

# Characterization and Conservation Status of Evergreen Rainforest Understory: Case of Campo Ma'an National Park (Cameroon)

Kabelong Banoho Louis-Paul-Roger<sup>1, \*</sup>, Zapfack Louis<sup>1</sup>, Weladji Robert Bertrand<sup>2</sup>, Nasang Julliete Mancho<sup>1</sup>, Chimi Djomo Cedric<sup>1</sup>, Nyako Melanie Chichi<sup>1</sup>, Madountsap Tagnang Nadège<sup>1</sup>, Essono Damien Marie<sup>1</sup>, Sahnone Pambouro Jean Marc<sup>3</sup>, Remi Jiagho<sup>4</sup>, Kwomegne Tchoupo Leonce Morel<sup>1</sup>, Tabue Mbobda Roger Bruno<sup>1</sup>, Palla Florence Jeanne Sarah<sup>5</sup>

<sup>1</sup>Department of plant Biology, Faculty of Science, University of Yaounde I, Yaounde, Cameroon

<sup>2</sup>Department of Biology, Concordia University, Québec, Canada

<sup>3</sup>The Higher Institute of the Sahel, University of Maroua, Maroua, Cameroon

<sup>4</sup>International Union for Conservation of Nature, Yaounde, Cameroon

<sup>5</sup>IUCN World Commission on Protected Area, Yaounde, Cameroon

## Email address:

[rogerbanoho@yahoo.fr](mailto:rogerbanoho@yahoo.fr) (K. B. Louis-Paul-Roger)

\*Corresponding author

## To cite this article:

Kabelong Banoho Louis-Paul-Roger, Zapfack Louis, Weladji Robert Bertrand, Nasang Julliete Mancho, Chimi Djomo Cedric, Nyako Melanie Chichi, Madountsap Tagnang Nadège, Essono Damien Marie, Sahnone Pambouro Jean Marc, Remi Jiagho, Kwomegne Tchoupo Leonce Morel, Tabue Mbobda Roger Bruno, Palla Florence Jeanne Sarah. Characterization and Conservation Status of Evergreen Rainforest Understory: Case of Campo Ma'an National Park (Cameroon). *Journal of Plant Sciences*. Vol. 6, No. 4, 2018, pp. 107-116. doi: 10.11648/j.jps.20180604.11

**Received:** July 22, 2018; **Accepted:** August 7, 2018; **Published:** August 30, 2018

**Abstract:** The Campo Ma'an National Park is located in the evergreen rainforest area rich in biological diversity. This biological diversity remains poorly known, especially those of the understory. The objective of the present study is to characterize undersotory tree and to determine their IUCN conservation status. To know the floristic diversity of understory (5 cm  $\leq$  dbh < 10 cm) of this forest, a tree inventory using the plots method of 25 m x 25 m, in which 36 plots were placed out on 6 transects of 4 km each. The IUCN Red List was used to determine the status of inventoried species. The result showed a total richness of 256 species belonging to 148 genera and 50 families for the entire site has been identified. The Shannon diversity index is 4.90 and 4.02 for Old secondary forest (OSF) and Secondary forest (SFO), respectively. The floristic background belongs to the field of Guinean-Congolese endemism, with 6 endemic species in Cameroon. The conservation status analysis shows that 22 species are listed as endangered in the red list of the International Union for the Conservation of Nature. This study provides a base for reflection on the integration of understory trees species in inventories and in the development of conservation strategies.

**Keywords:** Evergreen Rainforest, Floristic Diversity, Endemism, Conservation Status, Campo Ma'an National Park

## 1. Introduction

Central African forests have remarkable biological diversity and play an important role in the well-being of people and provide shelter for wildlife [1]. However, they are

subject to anthropogenic activities contributing to their degradation. It is for this reason that they receive more and more attention internationally. It is in this sense that the conservation of biodiversity appears to be one of the main objectives set out in the Convention on Biological Diversity (CBD) and in many global and national conservation

strategies [2]. Nevertheless, until now, the conservation of plant diversity has received much less attention than the conservation of animals, because plants do not have the popular appeal of many groups of animals [3]. However, floristic diversity is an indicator that allows us to appreciate the links between the richness and abundance of trees. It also reflects the degree of heterogeneity and stability of vegetation [4]. It is home to a remarkable wildlife species that depends largely on its products and habitat for their survival. In order to better conserve biological diversity, it is important to first know have a good knowledge about it. The Global Strategy for Plant Conservation agreed at the CBD meeting in Nagoya in 2010 to include, as a primary goal for 2020, "an online flora of all known plants" [5]. This objective explicitly omits several species as being unknown to science [5]. [6] estimated the total number of angiosperm species at about 450,000, of which 10% to 20% are still unknown to science.

The majority of studies on floristic diversity in tropical moist forests are limited to tree species with a diameter at breast height (dbh)  $\geq 10$  cm as a reflection of the floristic composition and physical structure of tropical forest ecosystems [7-13]. This traditional flora inventory approach may not be sufficient for the assessment of plant diversity because, other taxa belonging to other forms of life, such as shrubs, small trees, lianas, herbaceous plants, and epiphytic flora are not taken into account [14].

Many plans and management strategies of tropical forests, tools of sustainable management do not always take into account tree understory [15]. But some trees can stay in the understory stages all their life because of the competition [14]. These trees can sometimes disappear before being known by science [16]. Most African countries including Cameroon have based their biodiversity conservation strategy on the creation and extension of protected areas (PA) [17-18]. However, even in these protected areas, the development of management plans does not take into account the specificities of understory (small diameter trees of  $5 \text{ cm} \leq \text{dbh} < 10 \text{ cm}$ ) or their conservation status, because these are most often neglected during floristic inventories; therefore, they remain little or unknown to science.

The Campo Ma'an National Park was erected in 2000 as compensation for the destruction of biodiversity during the construction of the Chad-Cameroon pipeline. It is a park located in an evergreen rainforest area, home to a remarkable biological diversity [14]. The management plan for this protected area, developed in 2014 for the period 2015-2020, presents the endemic and endangered species of the area without differentiating the strata or where are found. This management plan, like other tropical forest conservation plans and strategies, does not always take into account the specificities of understory trees, because the floristic studies carried out for their development often concern trees of  $\text{dbh} \geq 10 \text{ cm}$ . In addition, it is important to appreciate the floristic diversity of this tree strata in the different types of forest, because the impact of man on the different forests leaves more or less the marks with the time, this in order to arouse

their study and also systematically integrate this stratum into the development of conservation strategy in tropical forests. The objective of the present study is therefore to characterize trees of  $5 \text{ cm} \leq \text{dbh} < 10 \text{ cm}$  and to determine their IUCN conservation status in order to evaluate their inclusion in conservation strategies.

