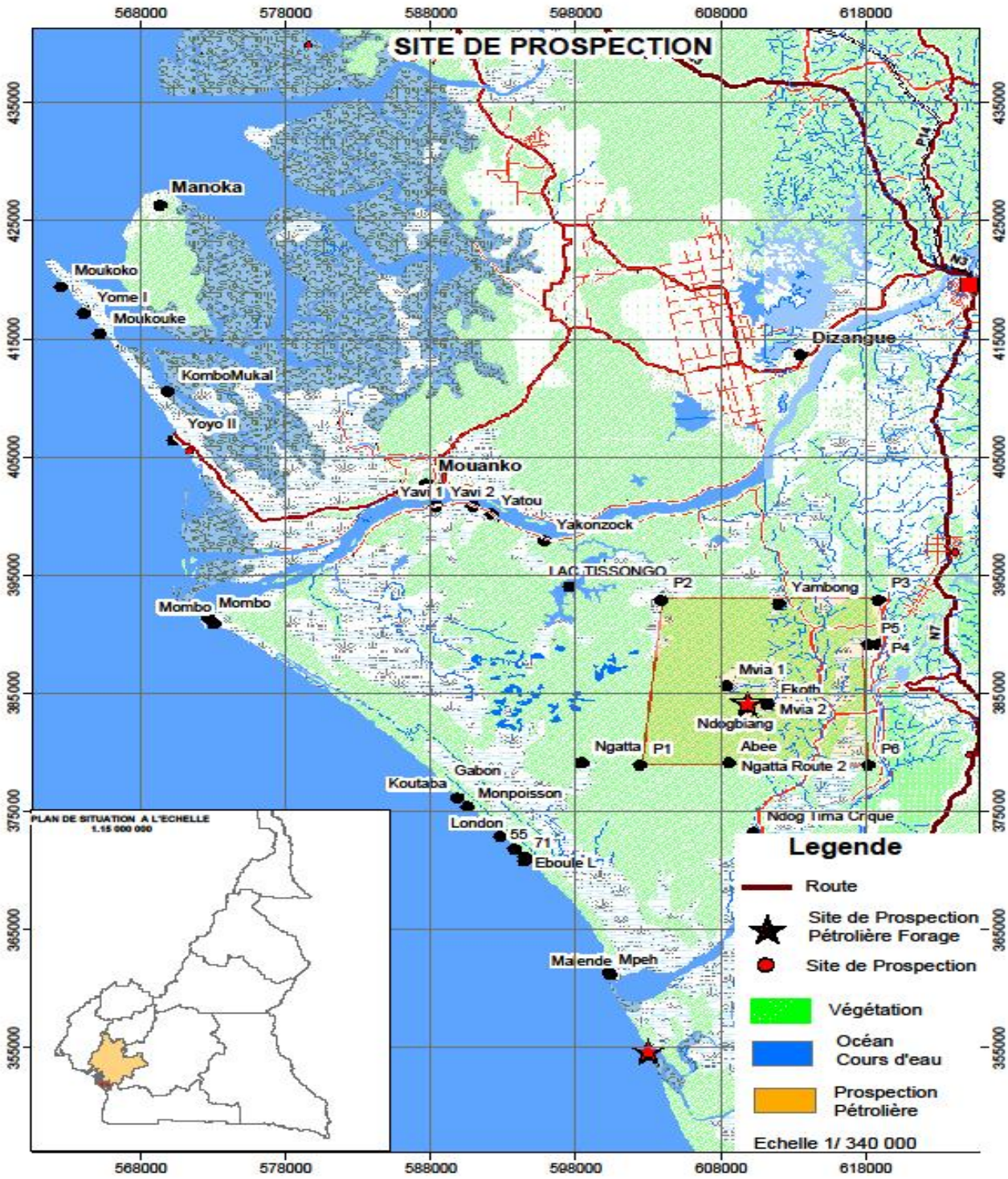

Fig.1. Plants preliminary study site

Undisturbed forests

Un disturbed forests or natural formations are characterized by the presence of large trees at locations where NTFPs are harvested, under the feet of species such as *Coulaeudulis*, *Irvingiagabonensis* and *Baillonellatoxisperma*. The specific composition of the Douala-Ede are serve is 500species identified with a wide dominance of Rubiaceae, Euphorbiceae, Cesalpiniaceae and Fabaceae. The canopy is high and there are severalstrata.

