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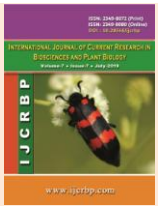

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# Floristic inventory of woody species of the Kupe Mountain Forest in the South-West Cameroon: Phytosociological approach

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**ABSTRACT**

This survey articulates around three aims : (1) to characterize the mountain vegetation of Mount Kupe (1 500-2 064 m altitude) of south western Cameroon, (2) to study the vegetation structure and woody species diversity in the Kupe mountain forest, and (3) to compare ours results with those of other tropical mountain forests. A quantitative inventory was realized on trees with diameter at breast height (DBH) ≥ 10 cm covering a cumulative surface of 2.125 ha, from 17 rectangular plots of 50 m x 25 m (1 250 m²). Standard methodology to calculate floristic diversity was employed. A total of 1819 trees belonging to 136 species, 83 genera and 42 families were recorded with a total basal area of 193.75m² per hectare. Most trees had a height between 10 and 15 m and diameter of 10-40 cm. However some individuals reached heights of 25 to 30 m. Ten species namely *Beilschmeidia acuta* (1 individual), *Carapaoreophila* (3 individual), *Cola acuminata* (3individual), *Entandrophragma angolense* (1 individual), *Loesenara talbotii* (3 individual), *Santiria trimera* (2 individuals), *Schefflera barteri*(3 individuals), *Syzugium staudtii* (2 individuals), *Trichilia procera* (3 individual) and *Zenkerella citrina* (1 individual) had a diameter of 165-170. Thirty-seven plant species then 27.21 % were represented by only one individual. The forest is marked by the abundance of *Rubiaceae*, *Sapindaceae*, *Celastraceae, Euphorbiaceae, Meliaceae*, *Moraceae, Anacardiaceae* and *Leguminosae*. The analysis of the floristic groupings has been made on the basis of the partition of the samples by Detrended Correspondence Analysis (DCA) and an Ascending Hierarchical Classification. The Kupe mountain forests presents five major plant sets: the heterogeneous high altitude forest of the northeastern zone with little disturbance, the mountain rainforest of the summit part of *Allophylus bullatus* and *Carapa oreophila*, the submontane rainforest southwesterly at the floor of the mountain storey, the edaphic forest hydromorphic soils (core of valleys forest) corresponding to areas more disturbed by human activities and the mature secondary forest of the eastern margin. A new association *Allophylo-Carapetum oreophilae* has been described. The presence of certain species such as *Leea guineensis*, *Laccodiscus ferrugineus*, *Rutidea glabra* and *Tarenna eketensis* shows that the present site of Mount Kupe was originally a marshy area that has been subjected to orogenesis over the years. The fundamental floristic nucleus of the forest is composed of ombrophilous species before the successional stages.

## Introduction

The Cameroonian Mountains form a floristic archipelago similar to that of eastern and southern Africa (White, 1983; Tchoua Tchetgnia and Noumi, 2016) and host to many important floristic sites. One of such important sites is the Kupe mountain situated at the southwestern edge of Cameroon, from north latitude 4° 44'- 4° 52'and east longitude 9° 41'- 9°52' NB-32-IV (Tchoua Tchetgnia, 2019). It summits at 2064 m is only thirteen to Mount Cameroon (4 095 m).

Mount Kupe is the highest peak in the east-west extends of the mountains that encompass Kupe, the Bakossi Mountains and the Rumpi Hills. It is about 90 and 55 km as the crow flies respectively northeast of Mount Cameroon and east of Mount Rumpi. This survey was carried out in the southwestern part of the Kupe montane between 1 500-2 064 m (Fig. 1).

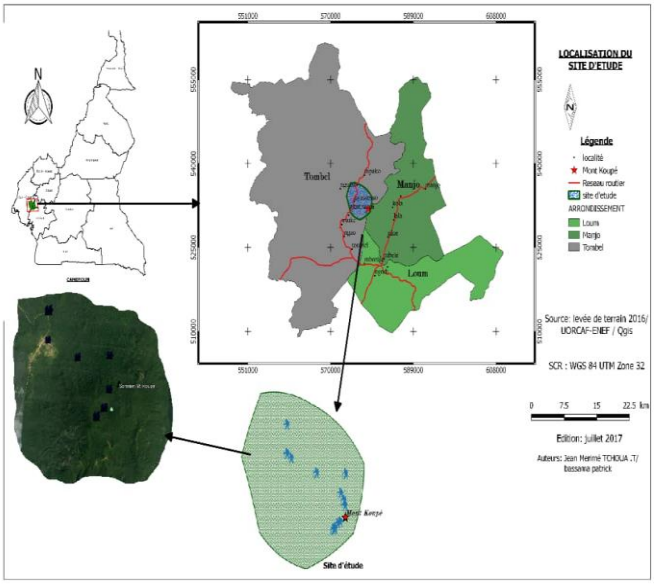



**Fig. 1:** Location of the Mount Kupe area from the map of Cameroun (Source: Bassama, 2019).

The Kupe mountain forest is located in the Kupe-Manenguba Division (South West Region of Cameroon). It is remarkable for its cloud dense vegetation (Fig. 2). It is formed by three summits associated in ranges of juxtaposed and unequal altitudes of which the highest named « Maxis trail »reaches 2064 meters at its highest point. The survival and the management of the forest and its biological diversity rest on the customary laws such as restriction to debark important species such as *Prunus africana* for medicinal purposes, encroaching boundary for traditional agriculture (Fig. 3).

**Fig. 2:** A partial view of Mount Kupe around 2 pm from Nyasoso (January, 2016).


**Fig. 3:** Notice board indicating the boundary limits of Kupe Mountain.

This study is based on axiom: a plant formation is a group of species gathered by the non-reciprocal attraction exercised on them by the various factors of the middle.

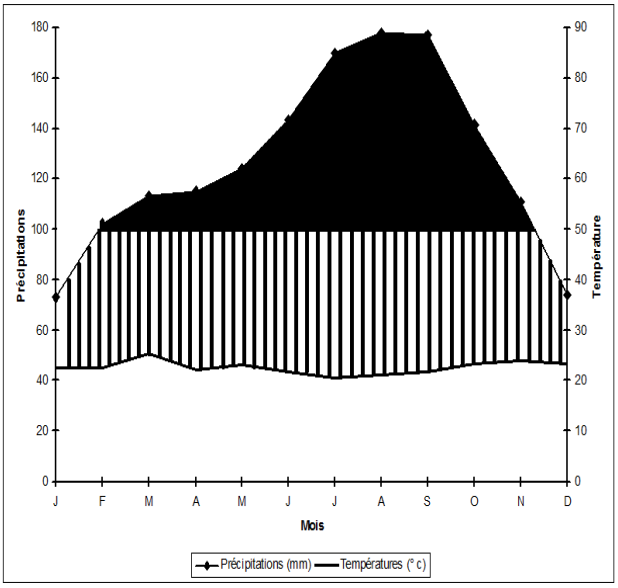
Several studies on the structure and biodiversity have been realized in the low and middle altitudes

forests of African, Malagasy and the Neotropic regions (Cain et al., 1956; Boom, 1986; Gentry, 1988, 1992; Villanueva, 1991; Spichiger et al., 1992, 1996; Lejoly, 1995; Rabevohitra et al., 1996; Sonke, 1998; Collin, 1998 ; Rakotomalaza and Messner, 1999; D'Amico and Gautier, 2000; Senterre, 2005; Miabangana and Lubini, 2015). These studies highlighted quantitative measures for families and the species diversities of these forest types. Some investigations in the submontane and afromontane forests have been conducted following similar methodology (Mohandass and Davidar, 2009; Noumi, 2012, 2013, 2015; Tchoua Tchetgnia, 2013; Tchoua Tchetgnia and Noumi, 2016; Makemteu and Noumi, 2015; Makemteu, 2017; Tchoua Tchetgnia, 2019). Could the structural characteristics and the species diversity of the Kupe mountain forest permit a singular scientific status just as its current phytosociological status?

The aim of the present survey were (1) to inventories tree species in the Kupe mountain forest by means of forest plots, while taking into consideration the trees species ≥ 10 cm diameter at breast height (DBH), (2) to quantify the parameters of diversity and structure, and (3) to characterize the plant formation in relation to existing data in various forests.