## 2. Material and Methods

### 2.1. Study Site

The Campo National Park is located in the southern part of Cameroon. It is located in the Ocean Division, between the Ntem Valley and the Mvila. It covers approximately 260,443 ha and extends between latitudes  $2^{\circ}10'-2^{\circ}52'N$  and longitudes  $9^{\circ}50'-10^{\circ}54' E$ . In accordance with the Food and Agriculture Organization (FAO) classification system, soils in the Campo-Ma'an region are generally classified as ferrasols and acrisols [19]. They are strongly altered, deep to very deep and clay to sandy texture around watercourses, acidic and nutrient-poor with pH values generally around 4. The altitude generally low, is from sea level (0 m) at about 500 m. The climate is typically equatorial with two distinct dry seasons (November-March and July-mid-August) and two rainy seasons (April-June and mid-August-October) [20]. The average annual rainfall varies between 2800 and 2950  $\text{mm} \cdot \text{year}^{-1}$ . The average annual temperature is  $25^{\circ}\text{C}$ . The hydrography of the region shows a dense pattern with many rivers, small river basins, fast streams and rivers in rocky beds containing many rapids and small waterfalls (Ntem, Lobe, Mvila, Biwome etc.). This area is mainly made up of evergreen rainforest vegetation (Atlantic forest) rich in gregarious legumes [7-21].

### 2.2. Sampling Method

The sampling device consists of 6 centrifugal transects (oriented from the periphery to the center of the park so as to cover 2 km outside and 2 km inside, whether 4 km long and 25 m wide). The choice of the layout of each transect was made randomly on the forest. On each transect, 6 plots units were systematically arranged ( $25 \text{ m} \times 25 \text{ m}$  plots, 650 m equidistant were installed, making a total of 36 plots). The study area sampled is therefore 2.25 ha.

### 2.3. Data Collection

In each sampling unit, the floristic inventory of understory woody species in the quadrats consisted of individually identification by their scientific, vernacular or commercial name of the all trees ranging from of  $5 \text{ cm} \leq \text{dbh} < 10 \text{ cm}$ . This diameter was measured at 1.30 m above the ground. Leaf samples and fertile organs of unidentified species in the field were collected, squeezed and dried; then their identification was made by comparison with the specimens available at the Yaounde National Herbarium and also with the aid of the different book of Flora of Cameroon.

The classification system APG (Angiosperms Phylogeny Group) IV (2016) was used. The analysis of the different

forest type was done on each quadrat. It consisted in determining the type of forest based on previous experiences, knowledge and field observations [22], combined with the [23] recommended classification criteria that takes into account species composition and traces of human activities. Two types of forest were characterize in periphery of Campo

Ma an National Park: secondary forests (SFO), where traces of human activities are clearly visible and where most trees are juvenile or in a growing stage (6 plots), old secondary forests (OSF), where traces of human activities are clearly visible and where most trees are mature (30 plots).

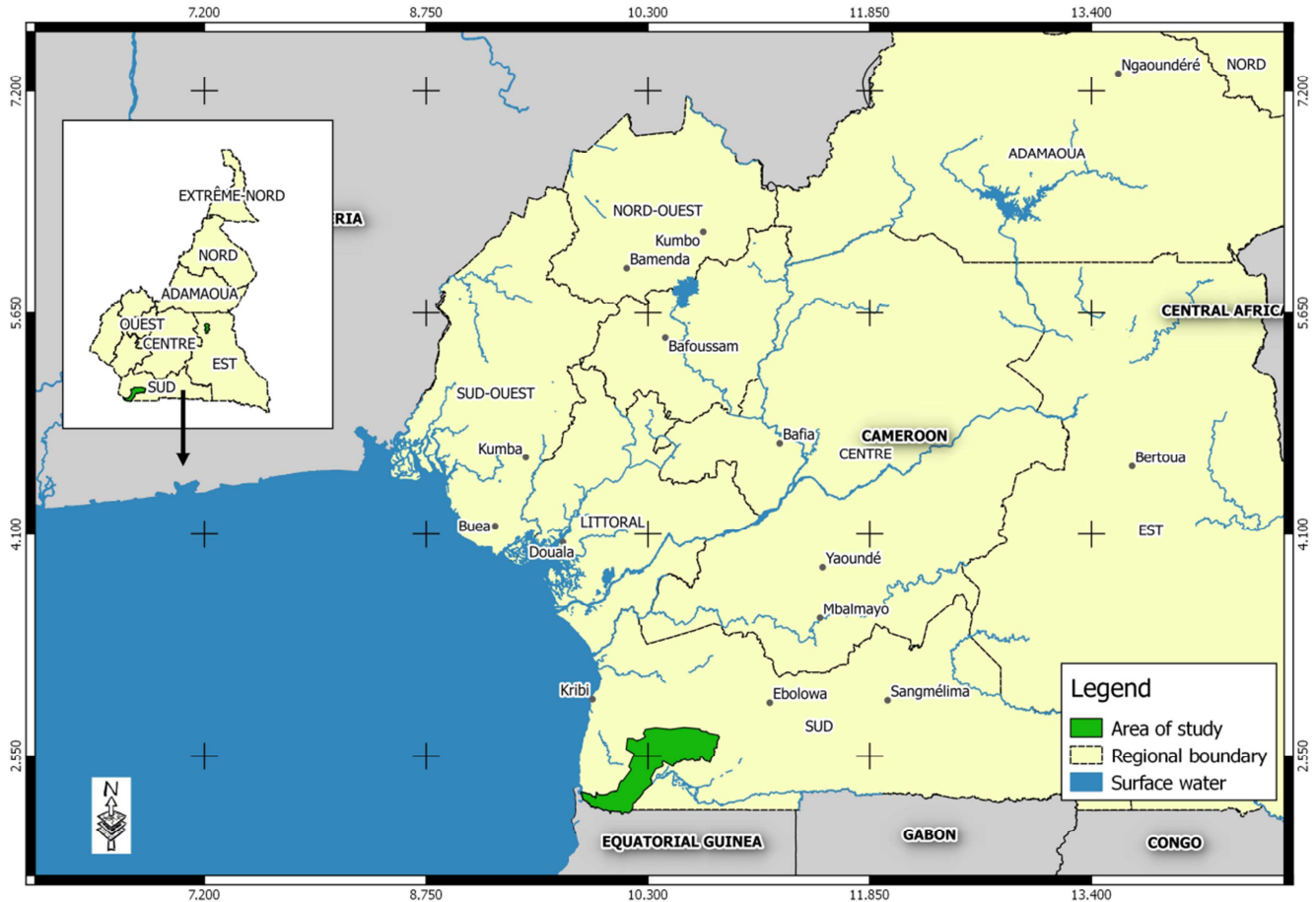


Figure 1. Location of the study site.