Three species dominate the leaf canopy namely *Coulaeudulis* and *Lophiraalata* in Mvia and *Baillonellatoxisperma* in Yavi and Yatou. The under grow this stripped in Mvia giving the appearance of aclimax formation.

Anthropic forests

This is a forest that has been disturbed due to human actions. These forests are found on the coast line around fishing camps where former agricultural fields are found.

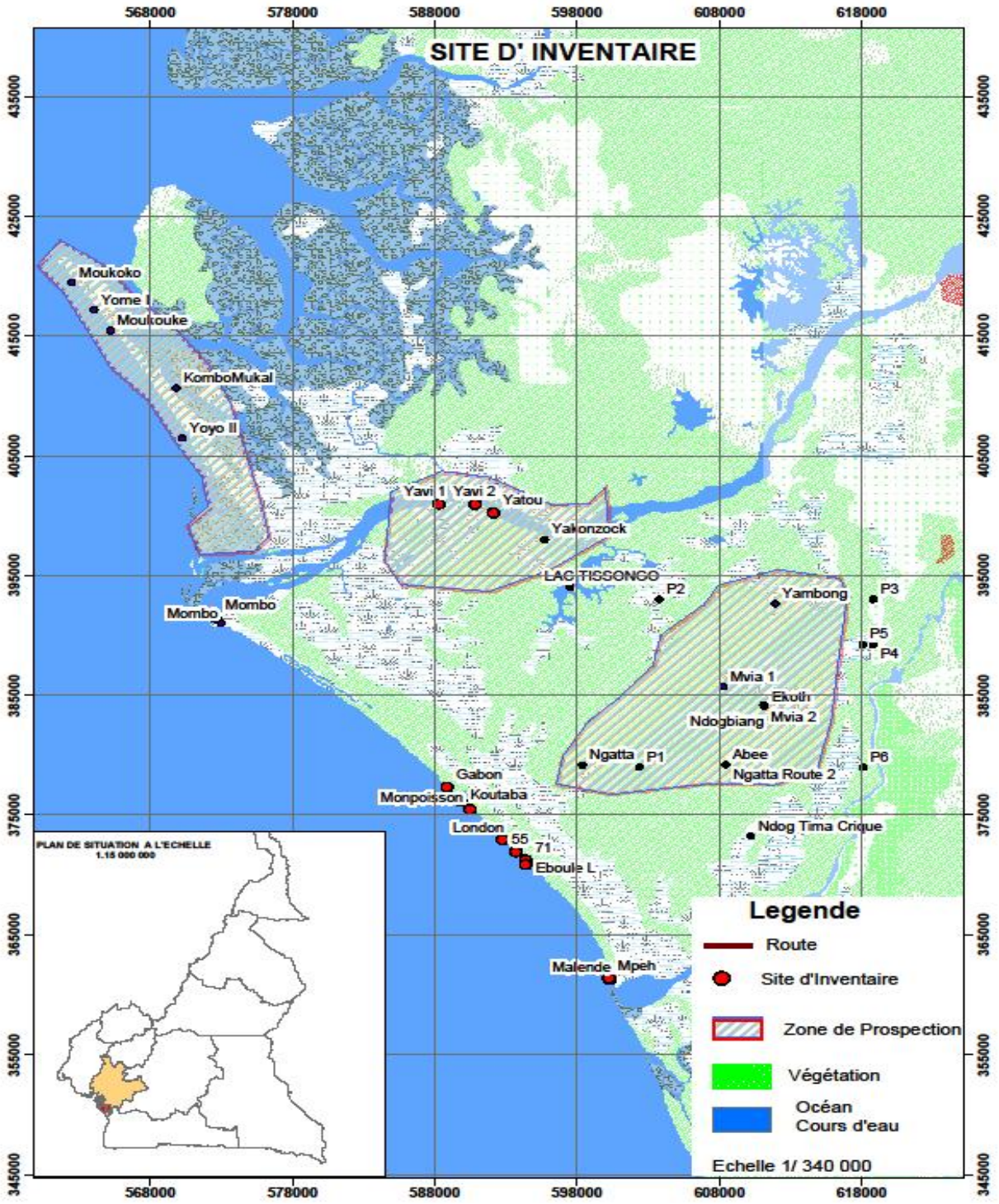

Fig.2. Plants inventory site location

Inside the reserve, access paths and the installation of economic activities lead to the migration of fauna, fragmentation of the ecosystem and various forms of pollution. The Forests of this reserve have been affected by oil exploration around the tail board. Characteristic species of forest disturbance could therefore be found in the study areas such as *Macarang aassas*, *Mussanga cecropioides* that heal the forest.

