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Altitudinal zonation of the vegetation of mount Kupe, Cameroon

Barthélemy Tchiengue*

National Herbarium of Cameroon, Yaounde, Cameroon

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Abstract

A detailed account of the vegetation of Mount Kupe, clothed by a luxurious forest is unknown and this study aims to fill that gap. From altitude 700m above farmlands to the summit, 29 plots of 5000m² each were demarcated and the floristic inventory involved the recording of all tree and shrub individuals of at least 5cm dbh. Diversity indices and many structural parameters were calculated. Important families and species were determined by calculating the family important and the species important value indices. The Shannon diversity index dropped from 4.1 in the lower dried submontane zone to 2.2 in the transition to montane zone. The Pielou evenness was 0.8 in the transition between lowland and submontane zone and decreased to 0.6 in the transition to montane zone. Some of the 11 important plant families are Euphorbiaceae, Guttiferae, Sterculiaceae and Meliaceae. Species A total of 198 species were recorded in the plots and five vegetation zones were discriminated. Amongst species with high IVI there are many Guttiferae (*Allanblackia gabonensis* Oliv., *Garcinia lucida* Vesque, *G. smeathmannii* (Planch. & Triana) N.Robson, *Pentadesma grandifolia* Bak. F.), and other like *Santiria trimera* (Oliv) Aubrév., *Carapa oreophila* Kenfack, *Dacryodes klaineana* (Pierre) H.J. Lam, and *Cylicomorpha solmsii* (Urb.)Urb. The distribution of stem individuals according to dbh indicates that large trees are not well represented. Since the forest on mount Kupe is stable, a situation favoring the presence of strict and narrow endemic species, the administration in charge of forestry must control encroachment in order to preserve this treasure.

***Corresponding Author:** Barthélemy Tchiengue ✉ btchiengu@yahoo.fr

Introduction

Tropical mountains are covered by vegetation comprising different landscapes. On the same mountain, the vegetation changes from forest on the lower slopes, to montane forest or montane grassland at the top. These mountains are home of most rare and endemic animal and plant species. Despite their high scientific importance, montane forests are unfortunately subjected to destruction because of their fragile ecology. Tropical mountains had been for a long time a matter of main scientific concern by researchers.

In West Africa, four main areas of highlands are distinguished: the Guinea highlands, the Togoland Hills, the Jos Plateau in Nigeria and the Cameroon system (Morton, 1986) In the West, the Guinea highlands host a set of mountains of moderate altitude one of which, the Nimba Mountain, rises at 1752m at Richard-Molard peak and spreads over 40km. The Cameroon montane ridge harbors the highest mountain on the West African coast, the Cameroon Mountain. It is well represented in Cameroon which is crossed by one of the most important volcanic mountain range of the African continent. This volcanic range takes place in the Atlantic Ocean where it involves islands of Pagalù, Bioko, Sao Tome and Principe. On the continent it concerns volcanic mountains such as Mount Cameroon, Manenguba, Bambuttos, and Oku then branches towards the Obudu plateau in Nigeria while on the Adamawa plateau, it supports the different peaks and important hills including the Tchabal Mbabo, Tchabal Gandaba, and Hosséré Vokré. Furthermore, this massif range also prolongs in Tchad and even far in Libya (Deruelle *et al.,* 1991; Kagou Dogmo, 1999) and not less than 60 anorogenic complexes (Lamilen, 1989) one of which, the Kupe Mountain and the southernmost of them, is clothed by a tropical forest.

Thanks to its coastal localization, Cameroon Mountain had been object to many studies. The first plant collector on that mountain was Mann who ascended it in 1861 (Hooker, 1864). His collection showed that the flora of this mountain comprised lot of species of temperate regions. Mountains situated in the hinterland had not benefited of such interest. With respect to mount Kupe (04°47' N 09°43' E; 2064m), little is known on its vegetation since few botanists such as Stahl (Letouzey, 1968a) Schlechter (Hutchinson and Dalziel, 1963) collected plants on it. In November 1954, Letouzey conducted a survey on mount Kupe, ascending it from the western slope to the summit. He mentioned a forest with lot of *Cola* and many Clusiaceae belonging to the genera *Garcinia* L., *Pentadesma* Sab. and *Symphonia* L.f. between 1000 and 1500m altitude while the summit was covered by a scrub. Leeuwenberg on the south western slope of this mountain especially at Mbulle had collected plants and his material Leeuwenberg 9298 was used by Letouzey (1977) to describe the new species *Rhaptopetalum depressum*. In 1992, students of the University of Aberdeen had carried out plant survey on this mountain. They found a small population of the near extinct Asclepiadaceae *Neoschumannia kamerunensis* Schltr around Kupe village on the southern slope of the mountain (Cheek *et al.*, 2004). During the decade 1980 to 1990, the International Council for Bird Preservation (ICBP) which later became BirdLife International initiated a series of biological studies on mount Kupe. Results of BirdLife showed that mount Kupe was home of many threatened bird species such as the rock fowl *Picathartes oreas* Reich., the mount Kupe bush shrike *Malacconotus kupensis*.