### 2.3.1. Centers of Endemism

The chorological subdivisions of Africa were made by several authors [10-24, 25-26]. As part of this study, the work of [8-10, 14-27] was used for species distribution by endemic center. The following endemic centers corresponded to those of the species identified in the two parks. These are: AM = African Malgache, CaGab = endemic in Cameroon and Gabon;; Gc = endemic to the Guineo-Congolese region; Gu = endemic to the Guinea zone; Ind = indeterminate zone of endemism; Lg = endemic to Lower Guinea; Pal = paleo tropical; Pan = pantropical; Sw-Cam = endemic to the southwest (Area of Kribi, Akom 2, Bipindi-Lolodorf); Tra = endemic to tropical Africa; WG = endemic to the Guinean West Zone; Zam = endemic to the Zambebian zone.

### 2.3.2. Overall Status of Conservation

The species identified during the inventory have been classified in the Red List categories of the International Union for Conservation Nature (IUCN). This list is

increasingly used to alert the international and scientific community about the decline of certain species (or their disappearance), but sometimes it justifies the actions to be taken. Its main purpose is to alert the public, developers, scientists and politicians to the extent of the risk of extinction of one or more species. The IUCN Red List includes 11 categories. But in this study, only 6 categories were used. It is: CR = critically endangered; EN = Endangered; LC = Least concern; NE = Not evaluated; NT = Near Threatened; VU = vulnerable.

### 2.4. Data Analysis

On the basis of field data, the flora was analyzed quantitatively through basal area, relative density, relative frequency and relative dominance.

The importance value index (IVI) and the family value index (FIV) of species and tree family were determined as the sum of relative frequency, relative density and relative dominance [28]. They made it possible to determine the

dominance of different species and different families in the types of forest studied.

$$\text{IVI} = \text{relative dominance} + \text{relative density} + \text{relative frequency}$$

$$\text{FIV} = \text{family relative diversity} + \text{relative density} + \text{relative dominance}$$

Community indices such as the species diversity ( $H'$ ) of different tree species, calculated using the Shannon diversity index [29], the Simpson index, Pielou equitability, the Margalef index allowed to characterize the floristic diversity and the floristic richness of the different types of forests:

$$H' = - \sum \left( \frac{n_i}{n} \right) \ln \left( \frac{n_i}{n} \right)$$

where  $n_i/n$  indicates the probability of importance of each species in a population, nor is the size of the species value, and  $n$  is the total number of individuals of all species in each forest type. The Simpson Index [30], which is the measure of how individuals are distributed among species of a community, was calculated by the following formula:

$$D = \sum \left( \frac{n_i}{n} \right)$$

where  $n_i$  and  $n$  are the same as those used in the calculation of the Shannon index.

Pielou equitability refers to the degree of relative dominance of each species in this area. It was calculated according to Pielou [31] formula as follows:

$$Eq = H' / \log S$$

where,  $H'$  = Shannon index,  $S$  = number of species. It varies from 0 to 1.

Species richness has been determined in two ways. The first was to determine the total number of species in each type of forest. The second is the Margalef index [32], which makes it easy to compare the two forest types. Mindful of the fact that the secondary forest only had six quadrats, a clue

was needed in other to better characterize wealth in proportion to the number of stems:

$$d = S / \log N$$

where  $S$  is the number of species and  $N$  is the number of tree in each type of forest.

The Sorensen similarity index was used to assess the similarity between the two forest types. It was calculated by the formula below:

$$S = \left( \frac{2c}{a + b} \right) * 100$$

where  $a$  = number of species present in the first station,  $b$  = number of species present in the second station and  $c$  = number of species common to both stations.

### 3. Results

#### 3.1. Species Richness and Diversity

The inventory identified 256 species from 148 genera and 50 families. The species richness of the different forest types was 231 and 83 species for OSF and SFO respectively (Table 1). The results showed that 58 species were common to both forest types, and 173 species were exclusively present in the OSF while 25 species are exclusively present in the SFO. The high values of the Shannon index in the two forest types, with 4.02 and 4.90 for SFO and OSF respectively, indicate the great diversity of the two forest types for the stratum studied. The Margalef index confirms the high specificity of the OSF (24) compared to the SFO (11) (Table 1). However, the Sorensen index shows the similarity between these two types of forest (58.59%).

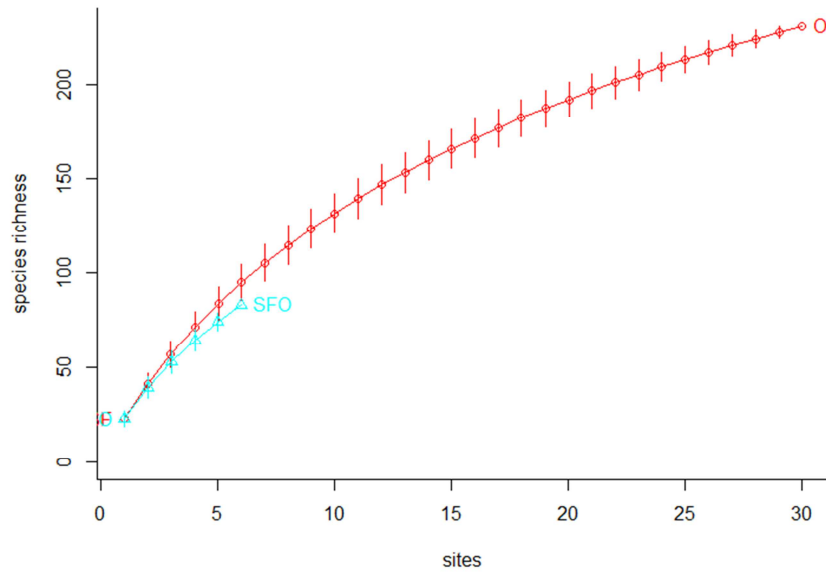
The average density of trees for the entire site was 426 stems.ha<sup>-1</sup>. The density of trees in the SFO is higher (467 stems.ha<sup>-1</sup>) than the density of trees in the OSF (418 stems.ha<sup>-1</sup>). The basal area in the two forest types studied is 1.79 m<sup>2</sup>.ha<sup>-1</sup> and 1.94 m<sup>2</sup>.ha<sup>-1</sup> respectively for OSF and SFO.