Swamp forests

Swamp forests are found in the vicinity of rivers. They are not very diversified, have clear undergrowth and only a few trees form the canopy. In the Ndogbiang quadrant, trees do not have large diameters, but we identified a foot of *Uapaca* whose foot hills lie up to 5 meters high. The maximum diameter at breast height (DBH) of this vegetation is about 30cm.

Woody species include *Anthocleista schweinfurthii* (35%), *Uapacaguinesis* (38.5%), *Santiria trimera* (9%). The under growth herbaceousflorais poor and consists of *Costus tappenbeckianus, Crinum natans, Cnestisferruginea, Nephrolepisbiserrata Alchornea sp and Cissus sp.*

Floristic diversity of the Douala-Edea wildlife reserve

Table 1. Some principal families according to the number of species identified

N°	Families	Number of identified species
1	Rubiaceae	31
2	Euphorbiaceae	20
3	Fabaceae-Cesalpinoideae	25
4	Ebenaceae	5
5	Ochnaceae	10
6	Clusiaceae	3
7	Dicapetalaceae	3

In total 268 species have been identified. Thus, among the diverse families, there are 31 species of the family *Rubiaceae*, 21species of *Euphorbiaceae*, 20 species of *Fabaceae-Cesalpinoideae*, 5 species of *Ebenaceae*, 10species of *Ochnaceae*, 3 species of *Clusiaceae*. Table I below shows the number of species completely identified based on their families.

Diversity of families in the reserve

A total of 76 families were identified in the reserve of which 16are paramount. These include *Rubiaceae* (17.66%), *Euphorbiaceae* (8.9%), *Fabaceae-Caesalpiniaceae* (7.3%), *Ebenaceae* (3.5%), *Ochnaceae* (3.5%), *Clusiaceae* (3,3%), *Connaraceae* (3.3%), *Loganiaceae* (3.3%), *Apocynaceae* (3.1%), *Araceae*(3.1%), *Annonaceae* (2.7%), *Violaceae* (2,3%) *Olacaceae* (2.1%), *Sterculiaceae* (2.1%), *Dichapetalaceae* (1.9%) and *Melastomataceae* (1.9%). Appendix 1shows the families identified according to their frequency values. Twenty-two families (22) are poorly represented with less than 0.2% frequency.

Vegetation characterization

Studies were carried out in five permanent plots of dense forest and results showed that the vegetation of the Douala-Edea wildlife reserve is very diverse. Evenness indices around 0.6 reflect the equal distribution of species in the plots. The calculated Shannon indices between 3 and 5 show that diversity is not maximal. Diversity remains moderately high. Thus, the probability that two random samples belong to the same taxon is low (around 0.1 and 0.2) for the Ekot, Mvia and Ndogtima creek plots and very low (around 0.6) for Abbe and Ngatta road. This probability is zero for some species like *Bartiera iturensis*, *Crotogyne impedita, Crystosepalumpelligrinianum, Heisteriaparviflora* (Table II).

Table 2. *Diversity* Indices according to botanical plots

Parameters/Plots	Equitability byPielou	Shannon index	Simpson index
Atlantic Forest(Abbot or Abbe)	0,6515	4,41	0,065
Swamp forest(Ekot).	0,576	3,81	0,132
AtlanticForests (Mvia2)	0,606	3,917	0,176
Swampforest (Ndogtima creek)	0,596	3,953	0,087
AtlanticForest, Lophiraalata(Ngattaroad)	0,6124	4,42	0,064

Table 3. Absolute frequencies of species in diameter classes (0-5cm)

