The importance of habitat characteristics for tree diversity in the Mengamé Gorilla Reserve (South Cameroun)

Fongnzossie Fedoung Evariste^{1,*}, Nkongmeneck Bernard-alloys¹, Tsabang Nolé² & Nguenang Guy Merlin¹

¹University of Yaoundé 1, Department of plants science, Laboratory of plant systematic and ecology

²National Institute of Medical Research and Medicinal Plants Studies (IMPM), Laboratory of Botany

*Corresponding author: Fongnzossie Fedoung Evariste, Tel: 00237 77207532, E-mail: fong_nzossie@yahoo.com

ABSTRACT Tree diversity and its relation to habitat was examined using the tree dataset of 57 linear transects totaling 70.2 ha in the Mengamé Gorilla Reserve (MGR), south Cameroon. In nine different habitats defined based on physiognomy and ecological criteria, all trees with average dbh ≥ 10 cm were enumerated. Caesalpiniaceae is the leading dominant family in MGR. Tree diversity totaled 304 species in 192 genera of 51 families. Included are 31 species cited in the IUCN red list of threatened species. Tree density varied from 80 to 366 stems/ha, basal area from 0.06 to 19.82 m²/ha, species richness from 11 to 269 species in each of the nine habitats. When compared with other tropical rainforests in Congo Basin, the results showed great similarities in tree density, family occurrence and Shannon diversity index values. Excluding the marshy grasslands where only 24 trees were recorded, 27 families and 30 species appeared common in the other eight habitats. We examined floristic similarities among the nine habitats using the NNESS similarity index, followed by a Chi-square test. The results revealed that habitat type affected tree composition, the main triggering factors being soil hygrometry, stage of stand development and disturbance. The study emphasizes the importance of the MGR as a refuge of threatened species and reinforces the idea of its inclusion in the African biodiversity hotspot.

Key words: Habitats, species richness, tree diversity, floristic similarities

INTRODUCTION

The Congo Basin forests of Central Africa cover a massive expanse of over 180 million hectares, spreading across the Democratic Republic of Congo (DRC), most of Congo-Brazzaville, the southeastern reaches of Cameroon, southern Central African Republic (CAR), Gabon and Equatorial Guinea. The region comprises 10 per cent of the world's remaining tropical rain and moist forests and forms the second largest block of rainforest in the world, after the Amazon Basin (Dkamela et al. 2009). This area is recognized for its exceptional biodiversity.

Cameroon is part of this vast floristic region and has the second forest cover in Africa after the Democratic Republic of Congo. Based on the work of Letouzey (1985) and Satabié (1997), Cameroon's forests cover an area of over 23 million hectares (11% of the Congo Basin forests), among which are about 17 million ha of dense rainforests and almost 6.5 million ha of degraded and fragmented forests. The area covered by tropical forests in Cameroon is broadly divided into three groups of ecosystems: coastal lowland rainforest, evergreen rainforest and semi-

deciduous ecosystems. Estimates of the number of plant species found in Cameroon are still quite diverse. According to Satabié (1997), this number is 8,000, of which approximately 156 are endemic.

Many tree census plots have been established in forest types throughout tropical regions to assess forest biodiversity (Manokaran et al. 1992, Ashton 1998, Phillips et al. 2003).

In Cameroon, unlike other protected areas like the Dja Biosphere Reserve (Sonké 2005), the Takamanda Forest Reserve (Sunderland et al. 2003), the Campo Ma'an National Park (Tchouto 2004), the Boumba Beck and Nki National Parks (Nkongmeneck 1999), the Korup National Park (Chuyong et al. 2004), where many botanical studies have been conducted, the Mengamé area is among the least botanically explored sites in Cameroon. The finding of a large population of gorilla in this rainforest has led the Cameroonian government in 1998 to establish a protected area devoted to habitat and wildlife conservation. This reserve of 96,500 ha is located along the border with Gabon, in a priority biodiversity corridor as it plays an important role in emerging

transboundary protected areas and partnerships. In order to collect baseline data necessary for developing a sustainable management plan for this reserve, vegetation surveys are underway in the reserve since 2003 with results indicating the presence of nine different habitat types (Nkongmeneck et al. 2004, Fongnzossie et al. 2008): the old secondary rainforest, the young secondary rainforests, the riparian forests, the swampy forests, the periodically flooded forests, *Raphia* forests, cocoa agroforests, crop fields and marshy grasslands. The criteria used to define these habitat types include mainly: the physical environment and soil hygrometry (swamp forest, *Raphia* forest, floodplain forest, riparian forest...), the stage of stand development, density or height, the nature of the forest (young secondary rainforest, old secondary rainforest), the origin and perturbations (crop lands, cocoa agroforests).

This research on aspects of tree diversity has been carried out with the main objective to compare the species diversity of the nine habitat types, and to study variations among habitats. The research focuses on tree species, because tree species diversity is an important aspect of forest ecosystem diversity (Rennolls and Laumonier 2000, Tchouto et al. 2006) and is also fundamental to total tropical forest biodiversity (Huan et al. 2003). The idea is to understand whether the dissimilarity of habitats is significant of real floristic differences.

MATERIALS AND METHODS

Study site

The Mengamé Gorilla Reserve (MGR) consisting of lowland forests is situated in the south Cameroon region, between 2°25' and 2°46'N, 11°85 and 12°65' E (Fig. 1). Altitudes vary from 530 meters in the east to 840 m in the west. The landscape is hilly. A network of rivers pass through the site, the major of which are Mboua in the West, Kom that borders Cameroon and Gabon in the south west and moves north-east, and Ayina that borders Cameroon and Gabon to the east.

The area is subject to a Guinean equatorial climate with four seasons divided as follows:

- a long dry season from December to mid-March;
- a short rainy season from mid-March to June;
- a short dry season in July-August and
- a long rainy season from August to November.

The average annual rainfall is 1710 mm. The average

Fig. 1. Location of the study site.

monthly temperatures vary between 23.8 °C to 26.1 °C.

The vegetation of this region is tropical mixed forest, based on the phytogeographic map of Cameroon (Letouzey 1985).

Data collection

We sampled a total of 57 transects in nine different habitats, 56 of which measured 2500 m × 5 m each, and 1 transect established in marshy grassland measured only 500 m because of overflowing (Fig. 2). The total length of transects was 140.5 km and the total area sampled was 70.25 ha. Along transects, all trees ≥ 10 cm dbh (diameter at breast height) were enumerated and identified. Habitat type was described every 100 m along the baseline. Determination of habitat types was based on physiognomic and ecological criteria, the stage of stand development, density or height, the nature of the forest and the origin of perturbations.

All plant specimens were identified to species using various floras (Letouzey 1982, CENADEFOR 1983, Vivien and Faure 1985, Wilks and Issembé 2000), and various volumes of Flora of Cameroon. Voucher specimens were collected and preserved using standard techniques for herbarium collections. Identification of sample specimens was confirmed at the National Herbarium of Cameroon.