**Table 1.** Species richness, floristic diversity and structural parameters of trees 5 cm ≤ dbh < 10 cm.

variables	Old secondary forest	Secondary forest
Species richness	231	83
Number of genus	136	62
Number of families	44	29
Number of exclusive species	173	25
Shannon index	4.90	4.02
Simpson index	0.99	0.97
Pielou equitability	0.62	0.63
Margalef index	24	11
Sorensen index	58.59	
Basal area (m <sup>2</sup> .ha <sup>-1</sup> )	1.79	1.94
Density of stem (trees.ha <sup>-1</sup> )	418	467

The species accumulation curve determined using the rarefaction method showed a continuous increase without constancy up to 30 plots without however reversing (for OSF). While the accumulation curve of SFO species showed

a steady progression up to plot 6, then fades without reaching a constant level. These two curves reflect the small number of plots studied.



SFO=Secondary forest; O=Old Secondary forest.

Figure 2. Species accumulation curve of 5 cm ≤ dbh < 10 cm in both forest types.

### 3.2. Family Importance Value (FIV)

The most abundant families in the SFO were Euphorbiaceae (42.05), followed by Apocynaceae (35.37), Annonaceae (29.43), Fabaceae (28.04) and Malvaceae (25.47). In the OSF, the most dominant families were

Fabaceae (38.78), followed by Annonaceae (34.55), Euphorbiaceae (30.77), Malvaceae (21.10) and Strombosiaceae (18.54). The ten most dominant families in the SFO and OSF account respectively for 74.50% and 71.12% of family dominance.

Table 2. Dominance of families based on the family importance value.

Forest type	Family	Relative Density	Relative Dominance	Relative Frequency	FIV
SFO	Euphorbiaceae	16.57	16.91	8.57	42.05
SFO	Apocynaceae	13.71	14.52	7.14	35.37
SFO	Annonaceae	10.29	10.57	8.57	29.43
SFO	Fabaceae	10.86	10.01	7.14	28.01
SFO	Malvaceae	8.57	9.76	7.14	25.47
SFO	Myristicaceae	5.14	5.77	5.71	16.62
SFO	Burseraceae	4.00	4.38	5.71	14.09
SFO	Salicaceae	3.43	3.14	5.71	12.28
SFO	Phyllanthaceae	4.00	3.69	4.29	11.97
SFO	Ebenaceae	2.86	2.48	2.86	8.20
OSF	Fabaceae	15.18	14.97	8.62	38.76
OSF	Annonaceae	12.88	13.05	8.62	34.55
OSF	Euphorbiaceae	11.73	12.27	6.77	30.77
OSF	Malvaceae	7.65	7.90	5.54	21.10
OSF	Strombosiaceae	6.38	5.71	6.46	18.54
OSF	Apocynaceae	5.74	6.36	5.23	17.33
OSF	Phyllanthaceae	5.61	5.39	4.92	15.93
OSF	Ebenaceae	4.34	4.01	5.54	13.88
OSF	Meliaceae	3.32	3.14	4.92	11.38
OSF	Rubiaceae	2.93	2.95	5.23	11.11

SFO=Secondary Forest; OSF=Old secondary forest.

### 3.3. Importance Value Index (IVI)

The IVI analysis of each forest type showed a dominance of some species. In secondary forest, the ten most dominant species in terms of IVI alone accounted for 36.53%. *Plagiostyles Africana* is the dominant species with an IVI of 29.49. The co-dominant species were *Tabernaemontana crassa* (16.82), *Polyalthia suaveolens* (10.51), *Canarium*

*schweinfurthii* (10.49) and *Funtumia africana* (7.97). In the OSF, the ten most dominant species in terms of IVI accounted for 23.90%. *Plagiostyles africana* is also the dominant species with 17.36%. The co-dominant species were *Polyalthia suaveolens* (9.47) *Anthonotha macrophylla* (7.26) *Strombosiopsis tetrandra* (7.04) and *Dialium pachyphyllum* (6.21).

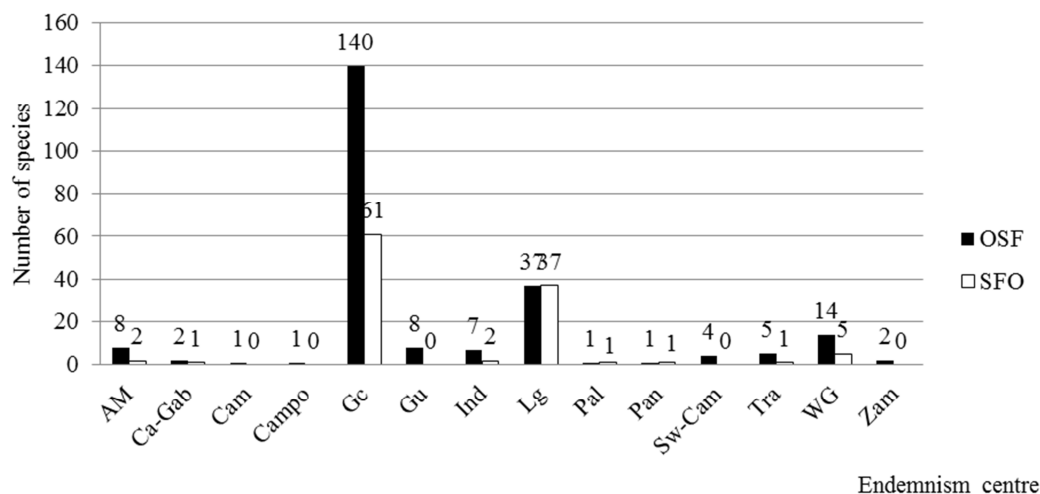
**Table 3.** Dominance of species based on the Importance Value Index (IVI).