Scientific name	Proportion (%)
OlaxlatifoliaEngl.	9,49
Anthonothamacrophylla Pal. Beauv.	8,45
Syzygiumguineense var. macrocarpum	5,19
Rinoreaoblongifolia	4,45
Rhabdophyllumarnoldianum	4,30
Heckeldorastandtii (Harms) Staner	3,56
Diospyroshoyleana	3,41
Garcinia manniiOliv.	2,96
Alexis cauliflora (Oliv.) Pierre	2,81
hymenostegiaafzelii	2,37
Campylospermumletouzeyi	2,22
Dichostemmaglauscecens pierre	2,07
Bertieraiturensis	1,92
Annickiachlorantha	1,78
PleiocarpabicarpellataStapf	1,78
Strombosiagrandifolia	1,78
Brenariabrieyi (G.Do) petit	1,63
Memecylonanishoffa	1,63
DiogozenkeriExell el Mendonca	1,48
CampilospernumolioeranumFarron	1,33
Chazaliellamacrocarpa Verde	1,33
Chytranthusgilletii	1,33
Garcinia gnetoidesHertch. Dalz	1,33
Xylopiaquintasii	1,33
ChazaliellacameroonensisLachenaud	1,18
Diospyrosfragans	1,03
Heisteriatrillesiana Pierre	1,03
Rhabdophyllum affine (Hook)	1,03

Qualitative studies of vegetation

Structure in diameter classes

To carry out this study, we proceeded by regrouping species according to classes of diameter. Thus fifteen (15) classes ranging from 5 cm to 5 cm were distinguished in the forest of the Douala-Edea wildlife reserve; from the Class 0-5 to the class 165-170 cm. Table III below shows the different species