Data analysis

For the floristic analyses, all the data of each habitat type were pooled and the total number of species and

Fig. 2. Transect sampling design in the Mengamé Gorilla Reserve.

individuals were tallied. Using the pooled data, overall species richness, genera and family level richness, stem densities per ha, species diversity and basal area ($\text{m}^2 \text{ha}^{-1}$) were calculated.

For each habitat, the leading dominant taxa were determined by calculating the Species Importance Value Index and the Family Importance value Index respectively.

The importance value Index, defined by Curtis and McIntosh (1950) is the sum of relative frequency, relative abundance and relative dominance of species:

Basal area = $(d^2/4) \times \delta$ where d = DBH.

Relative frequency = $\frac{\text{Number of 100-m transect sections where a species is found}}{\text{Total number of 100-m sections}} \times 100$

Relative abundance = $\frac{\text{Number of individuals of the species}}{\text{Total number of individuals}} \times 100$

Relative dominance = $\frac{\text{Total basal area of the species}}{\text{Total basal area of all species}} \times 100$

IVI = Relative Frequency + Relative Abundance + Relative Dominance.

The family Importance value Index used by Campbell et al. (2006) in the Gamba forest complex in Gabon is the sum of relative density, relative basal area and relative diversity of each family:

$$\text{FIV} = \frac{\text{Number of species of family X}}{\text{Total number of species identified}} + \frac{\text{Number of individuals of family X}}{\text{Total number of individuals}} + \frac{\text{Sum of basal areas of family X}}{\text{Total basal area}}$$

To assess species diversity, Shannon index H ($H = -\sum p_i \ln p_i$, where p_i is the proportion of i^{th} species), as in Magurran (1988) was calculated for all the habitats. This index, formulated on theoretical basis, does not account for tree size and size class variation, and is thus less sensitive when used in forest stands (Lahde et al. 1999). Because of differences in sampled area among habitats, Fisher's Diversity index was also calculated following the iterative methods described by Condit et al. (2004) using the formula $S = \hat{a} \times \ln(1 + N/\hat{a})$, where S is the number of species in a sample of N individuals, and $\hat{a}$ is a constant frequently used as a diversity index.

To assess floristic similarities among habitats, the NNESS similarity index between pairs of habitat type was calculated. The NNESS index of similarity was used because of the difference of size among samples. This index is used to compare with minimum bias the degree of similarity of two samples (i and j) on the basis of an identical data size k taken out at random from each sample. Similarity between two samples (i and j) is expressed by the Morisita-Horn index and by its generalization, the NNESS index, a variant of the NESS

index (Grassle and Smith 1976). The formula is given below and is computed using the software BiodivR 1.0 (Hardy 2005).

$$NNESS_{ij/k} = \frac{ESS_{ij/k}}{(ESS_{ii/k} + ESS_{jj/k})/2}$$

$ESS_{ij/k}$ is the expected number of species shared for random draws (without replacement) of k individuals from sample i and of k individuals from sample j . For each pair of samples, $NNESS_{ij/k}$ is computed for different k values, as long as $k \leq N_i$ (size of sample i).

The more this coefficient is close to 0, the more the two habitats considered have distinct species. The more the ratio approaches 1, the more species of the two habitats are common. The NNESS similarity index was applied to pairs of the nine habitats with four values of k (10, 100, 200 and 300).

Cluster analyses were conducted based on NNESS similarity index with $k = 10$ using PC-ORD 5.0 package (McCune and Mefford 2006). NNESS index was converted to distance measure by subtracting it from 1.

RESULTS

Structural and floristic characteristics of the studied habitats

Overall, the assessment of forest types have revealed that the old secondary forests are the most represented habitat type in the Mengamé reserve and they account for 58.7 % of the sampled area (Table 1). The presence of *Raphia* forest occupying about 20 % of the sampled area is characteristic of the Mengamé reserve. These are natural growing ecosystems forming monodominant swamps in

poorly drained valleys, edges of rivers and streams. Tree density here is relatively low, and the presence of *Raphia hookeri* and *Raphia monbuttorum* is characteristic of these ecosystems.

Tree density was higher in periodically flooded forest and old secondary rainforest while the largest DBH and basal area are recorded in old secondary rainforests.

Except in the marshy grasslands where tree density was very low, the size distribution of the tree species at the eight other habitats resembled the inverse J-shape (Fig. 3). This pattern characterizes a population maintaining a continuous regeneration of trees.

The floristic inventory in the 57 transects has identified a total of 24,160 trees belonging to 304 species, 192 genera and 51 families. Caesalpiniaceae is the leading dominant family in this forest and is among the top five dominant families in the majority of habitat types (Table 2). With regard to botanical families, only eight families (Annonaceae, Apocynaceae, Euphorbiaceae, Lauraceae, Meliaceae, Myristicaceae, Sapotaceae and Sterculiaceae) are common to the nine habitats.

A total of 26 common families were present in at least eight different types of habitat. Among these families, 18 are present in all habitats except marshy grasslands. These are: Anacardiaceae, Bignoniaceae, Bombacaceae, Burseraceae, Caesalpiniaceae, Cecropiaceae, Clusiaceae, Combretaceae, Ebenaceae, Irvingiaceae, Lecythidaceae, Mimosaceae, Moraceae, Olacaceae, Pandaceae, Rubiaceae, Tiliaceae and Ulmaceae.

The families occurring in four to seven different habitats include: Capparidaceae, Passifloraceae, Violaceae, Flacourtiaceae, Rhizophoraceae, Lepidobotryaceae, Rhamnaceae, Rutaceae, Sapindaceae and Samydaceae.

The rare families were those present in only two different habitats and include: Boraginaceae,

Table 1. Stand characteristics of the studied habitats.

Habitat type	Sampled area (ha)	Proportion (%)	Mean DBH (cm)	Max DBH (cm)	Total basal area (m ² ha ⁻¹)	Tree density (stems ha ⁻¹)
Old secondary rainforests	41.21	58.7	27.0	226.8	19.82	374
Young secondary rainforests	2.51	3.6	25.8	143.3	0.70	237
<i>Raphia</i> forests	14.11	20.1	25.8	156.1	4.90	317
Riparian forests	3.17	4.4	26.2	189.8	1.02	286
Swampy forests	2.2	3.1	23.9	127.4	0.70	333
Periodically flooded forests	4.1	5.8	24.5	143.3	1.46	369
Cocoa agroforests	1.45	2.1	32.8	127.4	0.45	165
Crop lands	1.25	1.8	27.3	133.8	0.39	226
Marshy grassland	0.25	0.4	39.2	143.3	0.06	80

Chrysobalanaceae, Dracaenaceae, Hypericaceae,

Fig. 3. Size-class distribution of trees in the nine habitats (a diameter class i comprise trees with $10i \text{ cm} \geq \text{DBH} > 10(i-1) \text{ cm}$).

Table 2. Family Importance Value Index (FIV) for trees ≥ 10 cm DBH of the nine study habitat (in bold-type are the top leading dominant families at each habitat).