Forest types	Scientific names	Relative density	Relative dominance	Relative frequency	IVI
SFO	<i>Plagiostyles africana</i>	12.00	12.98	4.50	29.49
SFO	<i>Tabernaemontana crassa</i>	5.71	6.60	4.50	16.82
SFO	<i>Polyalthia suaveolens</i>	3.43	3.48	3.60	10.51
SFO	<i>Canarium schweinfurthii</i>	3.43	3.46	3.60	10.49
SFO	<i>Funtumia africana</i>	2.86	3.31	1.80	7.97
SFO	<i>Anthonotha macrophylla</i>	3.43	3.50	0.90	7.83
SFO	<i>Xylopia acutiflora</i>	1.71	3.14	2.70	7.55
SFO	<i>Coelocaryon preussii</i>	2.29	2.40	1.80	6.48
SFO	<i>Christiana africana</i>	2.29	2.30	1.80	6.38
SFO	<i>Vernonia conferta</i>	2.86	2.28	0.90	6.04
OSF	<i>Plagiostyles africana</i>	7.14	8.08	2.14	17.36
OSF	<i>Polyalthia suaveolens</i>	3.32	3.24	2.91	9.47
OSF	<i>Anthonotha macrophylla</i>	2.68	2.45	2.14	7.26
OSF	<i>Strombosiopsis tetrandra</i>	2.68	2.42	1.94	7.04
OSF	<i>Dialium pachyphyllum</i>	1.91	2.35	1.94	6.21
OSF	<i>Coelocaryon preussii</i>	2.17	1.90	1.55	5.62
OSF	<i>Canarium schweinfurthii</i>	1.66	1.94	1.36	4.95
OSF	<i>Uapaca guineensis</i>	1.66	1.77	1.36	4.79
OSF	<i>Anthonotha fragrans</i>	1.53	1.72	1.36	4.61
OSF	<i>Macaranga barteri</i>	1.66	1.55	1.17	4.37

### 3.4. Endemisms

The analysis of the results on the belonging of the species of the two types of forest to the centers of endemisms makes it possible to group the centers of endemism in three groups. Group 1, consisting of large-scale species (Pan-tropical (Pan), paleo-tropical (Pal), Afro-Malagasy (AM), African tropical (Tra)) accounts for 6.49% and 6.02% respectively. Old secondary forest and secondary forest. Group 2, consisting of Sudan-Zambezian linkage species (Zambezian (Zam)) accounts for 0.87% and 0.00% respectively for secondary and secondary forest (Figure 3). Group 3, Guinean species (endemic in Cameroon and Gabon (Ca-Gab),

endemic in Cameroon (Cam), endemic to Campo area (Campo), endemic to the Guineo-Congolese region (Gc), endemic to Guinea (Gu), endemic to lower Guinea (Lg) and endemic to the southwest (Kribi, Akom 2 and Bipindi-Lolodorf area) (Sw-Cam) represent 89.61% and 91.57% respectively for secondary forest aged and secondary forest (Figure 3). In group 3, the study identified an endemic species in Cameroon (*Octoknema dinklagei*), an endemic species in the Campo Ma'an (*Beilschmiedia dinklagei*) zone and four endemic species in the Kribi, Akom 2 and Bipindi zones. Lolodorf (*Beilschmiedia papyracea*, *Cola fibrillosa*, *Cola subglaucescens* and *Cola sulcata*).

**Figure 3.** Distribution of species by center of endemism.

AM = Afro-Malagasy; Ca-Gab = endemic in Cameroon and Gabon; Cam = endemic in Cameroon, Campo = endemic to the Campo area; Gc = endemic to the Guineo-Congolese region; Gu = endemic to the Guinea zone; Ind = center of indeterminate endemism; Lg = endemic to Lower Guinea; Pal = paleo tropical, Pan = pantropical; Sw-Cam = endemic to the southwest (Kribi Zone, Akom 2, Bipindi-Lolodorf), Tra = endemic to tropical Africa, WG = endemic to the western Guinean zone; Zam = endemic to the Zambezian zone.

SFO= secondary forest; OSF= Old secondary forest.

### 3.5. Overall Status of Conservation

The analysis of the data in Figure 4 shows the number of species by IUCN category in both forest types. It has emerged that in the aged secondary forest, 21 species are threatened with extinction in different categories: *Microberlinia bisulcata* (CR), *Diospyros crassiflora* (EN), *Millettia laurentii* (EN), *Allanblackia floribunda* (VU), *Aucoumea klaineana* (VU), *Calpocalyx heitzii* (VU), *C. klainei* (VU), *Cola hypochrysea* (VU), *Diospyros barteri* (VU), *Duguetia barteri* (VU), *Entandrophragma angolense*

(VU), *Garcinia mannii* (VU), *Guarea cedrata* (VU), *G. thompsonii* (VU), *Hallea stipulosa* (VU), *Khaya anthotheca* (VU), *Lovoa trichilioides* (VU), *Memecylon dasyanthum* (VU), *Nauclea diderrichii* (VU), *Pterygota macrocarpa* (VU) and *Uvariadendron giganteum* (VU). In the secondary forest, it has emerged that in the secondary forest, 5 species are threatened with extinction in different categories, these are: *Diospyros crassiflora* (EN), *Calpocalyx klainei* (VU), *Khaya anthotheca* (VU), *Pterygota bequaertii* (VU) and *Uvariadendron giganteum* (VU).

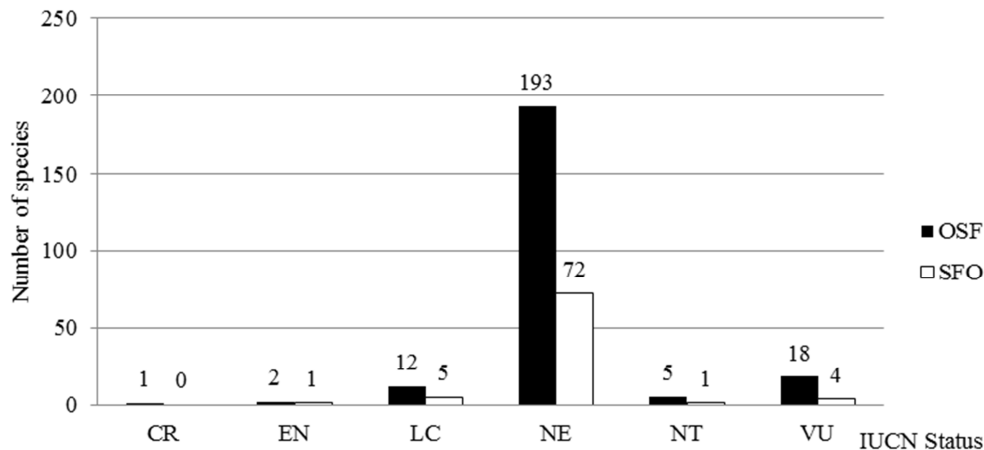


Figure 4. Distribution of species by IUCN status.