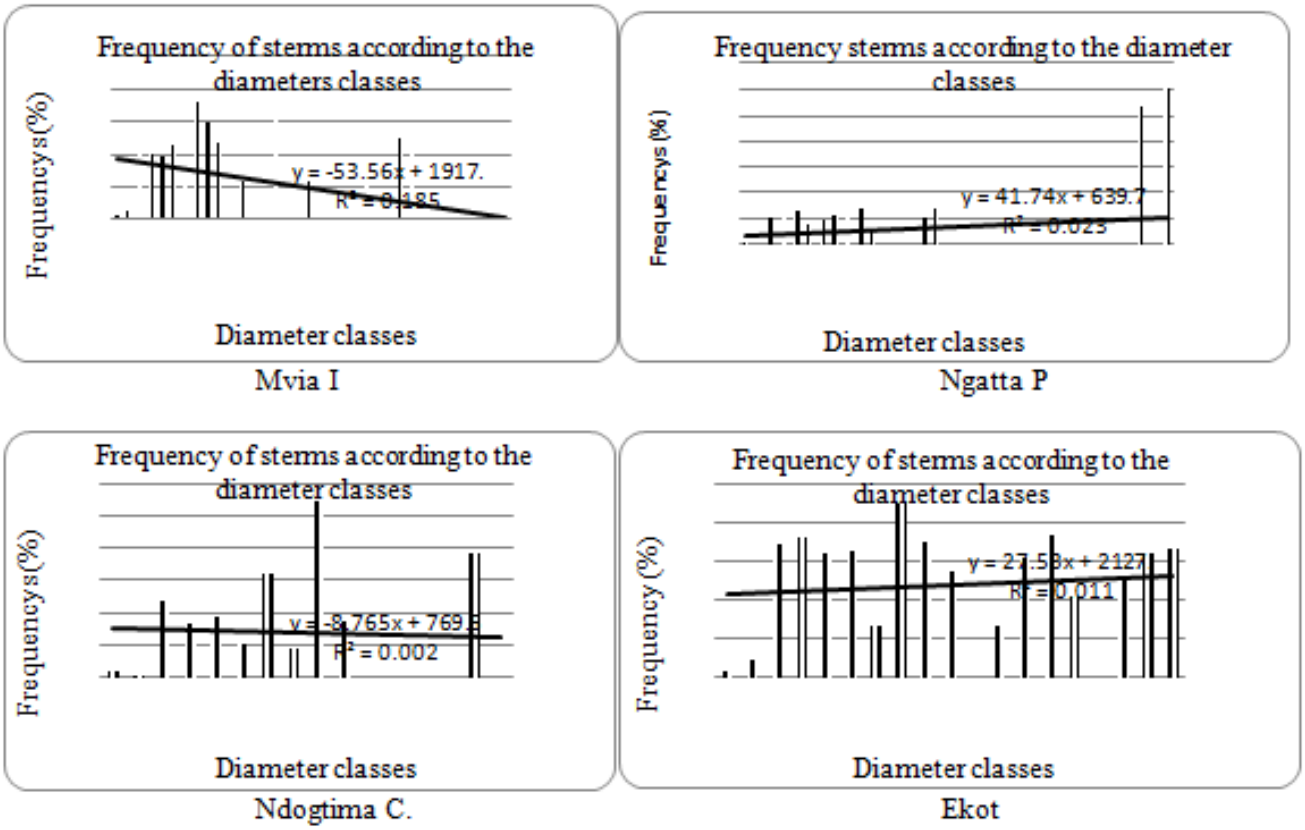

Fig. 3. Frequency of stems according to diameters classes

characterizing the 0-5 cm diameter class. This table shows that, apart from species that reach maturity in under growth such as *Memecylon anishoffa*, *Bertiera iturensis*, several young species will eventually emerge. Natural regeneration ensures a renewal of the forest.

Vegetation Density

The analysis of the frequency distribution histograms of stems according to diameter classes (Fig.3) shows based on trend lines, a single model. In this model, the curve decreases from the smallest diameter classes to the largest. The maximum frequency (20%) located in the diameter class (0-5) cm except in the Ekot site (15%) decrease regularly and cancels out in the diameter class (55-60) cm. But the evolution of classes in the frequency of stems with respect to diameter classes identified some characteristics related to the growth of species in the undergrowth. So all the sites have adominant under growth shrub layer of diameter class (0-5) cm except Ekot site where the dominant classes are between (10-15) cm. After this growth of species between diameter classes (0-5) cm, there is a sudden drop in the frequency of stems between the diameters of classes (5-10) cm. This would be caused by various adaptations. Density remains at its maximum around the classes (10-15) and regularly decreases with increasing diameter. These stems with diameters between (0-5) are the undergrowth shrubs.

Recovery of vegetation

Results obtained are presented as histograms that have special regards to the recovery analysis (Fig.6).

Thus in Ngatta and Ndogtima creek, the basal area is less important because of gaps in the forest. Both recoveries are statistically equal as to their average rate of basal area. The species that contribute to the recovery are shrubs and average trees located between intervals of (10-15) and (55-60). Young trees contribute very little to recovery in diameter classes (0-5cm.).

The Yavi and Ekot sites have an important recovery due to good distribution of species in the different classes of diameter. But these two sites are statistically different in their average recovery. All these plots are significantly different from each other. The value of Fread is less than F calculated and P. is less than 0.05.Thuswe can conclude that the average basal areas are statistically different. Two types of forest based on trend lines can be recognized from the shape of the frequency histograms. In the first type of forest with a regression trend line, the under growth is populated with many shrubs. The basal areas are divided into two modes, of which one corresponds to the largest diameter classesincluding «0-5 cm » and « 40-45 cm ».

The second and less important corresponds to the diameter classes above 70 cm. This model is found in the Ngatta, Abbe, Mvia 2, Yavi, Mvia I and Ndogtima C sites. The second type of forest has an gradual trend curve. It also presents a histogram with two lots, the first is smaller in diameter classes 0-5 to 45-50 cm and largest is found in diameter classes above 60cm. This model is found in Ngatta P. and Ekot. According to the analysis of basal surface histograms based on classes of diameters, it is apparent that there exist two types of

histograms based on the trend line. The figure below (Fig.6) shows the two types of histograms. Recovery of vegetation remains a function of class sizes and the number of stems per hectare. Between the classes« 15-20 » and « 45-50 », a large number of trees cause a huge recovery with peakat 18000 cm^2. Large trees found in diameter classes between« 105-110 » and « 165-170 » lead to very high recoveries with values exceeding 20000 cm^2. At this stage of vegetation, we find species such as *Lophira alata*, *Coulaeudulis* and *Baillonella toxisperma*.