N°	Familles	Ca	Cf	Swf	Pff	Rapf	Ripf	Ysrf	Osrf	Mg
1	Anacardiaceae	4,4	8,0	4,7	4,3	4,7	5,0	5,9	4,5	-
2	Annonaceae	20,8	10,1	15,9	41,1	26,3	22,0	16,2	21,1	28,0
3	Apocynaceae	11,1	11,0	8,2	7,5	8,1	6,6	10,4	15,1	33,5
4	Asteraceae	1,6	-	-	-	-	-	-	0,4	-
5	Bignoniaceae	12,3	1,6	2,1	1,8	3,7	2,3	1,7	3,3	-
6	Bombacaceae	4,7	1,5	5,1	2,5	2,0	1,7	3,4	3,7	-
7	Boraginaceae	-	-	-	-	0,7	-	-	1,0	-
8	Burseraceae	5,3	2,6	9,6	8,8	8,9	7,3	6,6	6,6	-
9	Caesalpiniaceae	26,4	26,1	38,1	43,6	36,5	49,1	30,9	30,7	-
10	Capparidaceae	-	-	-	0,9	0,6	0,9	-	0,4	-
11	Cecropiaceae	15,2	43,5	3,4	2,9	2,1	5,0	16,8	7,4	-
12	Chrysobalanaceae	-	-	-	-	0,5	-	-	1,3	-
13	Clusiaceae	1,6	1,8	4,7	4,2	6,1	6,3	3,1	3,6	-
14	Combretaceae	24,7	11,6	1,2	1,7	1,8	3,3	9,0	6,5	-
15	Dracaenaceae	-	-	-	-	0,5	-	-	0,9	-
16	Ebenaceae	1,6	2,4	4,1	6,7	3,5	7,6	1,6	4,9	-
17	Euphorbiaceae	24,2	38,6	21,2	21,8	21,5	26,0	43,3	25,3	18,0
18	Fabaceae	-	-	-	-	10,4	-	-	4,1	-
19	Flacourtiaceae	-	-	1,0	0,8	1,6	1,0	-	3,1	-
20	Hypericaceae	-	-	-	-	-	-	1,5	0,4	-
21	Irvingiaceae	4,0	7,1	9,7	9,9	10,1	11,3	10,8	11,6	-
22	Ixonanthaceae	-	-	-	-	-	-	-	0,5	-
23	Lauraceae	10,0	5,5	1,0	1,8	2,3	1,8	1,4	1,3	14,1
24	Lecythidaceae	2,3	10,9	3,0	2,3	2,8	4,2	11,5	7,9	-
25	Lepidobotryaceae	-	1,7	-	0,8	1,5	1,8	1,1	0,8	-
26	Loganiaceae	-	-	-	2,3	1,6	-	-	-	25,7
27	Melastomataceae	-	-	-	0,8	0,5	0,9	-	-	-
28	Meliaceae	11,2	4,5	31,0	16,1	22,6	13,5	14,1	13,9	16,5
29	Mimosaceae	35,5	21,5	23,2	23,0	14,1	21,1	26,0	18,8	-
30	Moraceae	22,6	5,9	3,1	5,2	3,9	4,9	6,3	5,3	-
31	Myristicaceae	8,0	12,4	9,7	11,9	8,6	10,9	19,8	13,6	14,1
32	Myrtaceae	-	-	-	-	0,6	-	-	0,8	-
33	Ochnaceae	-	-	-	-	1,0	-	-	0,4	-
34	Olacaceae	3,2	3,7	11,3	11,3	17,3	14,5	6,2	10,0	-
35	Oleaceae	-	-	-	0,8	-	-	-	0,4	-
36	Pandaceae	1,8	1,6	1,9	2,3	2,6	1,1	1,1	2,7	-
37	Passifloraceae	-	1,9	-	-	0,7	1,1	-	0,7	-
38	Rhamnaceae	-	2,4	19,3	11,6	6,3	2,9	1,9	1,3	-
39	Rhizophoraceae	-	1,5	-	-	0,6	1,0	1,1	1,1	-
40	Rubiaceae	3,7	1,6	14,8	11,2	16,9	12,9	3,4	7,4	-
41	Rutaceae	9,0	2,0	2,3	2,4	3,0	-	2,3	3,7	-
42	Samydaceae	-	1,5	1,0	1,5	0,8	2,3	2,1	1,5	-
43	Sapindaceae	-	-	4,2	3,6	3,6	4,8	2,4	4,8	15,7
44	Sapotaceae	2,1	5,5	3,0	8,2	4,4	4,7	5,7	8,6	66,9
45	Simaroubaceae	-	-	-	-	-	-	-	0,5	-
46	Sterculiaceae	11,6	16,2	27,1	18,8	23,4	22,1	17,0	16,7	67,6
47	Tiliaceae	7,1	4,4	6,2	2,9	4,7	9,4	3,3	9,5	-
48	Ulmaceae	14,2	30,6	8,7	3,6	5,0	7,7	11,9	10,7	-
49	Verbenaceae	-	-	-	-	-	-	-	0,4	-
50	Violaceae	-	-	-	1,6	0,7	0,9	-	0,5	-
51	Vochysiaceae	-	-	-	-	0,5	-	-	-	-

Legend: Ca = cocoa agroforest. Cf = crop field. Swf = swampy forest. Pff = periodically flooded forest. Rapf = *Raphia* forest. Ripf = riparian forest. Ysrf = young secondary rainforest. Osrf = old secondary rainforest. Mg = marshy grassland.

Myrtaceae, Ochnaceae, Oleaceae, Fabaceae, Melastomataceae and Gentianaceae

Four families (Ixonanthaceae, Simaroubaceae, Verbenaceae, Vochysiaceae) were present in only one habitat type, all represented by one species and few individuals. However, habitat association with rare families must be considered with care because these may simply reflect sampling errors.

The highest number of species (and families) was obtained in old secondary rainforests. Shannon diversity index was higher in young secondary rainforests and riparian forests, while Fisher's alpha Diversity Index was higher in Cocoa agroforest, old secondary rainforest and *Raphia* forest (Table 3).

Habitat association at family level masked finer differences at the species level. It was found that 81 species were present in only one habitat; only four species (*Alstonia boonei*, *Coelocaryon preussii*, *Duguetia staudtii* and *Tabernaemontana crassa*) appeared in all the nine habitats. Excluding the marshy grasslands where only 24 trees were recorded, 30 species appeared in the eight other habitats.