## Study area

The Mount Kupe is a volcano-tectonic horst (Lamilen, 1989; Lamilen et al., 1998; Tchoua Tchetgnia, 2019) with irregular shapes. The geology of the mountain is essentially constituted of granitic volcanic formations giving a ferruginous soil (Lamilen, 1989; Lamilen et al., 1998). They are characterised more or less by the abundance of fragments of deteriorating basalt (Geze, 1943). These soils have rich organic content because of its altitude and climate. The massif carries a highlander forest. The local climate of the Kupe forest area can be deduced from that of Tombel city (1000 m altitude) situated at 50 km from the Kupe mountain summit, with annual precipitations of 4891 mm, average annual temperature of 20° C and relative humidity above 87 % throughout the year (Tchoua Tchetgnia, 2013; Tchoua Tchetgnia, 2019). The ombrothermic diagram is presented in Fig. 4. We thus expected the rainfall in the Kupe forest to be higher because of higher altitude than Bangem.




Legend:
Very wet period exceeding 100 mm.
Wet period.

**Fig. 4.** Ombrothermic diagram of Kupe by Bagnouls and Gaussen (1957), modified according to the method of Walter and Lieth (1964): on the curve of monthly mean of rainfalls, the scale is reduced to the 1/10 from 100 mm. (Source: Subdivisional delegation of Agriculture at Tombel).

Mount Kupe is one of the outstanding mountains in the South West Region of Cameroon. It rises to 2064 m above sea level and approximately 100 km North East of Mount Cameroon. It is part of a range of mountains that run from Bioko (Fernando pô) to the Bamenda highlands and then to the Adamawa massif in the East, with two extensions into Nigeria (the Obudu and Manbila Plateau) (Cheek et al., 2004; Tchiengue, 2004; Tchoua Tchetgnia, 2013; Tchoua Tchetgnia and Noumi, 2016; Tchoua Tchetgnia, 2019)

The Kupe Mountain was formed by block-faulting in the Earth's crust, which pushed up a huge horst bounded by structural troughs. Later, volcanic activity in the troughs created small cones that are still visible on the lower slopes. The relief is dramatic with steep slopes, long narrow ridges, outcrops of bare rocks cliffs and small peaks.

## Materials and methods

The survey is sustained by the theory according to which "the visible elements of vegetation are the indicators that permit to have visions of the facts

or phenomena that took place before the present stage" (Noumi, 2008; Makemteu, 2017; Tchoua Tchetgnia, 2019). Fieldwork was conducted in 2014-2016 in the Kupe mountain forest. Woody plant diversity was inventoried by sampling seventeen plots of 25 m × 50 m (1 250 m²). These plots were all identical to the mesologic and physiognomic point of view. A trail of 50 m in the center of rectangle facilitated the sampling of 12.5 m on one side, then on the other of the trail (Méthot et al., 2014; Tchoua Tchetgnia, 2013; Tchoua Tchetgnia and Noumi, 2016; Noumi, 2013, 2015; Noumi and Tagne, 2016). All trees and lianas with diameter at breast height (DBH)≥ 10 cm, i.e., 130 cm above the ground were measured on 12.5 × 10 m² surface portions along the 50 m strike. Some species are determined on foot (Normand, 1965, Vivien and Faure, 1985). Unidentified species were collected as vouchers for further identification at the laboratory of Botany of the Department of the Biological Sciences, Higher Teachers' Training College. Confirmation of the identification were also done at the National Herbarium of Cameroon (YA) with the assistance of mounted specimens, identification keys, local flora, and check list (Aubréville et al., 1963-1998; Lebrun and Stork 1991, 1992, 1995, 1997), Flora of West Tropical Africa, FWTA (Hutchinson and Dalziel, 1954-1972), and some books (Curtis and MC Intosh, 1950; Cottam and Curtis, 1956; Normand, 1965; Gounot, 1969; Guinochet, 1973; Jaeger, 1979; Cable and Cheek, 1998; Cheek et al., 2004).

Their phytogeographical distribution types (TP) were established according to the works of Schnell (1952) for the inter-tropical massif orophytes; of White (1983) for the big chorological subdivisions of Africa and Letouzey (1985) for the phytogeography of Cameroon. The synthetic features of flora were considered in a synthetic manner through the main physionomic specters. The biologic types (BT) were distinguished according to the classification of Raunkiaer (1934), darn by Schnell (1971), Noumi (2005), Senterre (2005) and Tchoua Tchetgnia (2013). The leaf size types are determined using the classification of Raunkiaer (1934), Mosango (1990) and Lubini (1997, 2001). The phytosociological units (PU) were based on the classification of Lebrun and Gilbert (1954), of the works of Noumi (1998), of De Foucault et al. (1999), Duvigneaud (1949 b) and of the synthesis of Schmitz (1988).The coverage of the species has been established according to the Braun-Blanquet (1932). The «Detrended Correspondence Analysis» (DCA) techniques was used for the treatment of the data, which is an improvement of the Correspondence Factorial analysis method (AFC), a method that permits us to regroup clouds of similar samplings and by species. The ordination of the samplings was done using the Two Way Indicator Species Analysis software (Twinspan) (Hill, 1994). The ascending hierarchical classification (CAH) is a powerful analysis method that permitted us to regroup the objects following a matrix of distance (the similarity in our case) between these objects (the summaries in our case). The dendrogram obtained from the ascending hierarchical classification (CAH) was with the help of the Multi-Variate Statistical Package (MVSP 3.22) software using the method of Ward on the basis of the distance of Bray-Curtis, clustering by UPGMA (Kovach, 1997, 2003). The factorial plans are gotten with the software MVSP 3.22 on the basis of a DCA.

The comparison of the specific diversity of grouping vegetable (plant) has been realized on the base of specific richness respectively (S) and the index of diversity calculated with the floristic inventories obtained and whose doorstep are difined by Gillet (2000) and Dajoz (2006).

## Floristic analysis

To measure the specific diversity from a list of species and their number of individual partners, different indices were also calculated; basal area defined as the projected surface area covered all stems measured at ≥ 10 cm dbh. The present study used the Margalef (RMg), Shannon and Pielou indices to measure diversity and equitability (Shannon and Weaver, 1949; Pielou, 1966; Magurran, 2004); the Sørensen similarity index (1948) to compare the grouping.

$$R_{Mg} = (S - 1) / \ln (N)$$

Where, N is the number of individual.

$$ISH = -\Sigma Ni/N \log 2 Ni/N$$

Equitability of EQ = ISH/log2S

Where, *S* is the number of species of a given parcel; ni is the number of the species i and N the strength of all species.

$$K = 2a/(2a + b + c)$$

Where, 'a' is the common species of the 02 compared groupings vegetation, 'b' and 'c' are the number of species absent in the one but present in the other.

## Results

### Determination of plant groupings

Starting from the matrix of seventeen surveys and 136 species identified, five groupings were highlighted on the basis of the relative species frequencies (Fig. 5). The 61 per cent level of dissimilarity considered for the definition of the groupings made it possible to obtain the maximum possible. The criterion of stratification of surveys and realities of field guided the determination of the zone of vegetation corresponding to each of the five individualized groups:

- Grouping with *Zanthoxylum gilletii, Ficus exasperata, Pycnanthus angolensis* and *Entandrophragma angolense:* it corresponds to the mature secondary forest of the eastern edge zone of the forest above the cloud and mist zone (Gr A);
- Grouping with *Trichilia procera*, *Cola acuminata*, *Leea guineensis* (on wet and marshy soil), *Laccodiscus ferrugineus* (Sanaga gallery), *Drypetes leonensis*, *Rutidea glabra* and *Tarenna eketensis* (river banks and torrents): it corresponds to the riparian vegetation of the valleys where the streams and torrents of the montane forest flow (Gr B);
- Grouping with *Cola acuminata*, *Garcinia smeathmannii*, *Drypetes staudtii* and *Macaranga occidentalis*: it corresponds to the forest of clouds and mists of the South-West submontane stage (Gr C);
- Grouping with *Desplatsia subericarpa*, *Tabernaemontana crassa*, *Xylopia africana*, *Xylopia aethiopica* and *Zenkerella citrina*: it corresponds to the North-East zone, little disturbed of the forest, occupied by a heterogeneous vegetation of altitude just above the area of clouds and mists (Gr D);
- Grouping with *Carapa oreophila*, *Syzygium staudtii* and *Tricalysia okelensis* var. *okelensis*; it corresponds to the vegetal formation of the zone above the zone of clouds and mists (Gr E).