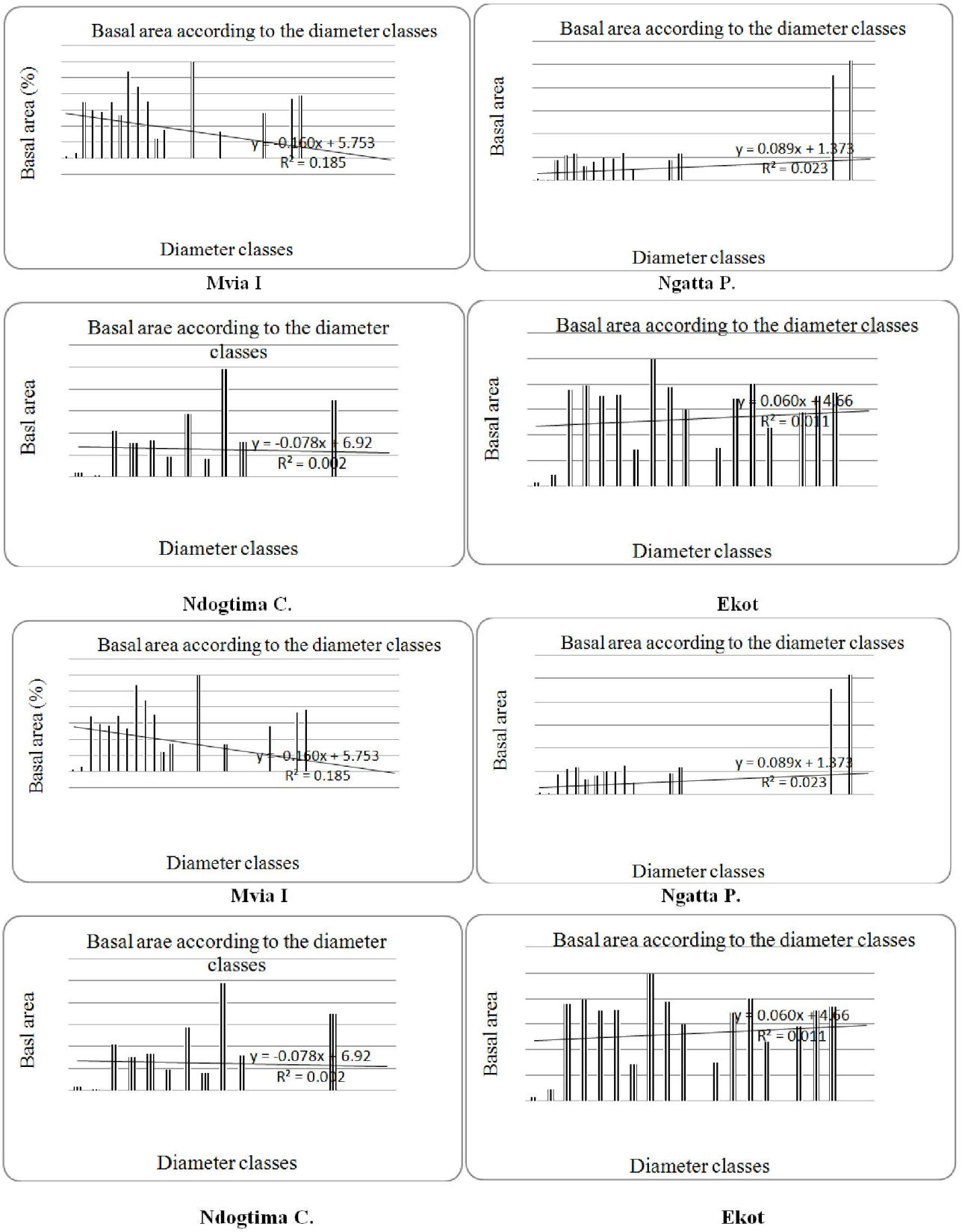

Fig. 4. Basal area according to diameter classes

DISCUSSION

Surveys in the forests of the Douala-Edea wild life reserve have allowed the identification of 516 species, 77 families. The largest family is that of *Rubiceae*. The forest is dominated by *Lophira alata*. Despite difficult accessibility, results obtained in this study confirm the major trends of coastal forests described by Tchouto (2000), as forests rich in biodiversity with 1,500 species, 45 families and 141 endemic species. These forests are part of the Atlantic District and At lantic coastal district described. by Letouzey (1968). A high Shannon index (ISH) corresponds to favorable environmental conditions for the installation of many species represented by a small number of individuals Dajoz (1982).