Three species (*Cassia spectabilis*, *Citrus aurantifolia* and *Croton macrostachyus*) were restricted to the cocoa agroforests. *Pseudospondias* sp. and *Berlinia bracteosa* were found only in crop fields and in swamp forests, respectively. *Diospyros preussii*, *Lannea* sp., *Napoleonaea gabonensis*, *Rinorea* sp. and *Schrebera* sp. were only present in periodically flooded forests. *Anthocleista vogelii*, *Antrocaryon Micraster*, *Autranella congolensis*, *Campylospermum reticulatum*, *Canthium arnoldianum*, *Cola gigantea*, *Crudia gabonensis*, *Dacryodes* sp, *Dialium guineense*, *Erismadelphus exsul*, *Erythrophleum guineensis*,

Gambeya perpulchra, *Garcinia epunctata*, *Memecylon memecyloides*, *Mostuea* sp., *Tetracarpidium conophorum* and *Uapaca staudtii* are present only in the *Raphia* forests. *Croton haumanianus* was found only in the riparian forests. A total of 53 species are only present in the old secondary rainforest. Apart from *Albizia* sp. and *Manilkara letouzeyi*, most species absent in the young secondary forests are also absent in the old secondary forests.

The analysis of the IVI scores of species at each forest type showed that the following species are the top leading dominant: *Terminalia superba* in the cocoa agroforest, *Myrianthus arboreus* in the crop field, *Carapa procera* in swampy forest, periodically flooded forest and *Raphia* forest, *Gilbertiodendron dewevrei* in riparian forest, *Petersianthus macrocarpus* in young secondary rainforest, *Tabernaemontana crassa* in old secondary rain forest and *Gambeya lacourtiana* in marshy grasslands (Table 4).

Analysis of floristic similarities

The NNESS similarity index varied from 0.06 to 0.89 (Table 5). With $k = 10$, relatively high similarities were found among the four wetland habitats (periodically flooded forest, swampy forest, *Raphia* forest and riparian forest), as well as between old and young secondary forests. The marshy grasslands generally showed most dissimilar composition from other habitats. These trends were clearly reflected in cluster analysis, which also indicated that old and young secondary forests were clustered with Cocoa agroforest and cropfield (Fig. 4). With k values of 100, 200 and 300, similar results were

Table 3. Number of families, number of species, Fisher's diversity index and Shannon diversity index at the nine studied habitats.

Habitat type	Number of families	Number of species	Shannon Index	Fisher's Diversity Index
Old secondary rainforests	48	269	5.8	46.3
Young secondary rainforests	33	112	6.3	40.8
<i>Raphia</i> forests	45	210	6.2	45.7
Riparian forests	36	136	6.3	44.8
Swampy forests	31	117	5.5	39.3
Periodically flooded forests	37	143	5.4	38.8
Cocoa agroforests	28	90	5.8	52.5
Crop lands	32	86	5.5	42.2
Marshy grassland	10	11	2.1	7.9

Table 4. Importance Value Index (IVI) for the top ten leading dominant species of each of the nine studied habitat (in bold-type are the top leading dominant species at each habitat).

N°	Species	Ca	Cf	Swf	Pff	Ripf	Ysrf	Osrf	Mg	Rapf
1	<i>Albizia adianthifolia</i>	18,5	12,0	-	-	-	4,4	1,2	-	-
2	<i>Albizia zygia</i>	17,2	-	-	1,5	-	5,3	0,4	-	-
3	<i>Alstonia boonei</i>	16,6	12,0	13,0	9,7	8,2	5,4	5,3	20,3	6,1
4	<i>Anonidium mannii</i>	-	35,4	10,1	8,1	19,3	16,6	6,7	-	2,1
5	<i>Anonidium mannii</i>	-	35,4	10,1	8,1	19,3	16,6	6,7	-	2,1
6	<i>Anthocleista</i> sp	-	-	-	2,6	-	-	-	59,4	0,0
7	<i>Beilschmiedia obscura</i>	-	13,1	2,5	8,4	7,5	4,5	2,8	19,3	2,1
8	<i>Bikinia letestui</i>	8,3	35,4	41,1	31,5	12,1	18,8	2,9	-	10,8
9	<i>Blighia welwitschii</i>	-	-	15,8	14,0	17,3	4,5	5,9	20,9	2,2
10	<i>Canarium schweinfurthii</i>	9,4	23,7	19,4	20,3	12,5	18,0	5,0	-	4,7
11	<i>Carapa procera</i>	4,0	-	55,0	32,5	17,9	21,2	4,9	21,7	14,5
12	<i>Celtis tessmannii</i>	5,9	54,7	5,2	4,5	12,0	11,7	6,2	-	2,0
13	<i>Celtis zenkeri</i>	17,9	33,6	11,8	3,9	5,6	14,4	4,7	-	0,6
14	<i>Coelocaryon preussii</i>	4,3	25,5	18,3	15,1	21,4	28,7	6,2	19,3	3,4
15	<i>Cola lateritia</i>	-	-	15,3	1,6	19,9	13,4	4,9	-	5,7
16	<i>Desbordesia glaucescens</i>	-	12,0	16,3	15,9	19,4	8,4	8,2	-	5,2
17	<i>Dialium pachyphyllum</i>	-	-	29,9	10,0	11,0	-	4,1	-	1,2
18	<i>Dialium zenkeri</i>	7,9	41,5	2,6	9,9	9,7	6,8	3,9	-	1,9
19	<i>Diospyros crassiflora</i>	-	16,0	10,4	11,0	21,2	4,8	4,2	-	0,6
20	<i>Distemonanthus benthamianus</i>	14,4	78,5	2,6	11,9	14,4	26,7	7,6	-	3,2
21	<i>Duboscia macrocarpa</i>	12,7	30,1	5,2	2,8	13,0	8,9	7,7	-	1,8
22	<i>Duguetia staudtii</i>	8,7	12,0	22,9	28,1	6,0	16,5	4,4	47,5	6,3
23	<i>Ficus exasperata</i>	19,7	12,8	-	-	-	4,4	0,4	-	-
24	<i>Ficus mucoso</i>	17,8	23,7	-	1,3	-	2,2	0,8	-	0,2
25	<i>Gambeya lacourtiana</i>	7,8	-	7,6	10,0	11,9	4,7	3,0	100,6	0,8
26	<i>Gilbertiodendron dewevrei</i>	-	-	4,1	16,2	28,7	-	1,9	-	2,0
27	<i>Guarea cedrata</i>	22,4	43,1	24,4	10,7	26,4	35,9	6,4	-	5,1
28	<i>Heisteria zimmereri</i>	3,9	23,7	15,3	12,5	21,2	4,5	3,6	-	4,6
29	<i>Lasiodiscus mannii</i>	-	-	45,8	28,4	11,9	-	0,5	-	5,8
30	<i>Macaranga</i> sp	10,2	39,4	-	7,7	-	27,5	3,6	-	0,8
31	<i>Markhamia lutea</i>	26,1	12,4	14,9	3,9	2,3	8,8	3,1	-	1,9
32	<i>Mitragyna stipulosa</i>	-	-	31,3	8,5	17,8	-	1,1	-	11,4
33	<i>Musanga cecropioides</i>	13,5	97,9	5,0	3,8	12,2	30,8	5,5	-	0,5
34	<i>Myrianthus arboreus</i>	27,0	98,2	8,1	2,6	9,1	27,0	6,6	-	0,7
35	<i>Parkia bicolor</i>	4,4	12,4	10,3	8,9	19,7	-	5,0	-	2,0
36	<i>Persea americana</i>	22,6	31,4	-	-	-	-	3,1	-	-
37	<i>Petersianthus macrocarpus</i>	4,7	59,2	15,8	5,7	11,5	44,0	8,1	-	2,8
38	<i>Piptadeniastrum africanum</i>	-	55,2	25,7	9,6	19,0	9,6	5,6	-	1,8
39	<i>Plagiostyles africana</i>	3,9	39,4	13,9	18,0	7,5	27,2	7,0	-	3,5
40	<i>Pterocarpus mildbraedii</i>	-	-	24,0	5,4	9,3	-	3,6	-	3,7
41	<i>Pterocarpus soyauxii</i>	14,7	-	4,9	20,1	5,6	23,8	2,2	-	9,1
42	<i>Pycnanthus angolensis</i>	13,7	55,5	17,7	17,5	6,0	32,5	7,9	-	3,2
43	<i>Santiria trimera</i>	-	12,0	26,2	18,9	6,2	13,7	3,2	-	3,8
44	<i>Sterculia subviolacea</i>	-	-	54,2	30,2	10,7	8,8	3,1	87,1	8,4
45	<i>Strombosiaopsis tetrandra</i>	-	12,0	41,5	24,8	6,5	14,8	3,9	-	11,0
46	<i>Tabernaemontana crassa</i>	7,9	25,2	9,4	6,4	7,4	31,8	9,7	37,8	1,3
47	<i>Terminalia superba</i>	44,1	40,1	2,6	-	5,7	8,4	5,0	-	0,7
48	<i>Uapaca guineensis</i>	-	12,0	-	3,9	10,1	7,9	2,6	23,2	0,9
49	<i>Xylopia staudtii</i>	3,9	-	-	22,8	7,6	-	1,6	-	2,8