CR = critically endangered; EN = in danger; LC = Minor concern; NE = Not evaluated; NT = Near Threatened; VU = vulnerable; SFO= secondary forest; OSF= Old secondary forest.

## 4. Discussion

Floristic inventories remain the main tools for understanding species composition, forest diversity and forest condition [33]. These inventories also provide vital information for forest conservation [34]. Species richness and diversity are among the main features of tropical forests [35]. However, many studies of floristic diversity in tropical moist forests in Africa are often limited to tree species (mainly medium or large trees, or dbh trees  $\geq 10$  cm) that reflect the floristic composition and the physical structure of the forest [7-10, 12-13, 27-36, 37-38, 39]. The purpose of this study was therefore to determine the floristic diversity and the conservation status of understory of tree under  $5 \text{ cm} \leq \text{dbh} < 10 \text{ cm}$ .

The results obtained in this study with respect to floristic diversity show that they are comparable to results obtained for dbh trees  $\geq 10$  cm in several tropical moist forests. The specific richness obtained in the aged secondary forest is slightly higher than the specific richness obtained for dbh tree  $\geq 10$  cm by [13] (205 species and 47 families) in the eastern periphery of the Dja Reserve. The specific richness of the secondary forest is slightly lower than the 99 species obtained for trees of dbh  $\geq 10$  cm by [39] in the 100 m x 100 m quadrat of Bidjouka 1 (BID 1). The specific richness of the whole site is similar to that obtained in the humid forests of

Campo Ma'an (231 species) by [14], but remains lower than the specific richness obtained by the same author in the forests of the coast (381 species) and mixed evergreen and semi-deciduous forests (441 species) for trees and  $1.5 \text{ cm shrub} \leq \text{dbh} < 10 \text{ cm}$ . It should also be mentioned that the dominant species are mostly large trees in the regeneration stage. The difference between the floristic wealth obtained in the SFO and the OSF can be explained by the areas inventoried for each type of forest. Indeed, the species accumulation curve showed that the minimum number of quadrat (minimum area) required achieving saturation was not reached in both forest types, but especially in secondary forest or alone. 6 quadrats have been inventoried. Other parameters may also explain the differences in the specific wealth obtained in the two types of forest. These include, for example, climate and anthropogenic activities. [40] showed that the microclimate was strongly correlated with floristic richness. In our results, the canopy of the aged secondary forest is denser than that of the secondary forest, creating a microclimate more conducive to species diversification. [41] showed that temperature is positively correlated with floristic diversity. Anthropogenic activities are also a source of species diversification. The more a forest is disturbed, the less it is diversified, but in this study, the type of forest was determined by the combination of visible human traces and the specific composition [23] still visible human traces, secondary forest is therefore more disturbed than the old

secondary forest.

With regard to the floristic diversity calculated using the Shannon index ( $H'$ ), the values obtained in the two types of forest, although different, are greater than 4. These values reflect the great diversity of these two types of forests. Indeed, [42] showed that a forest stand is rich and diverse if its Shannon diversity index is greater than or equal to 3.5. The two types of forest that are the subject of this study are therefore rich and diverse. [8] explains the high level of species diversity in that the study area is part of a series of rainforest refuges in West and Central Africa.

The results obtained for the species richness and Shannon diversity index are similar to those of [20] which showed that the diversity of the different tree strata follows the same trend. Indeed several authors had already demonstrated the great diversity of dbh trees  $\geq 10$  cm from the Campo Ma'an forest and its surroundings [8-20, 39].

In the aged secondary forest, the Fabaceae family is the most dominant in terms of IVF (38.76). This result corroborates the data of [39] that characterized the forest north of the Campo Ma'an and [21] that characterized the forest of Park area in this region as a Biafreal Atlantic evergreen rainforest rich in Fabaceae. The importance of this family is a characteristic of the Guinean-Congolese forests [8]. [39] goes further by showing that the Fabaceae family is characteristic of old-growth forests and can be refuges for species. In the aged secondary forest, the Rubiaceae family is among the most dominant in terms of IVF (11.11). This family (Rubiaceae) includes many species recognized as bio-indicators of rainforest refuges in the Campo-Ma'an region [43]. In secondary forest, the Euphorbiaceae Family is the most dominant in terms of IVF (42.05). But, other important families such as Burseraceae are also dominant in terms of IVF (14.09). This family is known to be a good indicator of old-growth Atlantic evergreen forests (moist evergreen forest) [44].

Membership of the endemic center showed that more than 89% of the species of both types of forest were Guinean species. This result confirms the fact that the trees of the undergrowth of the forest on the outskirts of the Campo Ma'an National Park preserve the Guinean-Congolese floristic background. Indeed, the Campo-Ma'an forest belongs to the Center of Guinean-Congolese Endemism [8-16]. The result also shows that 6 species are endemic to Cameroon. Of these 6 species, 03 are shrubs (*Octoknema dinklagei*, *Beilschmiedia dinklagei* and *B. papyracea*) that remain in the understory all their life, 02 species reach the stage of large trees when the conditions of the middle are favorable (*Cola fibrillose* and *C. sulcata*) while *Cola subglaucescens* a small tree that can also stay in the understory in the absence of a favorable condition. This result corroborates that of [14] who has shown that the majority of tropical plant species endemic to tropical forests are recruited from small trees, shrubs, herbaceous plants and lianas. But also, this result corroborates that of [8] and [20], which showed that the Campo Ma'an forest is a forest with a large number of endemic species. The low percentage of broad-distribution species confirms the low level of

degradation of both forest types for the stratum studied. But it also makes it possible to appreciate the need to create certain protected areas for the conservation of the forest ecosystem, not only for the conservation of wildlife, but also for the conservation of plant diversity in all its forms.