The vegetation of the coastal line of the RFDE has an ISH of 3.56 bits. This is relatively low compared to those obtained in other forest areas Fongnzossié *et al*. (2008); Dongmo (2006). It therefore appears that the forest near the ocean is undiversified. The equitability index of Pielou (Eq) is 0.49. Ecosystems haven't achieved a level of maturity. The value obtained here means that the majority of individuals surveyed belong to only a few species. In fact on the coast, four species constitute more than half of the total number of species. *Calophylluminophyllum* and *Terminalia catappa*, especially, are abundant on the beaches and back-beaches of the reserve because of their adaptation to sandy environments and tolerance to salt spray Angoni (2005).

Regarding the diametric distribution, the Douala-Ede are serve accounts for over47,30% of plants with diameter more than 10 cm, which is close to 55% of the plants obtained on the same plot size of 0.1hain the Campo Ma'ansite Angoni (2005). The work of Fongnzossié *et al*. (2008) report that this high number of small diameters and the exponential decay distribution which was obtained characterize much regeneration in the under growth and a population maintaining itself. As for recovery, it is 18.5 m^2 / ha for plants of at least 5cm in diameter in the coastal area of the Douala-Edea reserve. However the forests of the coastal strip of the Campo-Ma'an Technical operational Unit attain Surface Terrial values of 53 m^2/ ha Angoni *et al*. (2013). Those on alluvial deposits in New Caledonia reach ST values of 47 m^2/ ha for plants with diameter larger than 10 cm Jaffré and Veillonk (1991).

The low value of the basal area of the forest of the coastal line of the reserve is due to the low density of individual son one hand, and secondly to the very small number of trees with large diameters. Trees with diameters between 60 and120 cm represent only2.6%of the total, but constitute more than half of the basal area. In the forest of the Douala-Edea Wildlife Reserve, basal area is 82m^2 / ha and this coverage is influenced by the presence of trees with large diameters that dominate the canopy. It is therefore understand able after Mosango (1990) and Sokpon (1995) that the forests of the Douala-Ede are serve are mature. According to these authors, basal area is a good tool for assessing the maturity of forests. The basal area of 82 m^2/ ha is higher than the average of40 m^2/ ha of mature forest according to these authors. Given the results obtained, it should be said that the forest settlements are mature while forests in the coastal zone are not. This confirms the claims of Letouzey (1985) on the young vegetation of the coastline of the reserve which is in constant renewal because of tidal movement.

Conclusion

The Douala-Edea wildlife reserve, rich in plant biodiversity, contains different types of forests and stretches on the coastaledgelined with mangroves to riparian forests along the course of the Sanaga and Nyong. Characteristic species of mangrove forests of the Atlantic coast are *Terminalia catapa*, *Calophylluminophyllom*. In total 423 species were identified. Thus, among the abundant species are species of *Rubiaceae*, of *Euphorbiaceae*, species 20 species of *Fabaceae-Cesalpinoideae*, 5 species of *Ebenaceae*, 10species of *Ochnaceae* and 3 species of *Clusiaceae*. Abbe and Ngata road forests were disrupted by oil exploitation. In total 76 families have been identified in the reserve of which 16 are predominant among which are *Rubiaceae* (17.66%), *Euphorbiaceae* (8.9%), *Fabaceae- Caesalpiniaceae* (7.3%).

The observation of the frequency of stems according to class sizes showed that the maximum frequency (20%) are located in the diameter class (0-5) cm except in the Ekot site which records (15%) in these diameter classes, but whose values decrease steadily to cancel out with in diameter classes(55-60) cm. In observation stations, we identify adominantunder growth shrub layer of diameter class (0-5) cm except in Ekot site where the dominant classes are located between (10-15) cm. As for the analysis of basal are a histograms in Ngatta and Ndogtima creek, basal area is less important because of gaps in the forest. Both recoveries are statistically equal as to their average rate of basal area. The species that contribute to the recovery are shrubs and average trees located between intervals of (10-15) and (55-60). Young trees contribute very little to recovery in the diameter class (0-5cm.). The study of vegetation stations with in the reserve showed a fair distribution of species in the different stations. Trees between 0-5 cm have a higher density than trees with diameter between165-170 cm, thus reflecting natural regeneration ensuring species renewal. The vegetation cover is nevertheless provided by the large diameter trees. All plots are statistically different from each other. In the forest of the Douala-Edea Wildlife Reserve, basal area is 82 m^2 / ha and this coverage is influenced by the presence of trees with large diameters that dominate the forest canopy, these forests of the Douala-Ede are serve are mature, while forests in the coastal zone are young and disturbed.

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