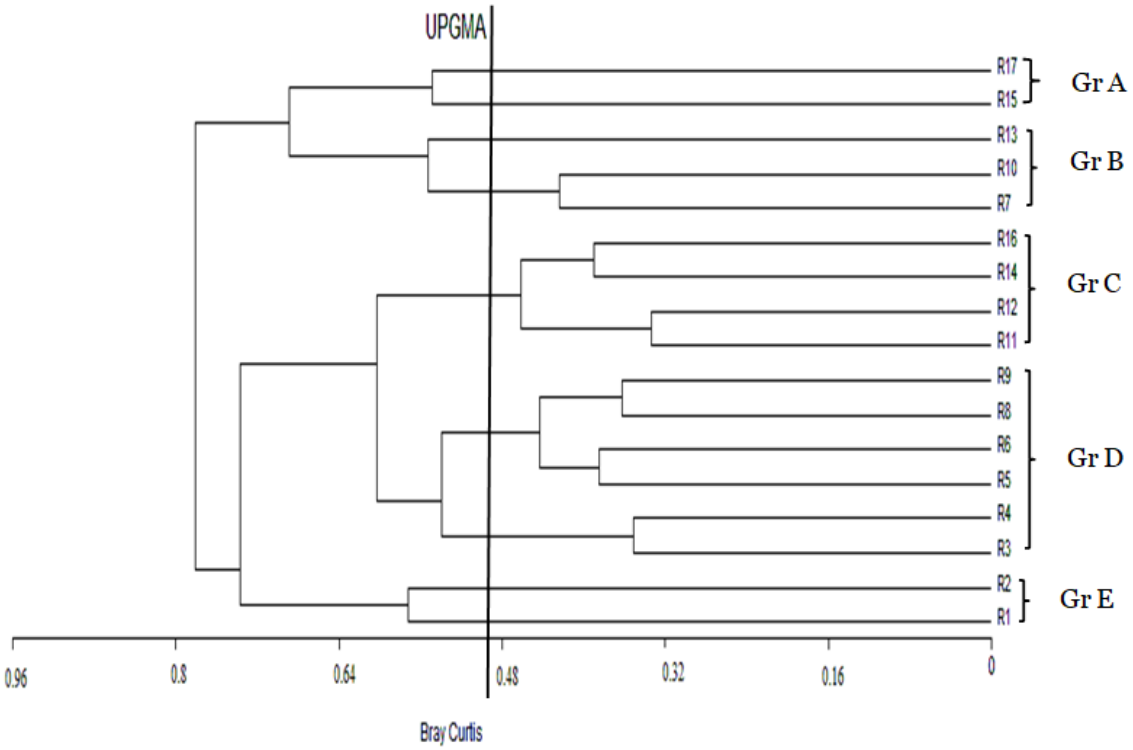



**Fig. 5:** Distribution of 5 individualized plant groups in Mount Kupe Mountain forest on a dendrogram.

## Ecological determinism of individualized plant groupings

The spatial distribution of individualized groups is shown in Fig. 6. The first two axes of the Principal Component Analysis (PCA) alone show a cumulative variance of 40.94 %. The ecological significance of the two axes is explained by the field observations, the stratification of the surveys and the ecology of the characteristic species.

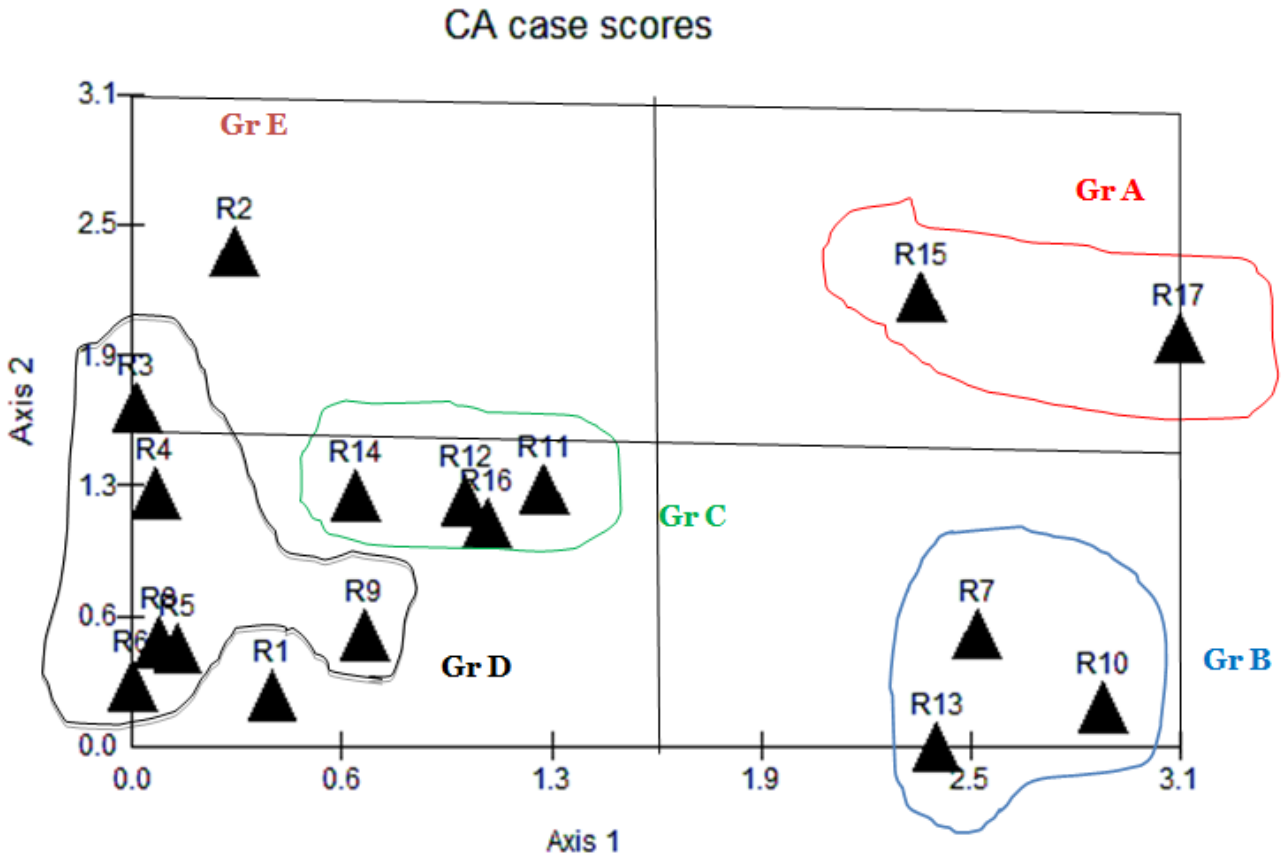



**Fig. 6:** Representation of the distribution of plant groups in the plan 1 and 2 of the PCA. Axis 1 represents the increasing gradient of anthropization while axis 2 expresses the increasing gradient of humidity.

Thus, on the negative side of the axis 1 (on the X-axis), half of the surveys forming the group E (the upper part of the forest, less disturbed) and D are located at 80% of the heterogeneous forest, as well as the surveys forming group C (transition forest) and group B (valley forest core), corresponding to the areas most affected by human activities such as hunting small animals with traps, collecting non-timber forest products, building timbers, also by degradations, rocky outcrops and soil quality, etc. Surveys corresponding to the forest area above the nephelophily, are dried by the wind.

On the positive side of this same axis, share out the surveys forming group A (mature secondary forest). Obviously, the axis 1 expresses a growing gradient of anthropogenic and/or edaphic disturbances from the central core of the forest towards its peripheral areas, which are the slopes.

Similarly, the negative side of the axis 2 (on the Y-axis), are positioned statements constituting the groups C, D and E. The group E corresponds to the floor of the mountain or floor is still felt a mesothermie. Group D corresponds to the zones whose hygrophilia is disturbed by very filtering soils and the topography with high air evaporation capacity. The latter corresponds to the less humid zone of the forest. For against, the positive side of this axis, are found statement forming the groups A and B. The group B corresponds to the wet flour area of the drill valleys along the streams or torrents which pass through the drill bit. Axis 2 represents a rising gradient of moisture from the

ground or air, from the highest to the lowest elevation.