Legend: Ca = cocoa agroforest. Cf = crop field. Swf = swampy forest. Pff = periodically flooded forest. Rapf = *Raphia* forest. Ripf = riparian forest. Ysrf = young secondary rainforest. Osrf = old secondary rainforest. Mg = marshy grassland.

Table 5. NNESS similarity index values with k values 10, 100, 200 and 300 for couples of habitats. In bold-type are the five most similar pairs of habitats.

Samples	NNESS index values for K = 10								
	Ca	Cf	Swf	Pff	Rapf	Ripf	Ysrf	Osrf	Mg
Ca	1.00								
Cf	0.51	1.00							
Swf	0.22	0.23	1.00						
Pff	0.22	0.24	0.77	1.00					
Rapf	0.30	0.29	0.85	0.84	1.00				
Ripf	0.34	0.36	0.59	0.69	0.75	1.00			
Ysrf	0.53	0.74	0.46	0.46	0.58	0.57	1.00		
Osrf	0.49	0.53	0.47	0.46	0.63	0.73	0.77	1.00	
Mg	0.09	0.06	0.26	0.33	0.27	0.25	0.25	0.26	1.00

Samples	NNESS index values for K = 100								
	Ca	Cf	Swf	Pff	Rapf	Ripf	Ysrf	Osrf	Mg
Ca	1.00								
Cf	0.64	1.00							
Swf	0.45	0.49	1.00						
Pff	0.46	0.49	0.74	1.00					
Rapf	0.52	0.55	0.86	0.88	1.00				
Ripf	0.53	0.58	0.77	0.82	0.87	1.00			
Ysrf	0.67	0.73	0.67	0.65	0.72	0.70	1.00		
Osrf	0.67	0.73	0.77	0.74	0.84	0.85	0.83	1.00	
Mg									

Samples	NNESS index values for K = 200								
	Ca	Cf	Swf	Pff	Rapf	Ripf	Ysrf	Osrf	Mg
Ca	1.00								
Cf	0.61	1.00							
Swf	0.52	0.53	1.00						
Pff	0.51	0.55	0.74	1.00					
Rapf	0.57	0.60	0.86	0.88	1.00				
Ripf	0.57	0.62	0.78	0.83	0.88	1.00			
Ysrf	0.66	0.73	0.67	0.66	0.74	0.72	1.00		
Osrf	0.70	0.74	0.81	0.79	0.88	0.86	0.83	1.00	
Mg									

Samples	NNESS index values for K = 300								
	Ca	Cf	Swf	Pff	Rapf	Ripf	Ysrf	Osrf	Mg
Ca									
Cf									
Swf			1.00						
Pff			0.74	1.00					
Rapf			0.86	0.88	1.00				
Ripf			0.78	0.83	0.88	1.00			
Ysrf			0.67	0.67	0.74	0.72	1.00		
Osrf			0.82	0.80	0.89	0.86	0.82	1.00	
Mg									

Legend: Ca = cocoa agroforest. Cf = crop field. Swf = swampy forest. Pff = periodically flooded forest. Rapf = *Raphia* forest. Ripf = riparian forest. Ysrf = young secondary rainforest. Osrf = old secondary rainforest. Mg = marshy grassland.

Fig. 4. Hierarchical classification of habitat types using cluster analysis (PC-ORD 5.0).

obtained. However, old secondary forests showed higher similarity with riparian and *Raphia* forests than with young secondary forests.

These analyses have shown that habitat type has significant influence on species composition in MGR, the main triggering factors being the soil hygrometry, the stage of stand development and disturbances.

Conservation status of plant species identified

Among the 304 species identified, 31 are listed in the IUCN red list of threatened species: two species are

critically endangered (*Autranella congolensis* and *Bikinia hedinii*), two are endangered (*Diospyros crassiflora* and *Gossweilerodendron basalmiferum*), 27 are in a category of vulnerable species (Table 6).

DISCUSSION

The MGR comprises a mosaic of various forest types. This great variety of ecosystems gives its intact habitats a high conservation value. Physiognomically, the different habitat types found in the reserve are similar to those described in the Dja Reserve (Sonké 2005). Similar habitat types are described in the Boumba Bek and Nki national parks (Nkongmeneck 1999). Among these habitats, secondary rainforests occupy nearly 63.3 % of sample area in MGR. This observation is in line with the conclusions of Rollet (1974) according to which most tropical rainforests in the world are old secondary forests that have undergone a development of their original tree stock after natural and/or anthropogenic disturbance. The proportion of secondary forest in this reserve is close to those obtained by Dupain et al. (2004) who

Table 6: Threatened and endangered species listed in the Mengamé gorilla reserve with reference to IUCN red list 2009.