By the end of the decade 1990, a team of botanists of the Royal Botanic Gardens Kew carried out many field trips in the large area of Kupe and Manenguba mountains, collecting plant species (Cheek *et al.*, 2004) Out of these studies, only those of Letouzey (1968b, 1985) give an account of the vegetation of the mountain. Cheek *et al.* (2004) summarized the vegetation of mount Kupe. Prior to this study, a detailed description of the vegetation of mount Kupe had not yet been achieved. The present paper aims to assess the different vegetation types present on mount Kupe and to characterize floristically and structurally each of them.

Materials and methods

Study area

Mount Kupe is situated at bird fly at about 45km North West of the Cameroon Mountain in the south western region and at the boundary between French speaking area in the East and English speaking area in the West.

The mountain is surrounded by not less than 10 villages, three of which Nlohe, Lala and Kola are found in francophone area (Fig. 1).

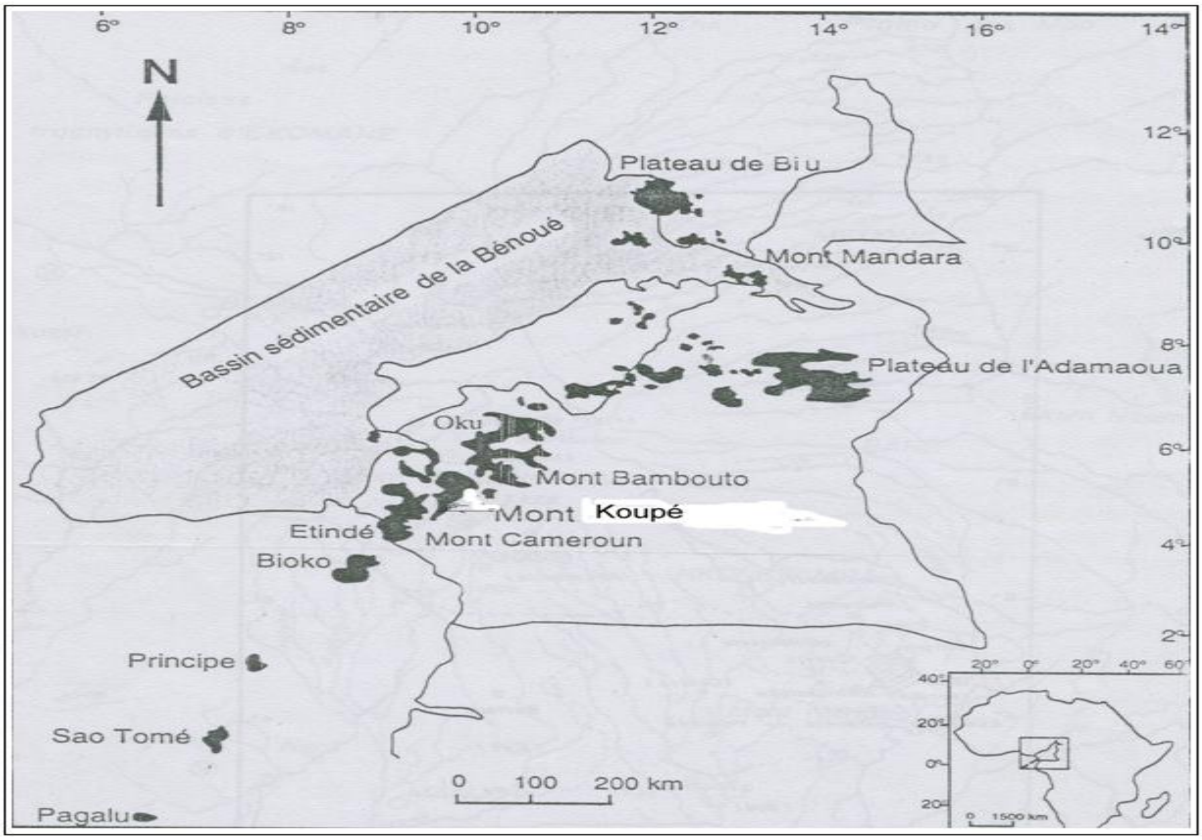


Fig. 1. Map of the Cameroon mountain ridge with mount Kupe (from Kagou Dogmo 1999).