## Biological diversity of plant groups

The values of species richness and other indices of diversity and equitability are given in Table 1. The Margalef index values show that the grouping corresponding to the heterogeneous montane zone (Gr D) is floristically more diverse than the four others. For this group, the value of the Margalef index is higher ($R_{Mg}$ = 24.66) than those of the others groups. The group E corresponding to the summit portion of the forest is the least diversified because it has a value of the lowest Margalef index ($R_{Mg}$ = 9.31). The values of the Piélou indices are greater than 0.70 for all groups. This means that, in the five groupings, the species share the ecological niches in a relatively equitable way.

The degree of similarity between the five plant groups compared two by two by the Sørensen similarity index is shown in Table 2. The floristic affinity between the five groups is in all cases less than 50 %. This shows that each individualized group is a unit relatively distinct from the others.

**Table 1.** Biological diversity index of plants groupings in Mount Kupe Montane forest.

| Groupings | Number of plots | Specific richness | Shannon index | Piélou equitability | Margalef index | Average recovering |
|---|---|---|---|---|---|---|
| Groupings A | 2 | 49 | 3.44 | 0.88 | 12.75 | 767.00 |
| Groupings B | 3 | 57 | 3.43 | 0.85 | 19.36 | 449.39 |
| Groupings C | 4 | 56 | 3.38 | 0.84 | 24.26 | 388.38 |
| Groupings D | 6 | 50 | 2.74 | 0.70 | 24.66 | 272.32 |
| Groupings E | 2 | 33 | 2.77 | 0.79 | 9.31 | 453.63 |

**Table 2.** Sørensen similarity value between pairs of plant communities in the Kupe Montane forest.

| Groupings | Groupings A | Groupings B | Groupings C | Groupings D | Groupings E |
|---|---|---|---|---|---|
| Groupings A | 100 | | | | |
| Groupings B | 43.39 | 100 | | | |
| Groupings C | 40.00 | 35.39 | 100 | | |
| Groupings D | 24.24 | 28.03 | 52.83 | 100 | |
| Groupings E | 19.51 | 24.44 | 26.96 | 40.96 | 100 |

## Identification of ecosociological groupings

In the summit forest of Mount Kupe, the classification of plant groupings in the higher syntaxons gives 03 Classes, 07 Orders and 05 Alliances:

- *Strombosio-Parinarietea* (Lebrun and Gilbert, 1954) (Str) class of evergreen rainforests represented by groups C, D and E, with several orders:
- Order of *Ficalhoeto-Podocarpetalia* (Lebrun and Gilbert, 1954) (Fic) of mountain rain forests; Alliance of *Galiniero-Parinarion holstii* Devred 1958. These syntaxons are represented by the grouping E of made of the mountain with two surveys R1 and R2.
- Order of the *Garcinietalia* (Noumi, 1998) (Gar) submontane forests; Alliance of *Garcinion* (Noumi, 1998), represented by group C on the floor of the mountain storey with four surveys R11, R12, R14 and R16.
- Heterogeneous groupings of altitude represented by the groupings D. The nucleus is formed by the species of *Strombosio-Parinarietea* which go from the lowlands (planitiary) formations on the top of the mountain represented by surveys R5 and R6 ; the Order of *Oleo-Jasminetalia* (Lebrun and Gilbert, 1954), Alliance of *Grewio-Carission edulis* (Lebrun and Gibert, 1954), is represented by the records R3 and R4 ; the Order of *Polyscietalia fulvae* (Lebrun and Gilbert, 1954), Alliance of *Polyscion fulvae* (Lebrun and Gilbert, 1954), represented by records R8 and R9.

- Class of *Mitragynetea* (Schmitz, 1963) (Mitra) of edaphic forests associated with hydromorphic soils represented by group B, with two orders :
- Order of *Mitragyno-Raphietalia* (Schnell, 1952 ; Lebrun and Gilbert, 1954), Alliance of the *Mitragyno-Symphonion* (Devred, 1958) of the marshy forests in the interior of the forest and the surroundings, tributary of the brooks and the torrents which are formed on the Mount and flow on the slopes, represented by the surveys R7 and R10. The characteristic species are *Leea guineensis, Laccodiscus ferrugineus, Rutidea glabra* and *Tarenna eketensis*.
- Order of *Pterygotetalia* (Lebrun and Gilbert, 1954) alluvial vallillary forests, high forest groups that occupy the fertile alluvial banks, subjected to short-term floods and which contribute to periodically rejuvenate the alluvium, represented by the R13 survey.
- Class of *Musango-Terminalietea* (Lebrun and Gilbert, 1954) of secondary forests represented by group A, with an order:
- Order of *Zanthoxylo-Terminalietalia* Lebrun and Gilbert, 1954 Lubini, 1986, Alliance of *Pycnantho-Zanthoxylion gilletii* Lubini (1982) 1986 of mature secondary forests with two surveys R15 and R17.

## Ecosociological groups

The results of the analysis of the ecosociological unit types of the species of the plant formation are presented to the Table 3. The groupings of the ombrophile afromontane forests total are 52 species (38.24%). They are followed by the groupings of the mesophile semi-caducifolious forests that present 30 species that is 22.06% of the set of the species. In the weighted spectrum, the species of ombrophile and secondary forests reach recovering of 74.96% of the total average recovering of the study area. In this context, the set of the species of the *Ficalhoeto-Podocarpetalia* to which belongs *Carapa oreophila* reach a relative recovering of 23.80%. They largely determine the physiognomy of the Kupe sylva. The forest (*senso-stricto*) totals 15 species (11.03%) reaching a relative coverage of 16.04% that places it in the 2nd position of the relative coverage. *Allophylus bullatus* belongs to this set described as plant association, whose species determine largely the evolutionary dynamic of the Kupe sylve.

**Table 3.** Ecosociological groups Spectra.

| **Phytosociologic status** | | **Raw spectrum** | | **Weighed spectrum** | |
|---|---|---|---|---|---|
| **Class** | **Order** | **Species number** | **(%)** | **Coverage** | **(%)** |
| **Species of the ombrophile forests** | | 72 | 52.95 | 2235.08 | 59.13 |
| *Strombosio-Parinarietea* | | 15 | 11.03 | 606.07 | 16.04 |
| | *Gilbertiodendretalia dewevrei* | 5 | 3.68 | 192.70 | 5.09 |
| | *Garcinietalia* | 20 | 14.71 | 536.66 | 14.20 |
| | *Ficalhoeto-Podocarpetalia* | 32 | 23.53 | 899.65 | 23.80 |
| **Species of the mesophile semi-caducufoilous forests** | | 30 | 22.05 | 617.42 | 16.34 |
| | *Piptadenio-Celtidetalia* | 22 | 16.17 | 463.67 | 12.27 |
| | *Oleo-Jasminetalia* | 8 | 5.88 | 153.75 | 4.07 |
| **Species of secondary forests** | | 23 | 16.89 | 598.17 | 15.83 |
| *Musango-Terminalietea* | | 13 | 9.55 | 299.26 | 7.92 |
| | *Polyscietalia fulvae* | 7 | 5.14 | 218.41 | 5.78 |
| | *Zanthoxylo-Terminalietalia* | 1 | 0.73 | 62.50 | 1.65 |
| | *Haumano-Musangetalia cecropioidis* | 2 | 1.47 | 18.00 | 0.48 |
| **Species of edaphic forests linked to the hydromorphe soils** | | 5 | 3.67 | 69.71 | 1.84 |
| *Mitragynetea* | | 5 | 3.67 | 69.71 | 1.84 |
| **Species of gallery forests** | | 4 | 2.94 | 210.75 | 5.58 |
| | *Pterygotetalia* | 4 | 2.94 | 210.75 | 5.58 |
| **Species of the non steppic savannas in the region** | | 2 | 1.47 | 48.25 | 1.28 |
| *Hyparrhenietea* | | 2 | 1.47 | 48.25 | 1.28 |
| **Total** | | **136** | **100** | **3 779.39** | **100** |

## Phytogeographic affinities

The floristic fund of the Kupe Mountain forest shows the abundance of the Guineo-Congolese species (more than 77 % of the total species), against 23 % of the large distributed species (Fig. 7). Among this latter, 9 % belong to the group of endemic species of the Cameroonian highlander archipelago, including Bioko, 2850 m (ex Fernando Pô) (Letouzey, 1985; Tchoua Tchetgnia, 2019).