The assessment of the conservation status of the inventoried species shows that 22 species are threatened in both types of forests. Most of the species identified in this study are not evaluated in the IUCN Red List, which highlights the need to study the conservation status of many species. This result also highlights the information deficit that emerges when studies focus only on trees of large diameters. The assessed species that are threatened with extinction are tree species that are just in the regeneration stage. It also emerges from the study that the species being classified in the IUCN list are those that are of interest to humans. [45] showed that all tropical forests have many rare species, which generally have a high risk of extinction at least at the local level. Although threatened species are large trees still in the regeneration stage, Wood deserves attention because some trees may remain in the shrub or woody stage of the undergrowth as a result of competition in tropical forests. A management plan or conservation strategy developed by omitting or disregarding these species remains critical to species conservation. Given the great diversity and the relatively large number of endangered species, although it is at different statuses, it can be confirmed that the Campo Ma'an area is a hotspot for floristic diversity.

The floristic inventory is a prerequisite for conducting many basic researches on the ecology of tropical communities, such as modeling species diversity or understanding the distribution of species. However, studies of dbh  $\geq 10$  cm trees do not provide a better picture of the composition of tropical forests. Comprehensive studies should help provide the necessary context for the planning and interpretation of long-term ecological research [33]. This is the case of this study, where the inventory of understory woody species should completed the data on plant diversity and better guide future management plans. The floristic inventory of trees in the undergrowth and trees large diameters also allow planning of protected areas and the development of more adequate methods of conserving plant diversity at the scale of the forest ecosystem. These inventories help support scientific and policy decisions on forest resources to better plan conservation axes and development activities such as logging.

## 5. Conclusion

The Plant Diversity Inventory provides information on species richness, diversity and other parameters that characterize forests. The present study has determined the floristic diversity of understory woody trees in two forest types belonging to dense moist evergreen forest. The study shows that both types of forest are rich and diverse. However, aged secondary forest is richer and more diverse than secondary forest. These forests have kept their Guinean-



Congolese floristic background and are home to six endemic species in Cameroon. The conservation status shows that 22 species are threatened with extinction in both forest types. The study emphasizes by its results the need to include undergrowth of trees  $5\text{ cm} \leq \text{dbh} < 10\text{ cm}$  in studies prior to the development of strategies and management plans. Indeed, this forest layer is rich and diverse. It is also home to endemic species and endangered species, which are most often not found in the upper stratum ( $\text{dbh} \geq 10\text{ cm}$ ). The present study is therefore a basis for the analysis of undergrowth woody species, which should complement the studies already carried out on the large trees necessary for the knowledge and conservation of biodiversity. This will also have led to the systematization of studies in this woody stratum in tropical forest floristic inventories.

## Acknowledgements

We gratefully thank the “Organisation pour la Conservation et le Développement (OCD)” for its technical support and people of Campo Ma’an for their warm welcome, their contributions as guides and helpers installing the sample plots and carrying out the inventories.

## References

- [1] Megevand C., 2013. Dynamiques de déforestation dans le bassin du Congo: Réconcilier la croissance économique et la protection de la forêt. Washington, DC, World Bank, 201p.
- [2] Zilliox C. and Gosselin F., 2014. Tree species diversity and abundance as indicators of understory diversity in French mountain forests: Variations of the relationship in geographical and ecological space. *Forest Ecology and Management*, 321: 105-116.
- [3] Goettsch B., Hilton-Taylor C., Cruz-Piñón, G., Duffy J. P., Frances A. et al., 2015. High proportion of cactus species threatened with extinction. *Nature Plants*, 1, 15142. <http://dx.doi.org/10.1038/nplants.2015.142>.
- [4] Ifo A. S., Koubouana F., Jourdain C. and Nganga D., 2015. Stock and Flow of Carbon in Plant Woody Debris in Two Different Types of Natural Forests in Bateke Plateau, Central Africa. *Open Journal of Forestry*, 5: 38-47.
- [5] Corlett R. T., 2016. Plant diversity in a changing world: Status, trends, and conservation needs. *Plant Diversity*, 38: 10-16.
- [6] Pimm S. L. and Joppa L. N., 2015. How many plant species are there, where are they, and at what rate are they going extinct? *Ann. Mo. Bot. Gard.*, 100: 170-176.
- [7] Letouzey R., 1968. Etude phytogéographique du Cameroun. Paris, France, Encyclopédie Biologique, Ed. Lechevalier, LXIX, 508 p.
- [8] White F., 1983. The vegetation of Africa. UNESCO, Paris.
- [9] Sonké B. and Lejoly J., 1998. Biodiversity study in the Dja Fauna Reserve (Cameroon): using the transect method. In: Huxley C. R., Lock J. M. and Cutler D. F. (eds), *Chorology, Taxonomy and Ecology of the Floras of Africa and Madagascar. Royal Botanical Gardens, Kew*, pp. 171–179.
- [10] Sonké B., 1998. *Etude floristique et structurale des forêts de la réserve de faune du Dja (Cameroun)*. Thèse de Doctorat, Université Libre de Bruxelles. 267p.
- [11] van Valkenburg J. L. C. H., Ketner P. and Wilks C. M., 1998. A floristic inventory and preliminary vegetation classification of the mixed semi-evergreen rain forest in the Minkébé region, North East Gabon. *Adansonia*, 20: 139–162.
- [12] Djuikouo M. N. K., Doucet J.-L., Nguembou C. K., Lewis S. L. and Sonke, B., 2010. Diversity and aboveground biomass in three tropical forest types in the Dja Biosphere Reserve, Cameroon. *Afr. J. Ecol.*, 48: 1053-1063.
- [13] Tabue M. R. B., Zapfack L., Noiha N. V., Nyeck B., Meyan-Ya D. R. G., Ngoma L. R., Kabelong B. L. P. and Chimi D.C., 2016. Plant Diversity and Carbon Storage Assessment in an African Protected Forest: A Case of the Eastern Part of the Dja Wildlife Reserve in Cameroon. *Journal of Plant Sciences*, 4(5): 95-101.
- [14] Tchouto M. G. P., 2004. *Plant biodiversity in Central African rain forest: implications for biodiversity conservation in Cameroon*. Ph.D thesis, Wageningen University, the Netherlands, 208p.
- [15] MINFOF, 2014. Plan d’aménagement du Parc National de Campo-Ma’an et de sa zone périphérique 2014-2020. République du Cameroun, 150p.
- [16] Davis S. D., Heywood V. H. and Hamilton A. C., 1994. Centres of plant diversity: a guide and strategy for their conservation, vol 1: Europe South West Asia and the Middle East Africa. IUCN and WWF, Cambridge.
- [17] Mengue-Medou C., 2002. Les aires protégées en Afrique: perspectives pour leur conservation. *Vertigo - la revue électronique en sciences de l'environnement*, 3 (1). URL: <http://vertigo.revues.org/4126>; DOI: 10.4000/vertigo.4126.
- [18] Muhumuza M. and Balkwill K., 2013. Factors Affecting the Success of Conserving Biodiversity in National Parks: A Review of Case Studies from Africa. *International Journal of Biodiversity*, 20p.
- [19] Van Gernerden B. S. and Hazeu G. W., 1999. Landscape ecological survey (1:100,000) of the Bipindi- Akom II-Lolodorf region, Southwest Cameroon. Tropenbos-Cameroon Document 1, 163p.
- [20] Tchouto M. G. P., Yemefack M., De Boer W. F., De Wilde J. J. F. E. and Cleef A. M., 2006. Biodiversity hotspots and conservation priorities in the Campo-Ma’an rainforests, Cameroon. *Biodivers Conserv.*, 15: 1219-1252.
- [21] Letouzey R., 1985. Notice de la carte phytogéographique du Cameroun, vols 1–5. Institut de la carte Internationale de la Végétation, Toulouse.
- [22] Nguenang G. M., 2012. *Secondarissations et dynamique cicatricielle de la forêt du Dja (Est-Cameroun): application de l’aménagement des formations secondarisées*. Thèse de Doctorat Ph.D en Biologie des Organismes Végétaux, Université de Yaoundé I, 245p.
- [23] Branthomme A., Altrel D., Kamelarczyk K. and Saket M., 2009. Suivi et évaluation des ressources forestières nationales: Manuel pour le relevé intégré de données sur le terrain. FAO, Rome, Italy.