N°	Species	Family	IUCN Category
1	<i>Autranella congolensis</i>	<i>Sapotaceae</i>	Critically Endangered (CE)
2	<i>Bikinia hedinii</i>	<i>Caesalpiniaceae</i>	Critically Endangered (CE)
3	<i>Diospyros crassiflora</i>	<i>Ebenaceae</i>	Endangered (E)
4	<i>Gossweilerodendron basalmiferum</i>	<i>Caesalpiniaceae</i>	Endangered (E)
5	<i>Azelia bipindensis</i>	<i>Caesalpiniaceae</i>	Vulnerable (VU)
6	<i>Albizzia ferruginea</i>	<i>Mimosaceae</i>	Vulnerable (VU)
7	<i>Anoxyxis klaineana</i>	<i>Rhizophoraceae</i>	Vulnerable (VU)
8	<i>Antrocaryon micraster</i>	<i>Anacardiaceae</i>	Vulnerable (VU)
9	<i>Baillonella toxisperma</i>	<i>Sapotaceae</i>	Vulnerable (VU)
10	<i>Cordia platythyrsa</i>	<i>Tiliaceae</i>	Vulnerable (VU)
11	<i>Entandrophragma candollei</i>	<i>Meliaceae</i>	Vulnerable (VU)
12	<i>Entandrophragma cylindricum</i>	<i>Meliaceae</i>	Vulnerable (VU)
13	<i>Entandrophragma utile</i>	<i>Meliaceae</i>	Vulnerable (VU)
14	<i>Eribroma oblonga</i>	<i>Sterculiaceae</i>	Vulnerable (VU)
15	<i>Garcinia afzelii</i>	<i>Clusiaceae</i>	Vulnerable (VU)
16	<i>Garcinia kola</i>	<i>Clusiaceae</i>	Vulnerable (VU)
17	<i>Guarea cedrata</i>	<i>Meliaceae</i>	Vulnerable (VU)
18	<i>Guarea thompsonii</i>	<i>Meliaceae</i>	Vulnerable (VU)
19	<i>Lophira alata</i>	<i>Ochnaceae</i>	Vulnerable (VU)
20	<i>Lovoa trichilioides</i>	<i>Meliaceae</i>	Vulnerable (VU)
21	<i>Macaranga paxii</i>	<i>Euphorbiaceae</i>	Vulnerable (VU)
22	<i>Hallea stipulosa</i>	<i>Rubiaceae</i>	Vulnerable (VU)
23	<i>Nauclea pobeguinii</i>	<i>Rubiaceae</i>	Vulnerable (VU)
24	<i>Nesogordonia papaverifera</i>	<i>Sterculiaceae</i>	Vulnerable (VU)
25	<i>Pterygota macrocarpa</i>	<i>Sterculiaceae</i>	Vulnerable (VU)
26	<i>Rhodognaphalon brevicuspe</i>	<i>Euphorbiaceae</i>	Vulnerable (VU)
27	<i>Turraeanthus africana</i>	<i>Meliaceae</i>	Vulnerable (VU)
28	<i>Chlorophora excelsa</i>	<i>Moraceae</i>	Near Threatened (NT)
29	<i>Irvingia gabonensis</i>	<i>Irvingiaceae</i>	Near Threatened (NT)
30	<i>Entandrophragma excelsa</i>	<i>Meliaceae</i>	Least Concern (LC)
31	<i>Triplochiton scleroxylon</i>	<i>Sterculiaceae</i>	Least Concern (LC)

estimated the proportion of secondary forest at 65.8% for Ntonga site in the north of the Dja Reserve in Cameroon, and by Van Germerden and Hazeu (1999) who estimated secondary forests percentage at between 40 and 60% in the Campo Ma'an area in southern Cameroon. FAO, using a similar classification, distinguishing old secondary rainforests and young secondary rainforests estimated at 72.6% the proportion of the secondary forests in Cameroon (Bonnehin 2003). Letouzey (1985) and Nkongmeneck (1998) extensively described this process of secundarisation in tropical forests of Africa with emphasis on human disturbance and the action of

elephants. Mbida et al. (2001) points out the expansion of agriculture and Vermeleun (2000) reported several sites of ancient villages dating a little over half century in the Dja Biosphere Reserve.

Analysis of the floristic composition of different habitats in MGR showed that Caesalpiniaceae is the most diversified and the most frequent family. The importance of Caesalpiniaceae, Rubiaceae, Euphorbiaceae, Mimosaceae, Sterculiaceae, Annonaceae and Apocynaceae is reported by Doucet (2003) in central Gabon forests, Sonké (2005) in the Dja Biosphere Reserve and Nkongmeneck (1999) in the Boumba Beck

and Nki national parks in south east Cameroon. The importance of Caesalpiniaceae in MGR is seen not only in terms of species occurrence, but also in terms of tree density and basal area (Fongzossie et al. 2008).

The number of species (304) recorded in the present study was found to be more or less close to the number of species reported by other researchers in the different rainforests of Congo Basin using similar methodologies: 390 species in the Boumba Bek national park and 372 species in the Nki national park (Nkongmeneck 1999).

The average stand density of MGR is 344.15 stems/ha and average basal area is 29.66 m²/ha. Sonké (2005) obtained in the Dja Biosphere Reserve in East Cameroon, density values ranging from 368 to 645 stems/ha. Overall, the ecologically important species of MGR, based on their IVI scores comprise a majority of pioneer or disturbance indicator species like *Terminalia superba*, *Myrianthus arboreus*, *Tabernaemontana crassa*, *Petersianthus macrocarpus*. All these features portray an overall helophytic trend of the vegetation in this forest.

The Shannon diversity index of the whole forest was 6.75. Although this value may not be meaningfully compared with those from other surveys where different methodologies were used, the values of diversity index of the present study, lies within the range reported for most of the Congo Basin tropical forests. The values of the Shannon index obtained were close to values obtained by Sonké (2005) in the Dja Biosphere Reserve in south Cameroon (5.24 to 6.07); Senterre and Nguema (2001) in the Nsork forest in Equatorial Guinea (5.79). Clearly, the tropical forests of Africa do not reach the extreme degree of biodiversity that is observed in some tropical forests of Asia and South America. Indeed, Comiskey et al. (2001) identified 307 species (DBH $\geq$ 4) in a single plot of 1 ha in south-west of Peru. Millet (2004) reports Shannon index values of 8.00 in Tai Phu forest (Vietnam). However, the values of Shannon diversity index obtained in MGR are consistent with Tchouto (2004) and Adou Yao (2005); who states that the diversity produced by the only individuals of DBH $\geq$ 10 cm doesn't reflect all the diversity of a given area. Meanwhile, MGR remains among the richest sites throughout tropical Africa and in this respect, is similar to other Guineo-Congolian forests, such as the Lopé National Park, Gabon (Tutin et al. 1994), the Korup National Park, Cameroon (Chuyong et al. 2004), the Takamanda Forest Reserve Cameroon (Sunderland et al. 2003) and the Dja Biosphere Reserve (Sonké 2005).

In the whole study area, the old secondary rainforests were the sites where the greatest number of species was recorded (269). This great diversity of

species in this ecosystem can be explained by the theory of disturbance according to which a forest stand reaches its maximum diversity under intermediary disturbance regime. In the opposite, the poorest habitat in species (10) is found in marshy grasslands. This poverty is due to the fact that it is located in a very swamp zone where *Scleria spiciformis* (Cyperaceae) is the most abundant species. The permanent presence of water would have influenced the species richness of these zones.