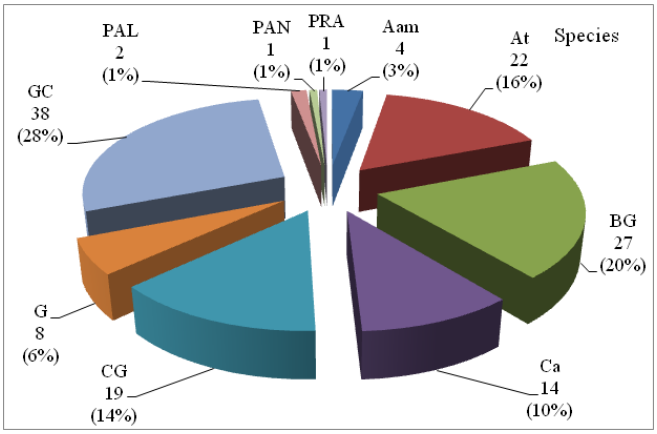



**Fig. 7.** Raw spectrum of the phytogeographical types.

## Spectrum of altitudinal variations

The regroupings by altitudinal floor of the specific whole give the absolute values and the centesimal proportions reported in Figure 8. For the aspects of forestry and altitudinal successions, the categories are deducted of the temperaments of the species. Only the intermediate combinations between two successive types of the pressure gradient (and non-disconnected) are generally feasible for species of link (Senterre, 2005; Noumi, 2013; Noumi and Tagne, 2016; Tchoua Tchetgnia and Noumi, 2016) (Fig. 8). The highlander groupings showed a total of 40 species (29%), with 10% of individuals. They are followed by the submontane groupings that totalize 39 species, either 29% of the set of the species represented by 19% of individuals.

## Mountain rainforest at *Carapa oreophila*

## Floristic composition

Two surveys (R1 and R2) made it possible to study the floristic and ecological composition of this group. It groups together 33 species listed alphabetically by species and phytosociological units. The number of species per surveys varies between 19 and 23 with an average of 21 species. The typical survey is represented by the R1 surveys (Appendix 1). The characteristic species of this forest *Carapa oreophila* and *Allophylus bullatus* are also found in eastern Nigéria.

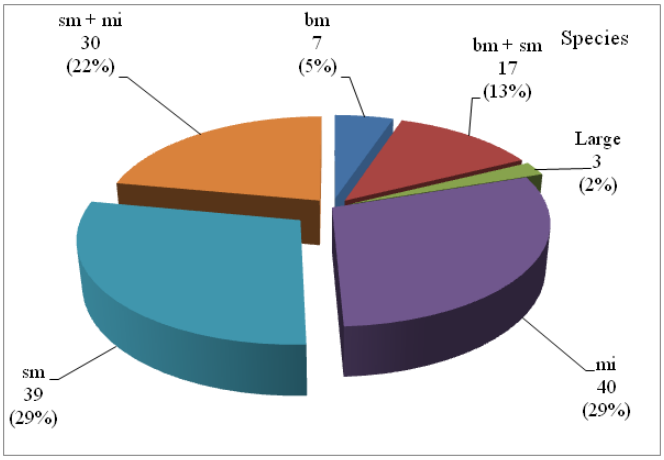
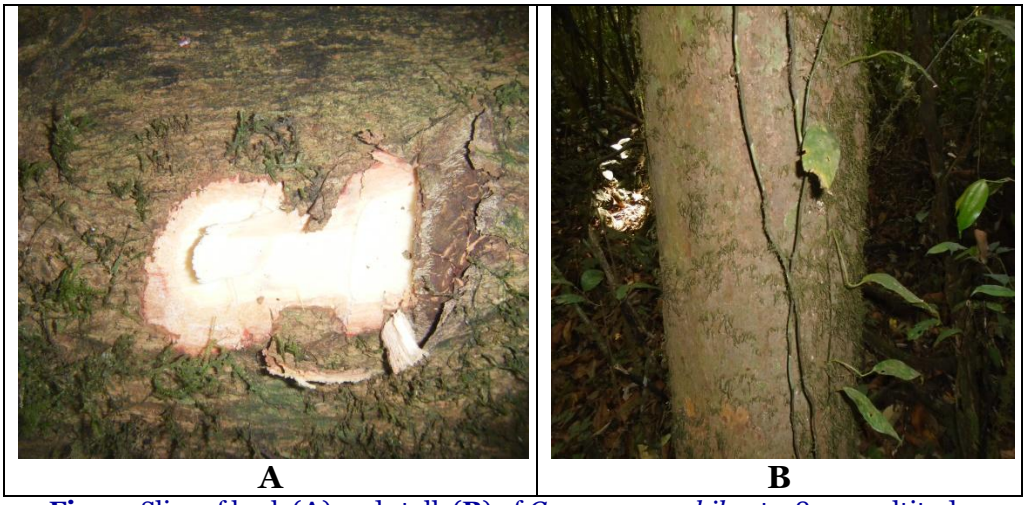



**Fig. 8:** Spectra of the altitudinal floors or altitudinal antecedents.

## Order of *Ficalhoeto-Podocarpetalia* Lebrun and Gilbert 1954

The montane forest of Mount Kupe is from the physiognomic point of view, a climax forest group that occupies the slopes of this massif. This forest benefits from a macroclimate favorable to the tightening of the slopes and characterized by high precipitations, well distributed during the year. These particular environmental conditions make it a rain forest. Lebrun and Gilbert (1954) defined the order of *Ficalhoeto-Podocarpetalia* consisting of mesothermal species, of medium size in the upper stratum and even less so at the highest altitudes. Many elements from the various Guinean forest types are found in the formation: deciduous species like *Chrysophyllum lacourtianum*, *Entandrophragma angolense*, *Prunus africana*; species of secondary forests such as *Polyscias fulva, Xylopia aethiopica;* species of evergreen forest like *Allophylus bullatus, Bersama abyssinica, Carapa oreophila* (Figure 9), *Strombosia pustulata*. The montane forest of Mount Kupe is included in this order. Most of the species mentioned above can be found in many northern locations and become quickly familiar.



**A** **B**

**Fig. 9:** Slice of bark (**A**) and stalk (**B**) of *Carapa oreophila* at 1,800 m altitude.

## Study of ecological spectra and phyto-geographic distribution

### Spectrum of biological types

The results of the detailed analysis of the biological types of the specific grouping are summarized in Table 4. The importance of microphanerophytes is highlighted with 54.54 % for the raw spectrum. This group is followed by the mesophanerophytes with 24.24 %.

### Spectrum of leaf size types

Table 5 presents the results of the analysis of leaf size types. The predominance of mesophylls is shown both for the raw spectrum (60.60 %) and the weighted spectrum (78.50 %). The microphylls come in 2nd position in raw spectrum with 24.24 % and also in weighted spectrum with 13.38 %. Nanophylls are the least represented with only 0.33 % of the relative recovery.

**Table 4.** Spectrum of biological types of mountain rainforest.

| Biological types | Raw spectrum | | Weighted spectrum | |
|---|---|---|---|---|
| | Species number | Percentage | Recovery | Percentage |
| Microphanerophytes | 18 | 54.54 | 502.25 | 55.35 |
| Megaphanerophytes | 1 | 3.03 | 3.00 | 0.33 |
| Mesophanerophytes | 8 | 24.24 | 384.00 | 42.32 |
| Nanophanerophytes | 3 | 9.09 | 9.00 | 0.99 |
| Climbing phanerophytes | 3 | 9.09 | 9.00 | 0.99 |
| **Total** | **33** | **100** | **907.25** | **100** |

**Table 5.** Spectrum of leaf size types of mountain rainforest.

| Leaf size types | Raw spectrum | | Weighted spectrum | |
|---|---|---|---|---|
| | Species number | Percentage | Recovery | Percentage |
| Macrophyll | 2 | 6.06 | 6.00 | 0.66 |
| Mesophyll | 20 | 60.60 | 712.25 | 78.50 |
| Microphyll | 8 | 24.24 | 120.50 | 13.28 |
| Nanophyll | 1 | 3.03 | 3.00 | 0.33 |
| Notophyll | 2 | 6.06 | 65.50 | 7.22 |
| **Total** | **33** | **100** | **907.25** | **100** |

## Phytogeographic distribution types

The results of the precise analysis of the phytogeographic distribution types are presented in Table 6. Guinean low species are the most represented with 26.16% of the relative recovery, followed by Afro-American species with 20.50%. The tropical Africa species come in 3rd position with 14.80 % of the relative recovery; the typically Cameroonian species represent 12.99%. Guinean species are the least represented with 3.70%.