- [24] Lebrun J., 1947. La végétation de la plaine alluviale au Sud du lac Edouard. *Inst. Parcs. Nat. Congo belge, Exp. Parcs Nat. Albert, mission Lebrun (1937-1938)* 1: 800p.
- [25] Robyns W., 1948. Les territoires phytogéographiques du Congo belge et du Rwanda- Urundi, in *Atlas general du Congo belge, Inst. Roy. Col. Belge.*, 240p.
- [26] Aubreville A., 1962. Position chorologique du Gabon, in *Flore du Gabon. Mus. natn. Hist. nat.*, 3: 3-11.
- [27] White L. J. T., 1996. Determinants of vegetation composition in the Lopé Reserve. Report to AGRECO/CTFT, Gabon.
- [28] Cottam G. and Curtis J. T., 1956. The use of distance measures in phytosociological sampling. *Ecology*, 37: 451-460.
- [29] Shannon C. E. and Weaver W., 1949. *The Mathematical Theory of Communication*. University of Illinois Press, Urbana.
- [30] Simpson E. H., 1949. Measurement of diversity. *Nature*, 163, 688.
- [31] Pielou E. C., 1966. Shannon's formula as a measure of species diversity: its use and misuse. *Am. Nat.*, 100, 463-465.
- [32] Margalef R., 1968. *Perspectives in ecological theory*. University of Chicago Press, 111p.
- [33] Phillips O. L., Martinez R. V., Vargas P. V., Monteagudo A. L., Zans M-E. C., Sanchez W. G., Cruz A. P., Timana M., Yli-Halla M. and Rose S., 2003. Efficient plot-based floristic assessment of tropical forests. *J. Trop. Ecol.*, 19: 629-645.
- [34] Gordon J. E. and Newton A. C., 2006. Efficient floristic inventory for the assessment of tropical tree diversity: A comparative test of four alternative approaches. *Forest Ecology and Management*, 237: 564-573.
- [35] Tarakeswara N. M., Premavania, D., Sutharib, S., and Venkaiaha, M., 2018. Assessment of tree diversity in tropical deciduous forests of Northcentral Eastern Ghats, India. *Geology, Ecology, and Landscapes*, 2(3): 216-227.
- [36] Mosango M., 1990. *Contribution a` l'étude botanique et biogéochimique de l'écosystème des forêts en région équatoriale (Ile Kongolo, Zaïre)*. Thèse de doctorat, Université Libre de Bruxelles.
- [37] Koubouana F., 1993. *Les forêts de la vallée du Niari, Congo: Etudes floristiques et structurales*. Thèse de doctorat, Université de Paris 6.
- [38] Lejoly J., 1995. Biodiversité végétale dans le Parc National d'Odzala, Congo. Rapport technique. Groupement Agreco-CTFT.
- [39] Gonmadje C. F., Doumenge C., McKey D., Tchouto G. P. M., Sunderland T. C. H., Balinga P. B. and Sonke B., 2011. Tree diversity and conservation value of Ngovayang's lowland forests, Cameroon. *Biodivers. Conserv.*, 20(12): 2627-2648.
- [40] Hawkins B. A., Field R., Cornell H. V., Currie D. J., Guégan J-F., Kaufman D. M. et al., 2003. Energy, water, and broad-scale geographic patterns of species richness. *Ecology*, 84: 3105-3117.
- [41] Lopez L. G. C., Medina E. A. S. and Peña A. M., 2016. Effects of Microclimate on Species Diversity and Functional Traits of Corticolous Lichens in the Popayan Botanical Garden (Cauca, Colombia). *Mycologie*, 37(2): 205-215.
- [42] Kent M. and Coker P., 1992. *Vegetation description and analysis*. Belhaven Press, London.
- [43] Tchouto M. G. P., De Wilde J. J. F. E., De Boer W. F., Van der Maesen L. J. G. and Cleef A. M., 2009. Bio-indicator species and Central African rain forest refuges in the Campo-Ma'an area, Cameroon. *Syst Biodivers.*, 7:21-31.
- [44] Doumenge C., 1992. *La Réserve de Conkouati: Congo Le secteur sud-ouest*. UICN, Gland, Suisse.
- [45] Kenfack D., Thomas D. W., Chuyong G. and Condit R., 2006. Rarity and abundance in a diverse African forest. *Biodivers Conserv.*, DOI:10.1007/s10531-006-9065-2.