Comparison of Fisher's alpha diversity index has shown increasing values from marshy grasslands to periodically flooded forest, swampy forest, young secondary rainforest, crop fields, riparian forest, *Raphia* forest, old secondary rainforest and cocoa agroforest. The analysis of floristic similarities showed that habitat type significantly influence species composition in MGR, the main triggering factors being the soil hygrometry, the stage of stand development and disturbance. This observation falls in line with the studies of Whitmore (1993) describing that tree diversity in tropical forests varies greatly from place to place, mainly due to variation in biogeography, habitat and disturbance.

ACKNOWLEDGMENTS This research was financially supported by the grant from the Jane Goodall Institute (Mengamé Gorilla Reserve Project) and the Disney Wildlife Conservation Fund. We wish to express our gratitude to the Director, staff and volunteers of the Mengamé Gorilla Reserve Project, for their supportive assistance during this study. We would like to extend our thanks to our Baka field guides (Balouma Jean Marie and Apalo Paul) and residents of all the adjacent communities for their co-operation, assistance and warm hospitality during the survey. Our sincere gratitude also goes to Prof. Laurent AKE ASSI and the National Herbarium of Cameroon for their assistance in identifying the numerous plant specimens collected during this study. We finally acknowledge M. Godswill Ntsomboh Ntsefong of the Agricultural Research Institute of Dibamba for proofreading this work.

REFERENCES

- Adou Yao, C.Y. 2005. Pratiques paysannes et dynamiques de la biodiversité dans la forêt classée de Monogaga (Côte d'Ivoire). Thèse de doctorat unique, département Hommes Natures Sociétés, MNHN, Paris, 233 p.
- Aiba, S. & Kitayama, K. 1999. Structure, composition and

- species diversity in an altitude-substrate matrix of rain forest tree communities on Mount Kinabalu, Borneo. *Plant Ecology* **140**: 139-157.
- Ashton, P.S. 1998. A global network of plots for understanding tree species diversity in tropical forests. In: *Forest Biodiversity Research, Monitoring and Modeling: Conceptual Background and Old World Case Studies* (eds. Dallmeier, F. & Comiskey, J.A.). pp. 47-62. UNESCO, Parthenon Publishing, Pearl River, NY.
- Bonnéhin, L. 2003. La gestion des forêts tropicales secondaires en Afrique: réalités et perspectives. Document thématique #2: Sur les aspects socioéconomiques des forêts secondaires en Afrique centrale et occidentale francophone. Actes de l'atelier FAO/EC LNV/GTZ Douala, Cameroun, 17 – 21 novembre 2003. 42 p.
- Campbell, P., Rivera, P., Thomas, D., Boubou-Boubou, H., Nzabi, T., Alonso, A. & Dallmeier, F. (eds.) 2006. *Bulletin of the Biological Society of Washington* **12**: 29-52.
- CENADEFOR (eds.) 1983. Manuel de Dendrologie (Cameroun), ONADEF (Office National de Développement Forestier), Yaoundé. 639 pp.
- Chuyong, G.B., Condit, R., Kenfack, D., Losos, E., Sainge, M., Songwe, N.C. & Thomas, D.W. 2004. Korup Forest Dynamics Plot, Cameroon. In: *Forest Diversity and Dynamism: Findings from a network of large-scale tropical forest plots*. (eds. Losos, E.C. & Leigh, E.G.) Chapter 29. University of Chicago Press, Chicago, IL.
- Comiskey, J.A., Campbell, P., Alonso, A., Mistry, S., Dallmeier, F., Nuñez, P., Beltrán, H., Baldeón, S., Nauray, W., De la Colina, R., Acurio, L. & Urdary, S., 2001. The vegetation communities of the Lower Urubamba Region, Peru. In: *Urubamba: the Biodiversity of a Peruvian Rainforest. SIMAB Series #7* (eds. Alonso, A., Dallmeier F. & Campbell, P.), pp. 9-32. Smithsonian Institution Monitoring and Assessment of Biodiversity Program, Washington, D.C.
- Condit, R.S., Leigh, J., Giles, E., Loo de Lao, S., Ashton, M.S., Brokaw, N.V.L., Bunyavechwin, R., Chuyong, G.B., Co, L.L., Dattaraja, H.S., Davies, S.J., Esufali, S., Ewango, C.E.N., Foster, R.B., Gunatilleke, N., Gunatilleke, S., Hart, T.H., Hernandez, C., Hubbell, S.P., Itoh, A., John, R., Kanzaki, M., Kenfack, D., Kiratiprayoon, S., LaFrankie, J.V., Hua-Seng, L., Liengola, I., Makana, J.R., Manokaran, N., Hernandez, M.N., Ohkugo, T., Perez, R., Pongpattananurak, N., Samper, C., Sri-ngernyuang, K., Sukumar, R., Fun, L.F., Sureh, H.S., Tan, S., Thomas, D.W., Thompson, J.D., Vallejo, M.I., Munoz, G.V., Valencia, R., Yamakura, T. & Zimmerman, J.K. 2004. Species-area relationships and diversity measures in the forest dynamics plots. In: *Tropical forest diversity and dynamism: Findings from a large-scale plot network* (eds. Elizabeth, C., Losos, J.R., & Leigh, E.G.), pp 79-89. University of Chicago Press.
- Curtis, J.T. & McIntosh, R.P. 1950. The interrelations of certain analytic and synthetic phytosociological characters. *Ecology* **31**: 434-455.
- Dkamela, G. P., Kabamba, F., Mbambu, Kemen, A., Minnemeyer, S. & Stolle, F. 2009. "Voices from the Congo Basin: Incorporating the Perspectives of Local Stakeholders for Improved REDD Design." WRI Working Paper. World Resources Institute, Washington DC. 8p.
- Doucet, J.L. 2003. L'alliance délicate de la gestion forestière et de la biodiversité dans les forêts du centre du Gabon. Thèse de Doctorat. Faculté universitaire des sciences agronomiques de Gembloux. 390p.
- Dupain, J., Guislain, P., Nguenang, G.M., De Vleeschouwer, K. & Van Elsaker, L. 2004. High chimpanzee density in a non protected area on the northern periphery of the Dja faunal reserve, Cameroon. *Oryx* **38**: 209-215.
- Fongnzossie, F.E., Tsabang, N., Nkongmeneck, B.A., Kamou, E., Auzel, P., Ellis, C., Halford, M., Valbuena, M., Mengue, V., Balouma, J.M. & Apalo, P. 2008. Les peuplements d'arbres du sanctuaire à gorilles de Mengamé. *Tropical Conservation Science Journal*. September 2008 [Vol.1| Issue3] pp. 163–306. <http://tropicalconservationscience.mongabay.com/content/v1/08-09-15-toc.html>.
- Grassle, J. F. & Smith, W. 1976. A similarity measure sensitive to the contribution of rare species and its use in investigation of variation in marine benthic communities. *Oecologia* **25**: 13-22.
- Hardy, O. 2005. BiodivR 1.0. A program to compute statistically unbiased indices of species diversity within samples and species similarity between samples using rarefaction principles. User's manual. Laboratoire Eco-éthologie Evolutive, CP160/12. Université Libre de Bruxelles. 5p.
- Huang, W., Pohjoenen, V., Johansson, S., Nashanda, M., Katigula, M.I.L. & Luukkanen, O. 2003. Species diversity, forest structure and species composition