## Ecosociological groups

The main ecosociological groups are highlighted: the *Ficalhoeto-Podocarpetalia* species group (10 species), the *Garcinietalia* species group (5 species), the *Oleo-Jasminetalia* species group (4 species) and that of *Strombosio-Prinarietea* species (4 species) (Table 7).

**Table 6.** Spectrum of the phytogeographic distribution types of mountain rainforest.

| Phytogeographic types | Raw spectrum | | Weighted spectrum | |
|---|---|---|---|---|
| | Species number | Percentage | Recovery | Percentage |
| Aam | 2 | 6.06 | 125.00 | 13.77 |
| At | 7 | 21.21 | 128.75 | 14.19 |
| BG | 5 | 15.15 | 255.50 | 28.16 |
| Ca | 4 | 12.12 | 131.75 | 14.52 |
| CG | 5 | 15.15 | 127.75 | 14.08 |
| G | 2 | 6.06 | 102.50 | 11.29 |
| GC | 8 | 24.24 | 36.00 | 3.96 |
| **Total** | **33** | **100** | **907.25** | **100** |

Aam: Afro-American; At: Tropical Africa; BG: low Guinean; Ca: Cameroon; CG: Centro-Guinean; G: Guinean; GC: Guinean-Congolese.

**Table 7.** Spectrum of the ecosociological groups of mountain rainforest.

| Phytosociological units | | Raw spectrum | | Weighted spectrum | |
|---|---|---|---|---|---|
| **Classes** | **Orders** | **Species number** | **Percentage** | **Recovery** | **Percentage** |
| *Strombosio-Parinarietea* | | 4 | 12.12 | 59.00 | 6.50 |
| | *Gilbertiodendretalia dewevrei* | 1 | 3.03 | 15.00 | 1.65 |
| | *Ficalhoeto-Podocarpetalia* | 10 | 30.30 | 309.50 | 34.11 |
| | *Garcinietalia* | 5 | 15.15 | 134.75 | 14.85 |
| | *Piptadenio-Celtidetalia* | 3 | 9.09 | 93.50 | 10.30 |
| *Mitragynetea* | | 1 | 3.03 | 3.00 | 0.33 |
| | *Pterygotetalia* | 1 | 3.03 | 87.50 | 9.64 |
| *Musango-Terminalietea* | | 2 | 6.06 | 90.50 | 9.97 |
| | *Oleo-Jasminetalia* | 4 | 12.12 | 24.00 | 2.64 |
| | *Polyscietalia fulvae* | 2 | 6.06 | 90.50 | 9.97 |
| **Total** | | **33** | **100** | **907.25** | **100** |

## New association: Association of *Allophylo-Carapetum oreophilae* (*Allophylus bullatus* Radlk and *Carapa oreophila* Kenfack)

The *Allophylus bullatus* and *Carapa oreophila* Association forms a tree-like vegetation of mountain flanks between 1 800 and 2064 m altitude whose physiognomy is determined by *Carapa oreophila*. This Association is classified in the Order of *Ficalhoeto-Podocarpetalia;* Alliance of *Galiniero-Parinarion holstii* Devred 1958. It remains strongly related to very wet habitats, bedrock and high altitude above 1 000 m and is distributed on the ridges of Kupe mountain. It usually has two strata, a tree layer and a shrub

stratum. The floristic composition is given by 2 plots (R1 and R2). The number of species varies from 19 to 23 with an average of 21 per survey. The typical survey is number 2. *Allophylus bullatus* is a mesophanerophyte of the *Sapindaceae* family with mainly Cameroonian montane distribution from Mount Cameroon to the highlands of Bamenda. It is a small tree with white flowers up to 18 m tall, also described as a « soap tree stem and bristling leaves ». Its natural habitat is subtropical or tropical moist montane. As for the species *Carapa oreophila*, it is a 12 m tall microphanerophyte of the *Meliaceae* family with a montane distribution, endemic in Cameroon and eastern Nigeria. It is a species to have been straight and branched low into dense crown, the base being more or less cylindrical, the bark is smooth with a blood-red slash exfoliating in larger plates downwards; slice more or less fibrous red; wood more nervous; leaves are 45-65 cm long with a petiole 20-30 × 0.5-0.7 cm, the base being swollen and generally with 2 nectaries; diameter up to 70 cm. The shrub layer is made up of various species, the most common of which are *Bersama abyssinica*, *Hypericum revolutum, Loesenara talbotii*, *Pavetta camerounensis, Pavetta kupensis*, *Pittosporum viridiflorum*, *Tricalysia pallens* and *Tricalysia okelensis*. It is an ombrophilous forest related to the atmospheric moisture. The *Allophylus bullatus* forests are slightly open in their upper strata, which leaves the light is easily filtered; consequently they remain closed in their low stratum consisting mainly of common species. Many of the secondary forest species of *Polyscietalia fulvae* (*Polyscias fulva*) and the evergreen forest (*Prunus africana*, *Strombosia pustulata*, *Zanthoxyllum gilletii*) are dominant species from the various forest types in Guinea.

## Discussion

The vegetation group study constitute a fundamental source of basic data important for the conservation, converting and durable natural ecosystems even if, in certain cases, the ecological interpretation of identified groups may seem difficult (Sonke, 1998; Bangirinama et al., 2010; Tchoua Tchetgnia, 2013; Makemteu and Noumi, 2015; Noumi and Tagne, 2016; Tchoua Tchetgnia and Noumi, 2016; Makemteu, 2017; Tchoua Tchetgnia, 2019). The individualized plant groups in the Kupe mountain forest explain the spatial heterogenity of this forest ecosystem.

The analysis of this spatial heterogenity show that the Kupe mountain forest is subdivided in five floristically distinct zone: the part of the mature secondary forest, dominated by trees like *Zanthoxylum gilletii, Ficus exasperata, Pycnanthus angolensis* and *Entandrophragma angolense* (group A); the part of the heterogeneous forest, dominated by big tree like *Desplatsia subericarpa*, *Xylopia africana, Xylopia aethiopica*, *Zenkerella citrina* (group D); the top trajet of the forest, less disturbed (group E) where dominate the species like *Carapa oreophila*, *Syzygium staudtii* and *Tricalysia okelensis* which are the mountain species; the cloud or mist forest of the submontane storey dominate by *Cola acuminata*, *Garcinia smeathmannii*, *Macaranga occidentalis* (group C); the riparian valley vegetation which flows the streams and torrents of the montane forest of which the species characteristics are *Leea guineensis, Laccodiscus ferrugineus, Rutidea glabra* and *Tarenna eketensis* (group B).

The Kupe mountain forest presents thus a mosaic organization. This characteristic, confirmed by the weak values of Sørensen index (Table 2) had been already underlined by the studies on the intertropical moist forest realized by Oldeman (1990); Hakizimana et al. (2012); Makemteu (2017); Tchoua Tchetgnia (2019). The values of the Piélou equitability index (table 1) show that the species of the four grouping plants share more or less equitably the ecological niche (Barbault, 1992, 1997; Gillet, 2000; Hakizimana et al., 2012; Tchoua Tchetgnia, 2019). Considering the ecological determinism factors (the humidity gradient and this one of human disturbance). One remark that the groupings A and B are floristically nears on the one hand, and that, on the other hand, the groupings C and D are equally floristically nears. This floristic bringing closer is equally confirmed by the values of Sørensen index.

In the Kupe mountain forest, the floristic diversity depends on the landscaped garden unity considered. In fact, the sommital part of the forest less disturbed (grouping B) is least diversified in species (Table 1). It is rich in forests species such as *Carapa oreophila* and *Syzygium staudtii*. These species assure the development of the important

inferior arborescent stratum constituted of *Pavetta kupensis* and *Prunus africana*. The altitude heterogeneous forest (grouping D), the ombrophilous submontane forests (grouping C) and the edaphic forests linked to the hydromorphe soils (grouping B) are more diversified. In fact, Forman and Godron (1986), Burel and Baudry (1999), Hakizimana et al. (2012) and Tchoua Tchetgnia (2019) assert that, until a certain doorstep, the disturbance increase the diversity of the ecosystem. Moreover, these authors indicate that the disturbance are intense in the peripheral area which tend toward a diversification, and are very weak or near nil in the interior area which tend toward the homogenization (Barot et al., 1999; Henkel, 2003; Hakizimana et al., 2012; Lubini, 2016).

The plant groupings identified in the Kupe mountain forest maybe connect to those already described by the others authors. The grouping of *Trichilia procera*, *Cola acuminata*, *Leea guineensis*, *Laccodiscus ferrugineus*, *Drypetes leonensis*, *Rutidea glabra* and *Tarenna eketensis* come across the riparian valley, the streams and torrents are similar to those described on the border of Lake Tanganyika by Hakizimana et al. (2012) and Bangirinama (2010). The grouping of *Desplatsia subericarpa*, *Tabernaemontana crassa*, *Xylopia africana*, *Xylopia aethiopica*, *Zanthoxylum gilletii* and *Zenkerella citrina* individualized in the Kupe slope is similar to those described in the Kouoghap submontane forest by Makemteu and Noumi (2015). The presence of those species *Combretum paniculatum* are the eloquent sign of the human disturbance actions fingerprint (stamping, hunting, and gathering) and the secondarisation of the forests of Kupe mountain.

The order of the *Ficalhoeto-Podocarpetalia* group includes mountain rain forests. This forest benefits from a favorable microclimate due to the tightness of the slopes or the collection of the valleys and characterized by well distributed rainfall during the year. Mesothermic species of medium size are found in the upper stratum (20-25 m) and even less at the highest altitudes. There is also the presence of many species of shade or tolerant. More intense radiation favors the maintenance of light species in higher strata and also the invasion and gregarism of shade species are much more attenuated than in the plain, presence of gymnosperms, high atmospheric humidity, relatively low temperature, foggy and light rainy conditions etc. Among the characteristic species of these order and present in our surveys, we have *Allophylus bullatus, Bersama abyssinica, Carapa oreophila, Schefflera barteri, Syzygium staudtii*. The new association described in this order and the Alliance of *Galiniero-Parinarion holstii* Devred 1958 is the *Allophylo-Carapetum oreophilae*.

The presence of the species *Leea guineensis* marsh plant of the order *Mitragyno-Raphietalia* at the top of Mount Kupe which belongs to the order *Ficalhoeto-Podocarpetalia* reflects an orogenesis that occurred on the present site of Mount Kupe over the years these species have adapted to its new environment. The existence of *Leea guineensis* sarcochore species carried by animals at the top of this mountain indicates the marshy origins on the site before the mountain.

Mount Kupe is a mountain resulting from orogenic phenomena. Orogenesis is the scientific term for all mountain formation mechanisms, various theoretical systems (geodynamic models) encompassing these processes of formation of the reliefs, and sets of orogenes (mountainous systems on a portion of the earth's crust that has undergone significant compressive stresses generating folds and layers of thrusting) succeeding each other through geological time, also called orogenic phases.

The climatic, edaphic and anthropic elements encountered in the station seem to play a role in vegetation dynamics. These elements strongly influence the specific composition and ecology of this forest (Tchoua Tchetgnia, 2019). The main dynamic role is played within the plant formation by species of the forest *cf.* ombrophilous evergreen.

## Phytogeographical affinities

The phytogeographic affinities of these species recorded falls within ten major distributions (Fig. 7); 77% species are widespread in the Guineo-congolese element. The extensively widespread species (23%) are either endemic of the Cameroonian highlander archipelago, including Bioko (ex Fernando Pô), either distributed in the tropical region with the montanes of Oriental

Africa and southern Africa, and their populations are thus geographically discontinuous (Noumi and Tagne, 2016; Tchoua Tchetgnia, 2019).

## The altitudinal affinities

Comparing floristic composition of the Mount Kupe montane forest and other highland rainforests sampled in Cameroon (Letouzey, 1985; Tchoua Tchetgnia and Noumi, 2016; Noumi and Tagne, 2016; Tchoua Tchetgnia, 2019), 35 (31%) species are shared with lower montane vegetation. They are: *Bersama abyssinica*, *Carapa oreophila*, *Pavetta kupensis, Prunus africana, Schefflera barteri*, *Syzygium staudtii*, *Tricalysia okelensis* var. *okelensis*; 12 (10%) species in the lowland vegetation and submontane forests; 2 (2%) species in the lowland vegetation; 29 (25%) species in the submontane and lower montane vegetation; and 33 (29%) species in the submontane vegetation; 3 (3%) species have a wide distribution. A total of 1819 individuals belonging to 136 species, 83 genera and 42 families were recorded. They reached a total basal area of 193.75 $m^2$/ha.

## Conclusion

This study allowed to identify and to characterize the plant groupings forming the vegetation of the Kupe mountain forest. A new association was highlighted, that of *Allophylo-Carapetum oreophilae*. The presence of certain species such as *Leea guineensis*, *Laccodiscus ferrugineus* and *Rutidea glabra* shows that the present site of Mount Kupe was originally a marshy area that has been subjected to orogenesis over the years. The orogenesis of the Kupe massif occurred in a geosyncline of a large deep Lake bordered by edaphic forests on hydromorphic soils. The spontaneous evolution of the vegetation on hydromorphic soils during the orogeny of the massif, leads to a forest of evergreen montane trees which one can get an idea of the former stage, by examining what remains of what was formerly the forests on hydromorphic soils. The fundamental floristic nucleus of the forest is composed of ombrophilous species before the successional stages. In comparison with the results obtained, the research perspectives that should be undertaken in the near future emerge. These include:

- The analysis, through diachronic observations, of the dynamic relationships in time and space between the vegetation groups that have been defined within the vegetation of Mount Kupe;
- In-depth analysis of the life history and ecology of the main tree species of this vegetation;
- An estimate of the carbon stocks that this mountain vegetation overflows in order to recognize the importance of altitude forests in mitigating climate change in the context of REDD+.

## Conflict of interest statement

Authors declare that they have no conflict of interest.

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## List of Appendices

**Appendix 1.** Floristic composition of the mountain forest in *Carapa oreophila order* of the *Ficalhoeto-Podocarpetalia* Lebrun and Gilbert 1954.

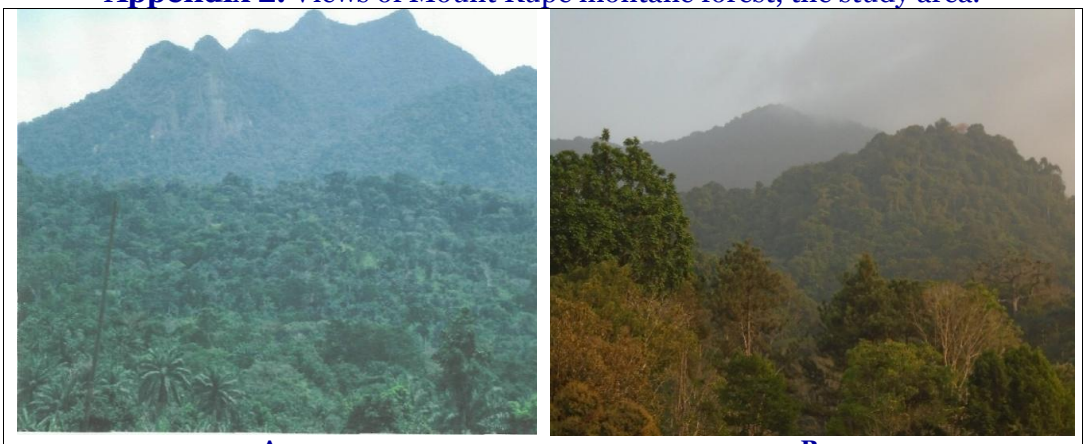
**Appendix 2.** Views of Mount Kupe montane forest, the study area.