- in Tanzanian tropical forests. *Forest Ecology and Management* **173**: 11–24.
- IUCN (eds.) 2009. The IUCN red list of threatened species. Base de données Internet. <http://www.iucnredlist.org/search>.
- Lahde, E., Laiho, O., Norokorpi, Y. & Saksa, T. 1999. Stand structure as the basis of diversity index. *Forest Ecology and Management* **115**: 213–220.
- Letouzey, R. 1982. Manuel de botanique forestière. Afrique tropicale, CTFT, Tome 2A et 2B. 461 p.
- Letouzey, R. 1985. Carte phytogéographique du Cameroun et notice. Inst. Carte. Internat. Vegetation, Toulouse. 240 p.
- Magurran, A. 1988. Ecological Diversity and its Measurement, Princeton University Press, New Jersey. 179 p.
- Manokaran, N., Lafrankie, J.V., Kochummen, K.M., Quah, E.S., Klahn, J., Ashton, P.S. & Hubbell, S.P. 1992. Stand Table and Distribution of Species in the 50 ha research plot at Pasoh Forest Reserve. Forest Research Institute of Malaysia, Kepong, Malaysia.
- Mbida, C.M., Doutrelepong, H., Vrydaghs, L., Swennen, R.L., Swennen, R.J., Beeckman, H., De Langhe, E. & De Maret, P. 2001. First archaeological evidence of banana cultivation in central Africa during the third millennium before present. *Vegetation history and archeology* **10**: 1–6.
- McCune, B. & Mefford, M.J. 2006. PC-ORD. Multivariate analysis of ecological data. Version 5. MjM Software, Gleneden Beach, Oregon, USA.
- Millet, J. 2003. Etude de la biodiversité arborée, de la structure et de l'évolution dynamique du massif forestier de Tan Phu (Vietnam) après son exploitation. Thèse de Doctorat présentée devant l'Université Claude Bernard – Lyon 1. 213 p.
- Nkongmeneck, B.A. 1998. Processus de secondarisation en forêt dense humide camerounaise. In La gestion des forêts denses africaines aujourd'hui. Séminaire FORAFRI, Libreville (eds. Nasi et al.). 7 p.
- Nkongmeneck, B.A. 1999. The Boumba Beck and Nki forest reserve. Botany and ethnobotany. WWF technical reports. 226p.
- Nkongmeneck, B.A., Tsabang, N., Fongnzossie, F.E., Halford, M., Valbuena, M., Kamou, E., Auzel, P., Ellis, C., Balouma, P., Apalo, P. & Mengue, V. 2004. Etude botanique du sanctuaire à gorilles de Mengine (Sud-Cameroun): Ressources ligneuses, faciès de végétation, degré de perturbation et sous-bois. Rapport Technique No 4, MINEF/IRAD/ Université de Yaounde1/Jane Goodall Institute. 64p.
- Phillips, O.L., Martinez, R.V., Vargas, R.N., Monteagudo, A.L., Zans, M.C., Sanchez, W.G., Cruz, A.P., Timana, M., Yli-halla, M. & Rose, S. 2003. Efficient plot-based floristic assessment of tropical forests. *Journal of Tropical Ecology* **19**: 629–645.
- Rennolls, K. & Laumonier, Y. 2000. Species diversity structure analysis at two sites in the tropical rainforest of Sumatra. *Journal of Tropical Ecology* **16**: 253–270.
- Rollet, B. 1974. L'architecture des forêts denses humides sempervirentes des plaines :Paris CTFT. 298 p.
- Satabié, B. 1997. La flore forestière du Sud-Cameroun. In : Proceedings du séminaire organisé à Yaoundé par le projet ASB sur le thème «Caractérisation biophysique de la zone forestière humide du Cameroun » (eds. ASB). 47 p.
- Senterre, B. & Nguema, N. 2001. La diversité des ligneux dans la forêt de Nsork (Guinée équatoriale). *Systematics and Geography of Plants* **71**: 837–846.
- Sonké, B. 2005. Forêts de la réserve du Dja (Cameroun). Thèse de Doctorat, Université libre de Bruxelles. 141pp.
- Sunderland, T.C.H., Comiskey, J.A., Besong, S., Mboh, H., Fonwebong, J., & Abwe, Dione M. 2003. Vegetation assessment of the Takamanda forest reserve. In *Takamanda: the biodiversity of an African rainforest*. (eds. SI/MAB Series # 8). Smithsonian Institution, Washington D.C. 182 pp.
- Tchouto, M.G.P. 2004. Plant diversity in a central African rainforest. Implications for biodiversity conservation in Cameroon. PhD thesis. Department of plant sciences. Biosystematics group. Wageningen University, the Netherlands. 206 p.
- Tchouto, G.P., De Boer, W.F., De Wilde, J.J.F.E. & Van der Maesen, L.J.G. 2006. Diversity Patterns in the Flora of the Campo-Ma'an Rain Forest, Cameroon: Do Tree Species Tell it All? *Biodiversity and Conservation* **15**: 1353–1374.
- Tutin, C.E.G., White, L.J.T., Williamson, E.A., Fernandez, M. & Mcpherson, G. 1994. List of plant species identified in the northern part of the Lopé reserve, Gabon. *Tropics* **3**: 249–276.
- Van Gernerden, B.S. & Hazeu, G.W. 1999. Landscape ecological survey (1:100 000) of the Bipindi-Akom II-Lolodorf region, southwest Cameroon. Wageningen (The Netherlands). Tropenbos-Cameroon Documents 1, Kribi. 232 p.
- Vermeleun, C. 2000. Le facteur humain dans l'aménagement des espaces ressources en Afrique centrale forestière: application aux Badjoué de l'Est

- Cameroun. Thèse de Doctorat. Faculté universitaire des sciences agronomiques de Gembloux. 344 p.
- Vivien, J. & Faure, J.J. 1985. Arbres des forêts denses d'Afrique Centrale. Ministère des relations extérieures. Coopération et Développement, ACT, Paris. 376p.
- Whitmore, T.C. 1993. An Introduction to Tropical Rain Forests, Oxford University Press, Oxford. 226 p.
- Wilks, C.M. & Issembé, Y. 2000. Guide pratique d'identification des arbres de la guinée équatoriale, région continentale. Projet CUREF Bata Guinée Equatoriale. 546 p.

Received 10th Mar. 2010

Accepted 27th Aug. 2010