**Appendix 1.** Floristic composition of the mountain forest in *Carapa oreophilaorder* of the *Ficalhoeto-Podocarpetalia* Lebrun and Gilbert 1954. TP: Phytogeographic types; TB: Biological types; TF: Types of leaf size; TD: Types of diaspores; TH: Type of habitat; PU: Phytosociological Units.

| TP | TB | TF | TD | TH | UP | Families | Species | R1 | R2 | Absolute frequency | Relative frequency | Recovery | Average Recovery |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Class of *Strombosio-Parinarietea* Lebrun and Gilbert** 1954 | | | | | | | | | | | | | |
| GC | Phgr | Nano | Scléro | bm + sm | Str | Combretaceae | *Combretum bracteatum* (M. A. Lawson) Engl. & Diels | 1 | | 1 | 50 | 3 | 3 |
| GC | MsPh | Méso | Sarco | Large | Str | Putranjivaceae | *Drypetes leonensis* Pax | | 1 | 1 | 50 | 3 | 3 |
| BG | McPh | Méso | Pogo | bm + sm | Str | Apocynaceae | *Strophanthus thollonii* Franch. | 1 | | 1 | 50 | 3 | 3 |
| Aam | MsPh | Méso | Sarco | bm + sm | Str | Meliaceae | *Trichilia procera* Forsyth. | 3 | 4 | 2 | 100 | 100 | 50 |
| **Order of *Ficalhoeto-Podocarpetalia* Lebrun and Gilbert 1954** | | | | | | | | | | | | | |
| Ca | MsPh | Méso | Scléro | sm + mi | Fic, End | Sapindaceae | *Allophylus bullatus* Radlk | 3 | 2 | 2 | 100 | 52.5 | 26.25 |
| At | MgPh | Macro | Scléro | mi | Fic | Melianthaceae | *Bersama abyssinica* Fresen. | | 1 | 1 | 50 | 3 | 3 |
| Aam | McPh | Méso | Sarco | mi | Fic | Meliaceae | *Carapa oreophila* Kenfack | 4 | 5 | 2 | 100 | 150 | 75 |
| Ca | McPh | Méso | Sarco | sm + mi | Fic | Rubiaceae | *Pavetta kupensis* S. Manning | 2 | | 1 | 50 | 15 | 15 |
| At | MsPh | Noto | Sarco | sm | Fic | Rosaceae | *Prunus africana* (Hook.f) Kalkm | 4 | | 1 | 50 | 62.5 | 62.5 |
| At | Phgr | Méso | Ptér | mi | Fic | Celastraceae | *Salacia pyriformioides* Loes | | 1 | 1 | 50 | 3 | 3 |
| GC | McPh | Micro | Sarco | sm | Fic | Araliaceae | *Schefflera barteri* (Seem.) Harms | 1 | 1 | 2 | 100 | 6 | 3 |
| G | MsPh | Méso | Sarco | sm | Fic | Myrtaceae | *Syzygium staudtii* (Engl.) Mildbr. | 5 | | 1 | 50 | 87.5 | 87.5 |
| CG | McPh | Méso | Sarco | mi | Fic | Rubiaceae | *Tricalysia okelensis* Hiern var. *okelensis* | 4 | 1 | 2 | 100 | 62.5 | 31.25 |
| Ca | MsPh | Micro | Sarco | mi | Fic, End | Araliaceae | *Schefflera mannii* (Hook. f.) Harms | 1 | | 1 | 50 | 3 | 3 |
| **Order of *Garcinietalia* Noumi 1998** | | | | | | | | | | | | | |
| CG | NnPh | Micro | Sarco | sm + mi | Gar | Myrsinaceae | *Ardisia staudtii* (Gilg) Mez | | 1 | 1 | 50 | 3 | 3 |
| BG | McPh | Micro | Sarco | sm | Gar | Lauraceae | *Beilschmiedia acuta* Kosterm. | 2 | | 1 | 50 | 15 | 15 |
| At | McPh | Méso | Sarco | sm + mi | Gar | Clusiaceae | *Garcinia smeathmannii* (Planch.& Triana) Oliv. | 2 | 5 | 2 | 100 | 102.5 | 51.25 |
| BG | McPh | Méso | Sarco | sm | Gar | Rutaceae | *Vepris lecomteana* (Pierre) Cheek & T.Heller | 5 | 3 | 2 | 100 | 125 | 62.5 |
| GC | Phgr | Méso | Ptér | mi | Gar | Celastraceae | *Salacia loloensis* Loes.var.*loloensis* | 1 | 1 | 2 | 100 | 6 | 3 |
| **Order of *Gilbertiodendretalia dewevrei* Lebrun and Gilbert 1954** | | | | | | | | | | | | | |
| G | McPh | Méso | Sarco | sm | Gil | Simaroubaceae | *Brucea guineensis* G. Don | 2 | | 1 | 50 | 15 | 15 |
| **Order of *Piptadenio-Celtidetalia* Lebrun and Gilbert 1954** | | | | | | | | | | | | | |
| GC | McPh | Macro | Sarco | Sm + mi | Pip | Malvaceae | *Cola acuminata* (P.Beau.) Schott et Endl | | 1 | 1 | 50 | 3 | 3 |
| BG | McPh | Micro | Sarco | mi | Pip | Leguminosae | *Loesenara talbotii* Baker f. | | 5 | 1 | 50 | 87.5 | 87.5 |
| At | McPh | Micro | Sarco | sm + mi | Pip | Annonaceae | *Xylopia aethiopica* (Dunal) A. Rich. | 1 | | 1 | 50 | 3 | 3 |

| TP | TB | TF | TD | TH | UP | Families | Species | R1 | R2 | Absolute frequency | Relative frequency | Recovery | Average Recovery |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Order of *Oleo-Jasminetalia* Lebrun and Gilbert 1954** | | | | | | | | | | | | | |
| CG | NnPh | Noto | Sarco | sm | Oleo, Gre | Rubiaceae | *Canthium vulgare* (K. Schum.) Bullock | | 1 | 1 | 50 | 3 | 3 |
| At | McPh | Méso | Ballo | mi | Oleo, Gre | Clusiaceae | *Hypericum revolutum* Vahl. subsp. revolutum | | 1 | 1 | 50 | 3 | 3 |
| GC | McPh | Micro | Sarco | mi | Oleo, Gre | Myrtaceae | *Eugenia fernandopoana* Engl. & Brehmer | 1 | 1 | 2 | 100 | 6 | 3 |
| GC | McPh | Méso | Sarco | bm + sm | Oleo, Gre | Myrtaceae | *Eugenia obanensis* Bak.f. | 2 | | 1 | 50 | 15 | 15 |
| **Class of *Mitragynetea* Schmitz 1963** | | | | | | | | | | | | | |
| CG | NnPh | Méso | Sarco | sm | Mitra | Rubiaceae | *Ixora guineensis* Benth. | | 1 | 1 | 50 | 3 | 3 |
| **Order of *Pterygotetalia* Lebrun and Gilbert 1954** | | | | | | | | | | | | | |
| Ca | McPh | Méso | Sarco | Sm + mi | Pter | Rubiaceae | *Pavetta camerounensis* S. Manning subsp. *Brevirama* s. Manning | | 5 | 1 | 50 | 87.5 | 87.5 |
| **Class of *Musango-Terminalietea* Lebrun and Gilbert 1954** | | | | | | | | | | | | | |
| GC | MsPh | Méso | Sarco | bm + sm | Mus | Flacourtiaceae | *Oncoba glauca* (P. Beauv.) Planch. | 1 | | 1 | 50 | 3 | 3 |
| CG | MsPh | Méso | Sarco | sm | Mus | Rutaceae | *Zanthoxylum gilletii* (De Wild) Waterman | 5 | | 1 | 50 | 87.5 | 87.5 |
| **Order of *Polyscietalia fulvae* Lebrun and Gilbert 1954** | | | | | | | | | | | | | |
| BG | MsPh | Méso | Sarco | bm + sm | Pol | Euphorbiaceae | *Macaranga occidentalis* (Müll. Arg.) Müll.Arg. | 5 | | 1 | 50 | 87.5 | 87.5 |
| At | McPh | Micro | Scléro | mi | Pol | Pittosporaceae | *Pittosporum viridiflorum* Sims '*mannii*' L. | 1 | | 1 | 50 | 3 | 3 |
| | | | | | | | **Total** | **23** | **19** | | | | |

**Appendix 2.** Views of Mount Kupe montane forest, the study area.



**A** **B**

**Fig. 1:** Mist forest of Mount Kupe. **A**: Coastal slope 10 am; **B**: South West slope 5 pm.

**A** **B**

**Fig. 2:** Inside the Mount Kupe forest. **A**: the researcher taking notes; **B**: the researcher taking the GPS coordinates of the sampled plot.

**A** **B**

**Fig. 3:** Seeds of some species. **A**: *Cola acuminata*; **B**: *Trichilia procera*.

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