It is found in an area of high precipitations. The annual rainfall is 4002mm at Nyasoso on the western side of the mountain, 4891mm in the south at Kupe village and 3658mm at Tombel (Suchel 1972, 1989). These figures are approaching that of Douala with an annual rainfall of 4125mm. Temperatures are moderate with low values of 20.6°C in June at Bangem and 23.4°C in March at Tombel (Suchel 1972, 1989). It is too warm in May at Tombel with 25.8°C and in March at Bangem where the highest temperature is 25.5°C. The study area is under the influence of the equatorial climate. Many subtypes of the equatorial climate are distinguished in Cameroon: the Guinean and the Cameroonian subtypes (Melingui *et al.* 1989, Tsafack 2007).

The Camerounian subtype is characterized by high precipitations as is the case at Nyasoso, Tombel and Kupe village. Mount Kupe is under the influence of the Cameroonian subtype of the equatorial climate.

Data collection

Data were collected in 29 rectangular plots of 0.5ha each demarcated at 100m intervals between altitudes 700 and 2000m on the northern, southern, western and eastern slopes. No plot had been established between 900 and 1000m because of the presence of farmlands and the steep outcrop which is not accessible to any human on the slopes at this altitudinal range. In each plot, floristic inventory involved recording of all trees and shrubs of at least 5cm diameter at breast height (dbh).

Fertile plant specimens were collected, identified and deposited at the National Herbarium of Cameroon (YA).

The topography of slope could be flat (1), gentle (2), steep (3) or very steep (4) and this information was documented as qualitative data. The geographical slopes East (E), North (N), South (S) and West (W) were considered as categorical variable. The forest clothing the mountain was found on either rocky soil or not.

Data analysis

A cluster analysis for vegetation classification was performed for vegetation classification using PC-Ord version 5.19 (McCune and Mefford, 2006). For interpretation reasons, the minimum number of plots per cluster was four. This software generates automatically the Shannon diversity index and the Pielou evenness which were used in this study. Indicator species of each vegetation zone were selected on the basis of their Importance Value Index (IVI) as calculated below.

Due to the difficulty to measure height of the trees in forest, the different strata were considered on the basis of the diameter classes of the trees and shrubs following Letouzey (1982). In this system, the shrub stratum comprises individuals with dbh stretching between 5 and 20cm. The lower tree stratum is composed of trees having a diameter of 20 to 50cm, the medium stratum where the diameter stands from 50 to 100cm and the upper tree stratum where all trees are more than 100cm dbh.

Description of the structure and floristic composition of the different vegetation units was done by calculating the following structural and phytosociological parameters and diversity indices:

Basal area $= \frac{1}{2}\pi d^2$ where d is the dbh of the species

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

$$\text{Relative frequency} = \frac{\text{Number of plots in which the species is present}}{\text{Total number of all plots}} \times 100$$

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

$$\text{Relative diversity} = \frac{\text{Number of species of the family}}{\text{Total number of species of all families}} \times 100$$

The Important Value index is the sum of relative frequency, relative dominance and relative density is the Important Value Index. It indicates how a species is ecologically important and significant.

IVI = Relative density + Relative frequency + Relative dominance.

The Family Importance Value was also calculated according to Mori *et al.* (1983). Its formula is: FIV = Relative Diversity + Relative frequency + Relative Dominance.

Diversity indices comprise the Shannon index (H') and the Pielou's evenness (Kent and Cooker 1992). They were calculated as follows:

$H' = -\sum p_i \ln p_i$, where p_i is the ratio of the number of individuals of species "i" over the total number of individuals of all species and ln is the log base e.

$E = \frac{H'}{\ln S}$ with S the total number of species of the sample

Ratio I/S where I is the total number of individuals and S the number of species.

Others statistical analyses including analysis of variance, correlation and descriptive statistics were carried out with Statistica 6.0 package.

Results and discussion

Zonation of the vegetation on mount Kupe

Five forest types (hereafter "zones") were discriminated in this study (Fig. 2). They are: a) zone 1 or the transition zone between lowland and submontane forests, b) zone 2 or the wet lower submontane zone, c) zone 3 or the dried submontane zone, d) zone 4 or the upper submontane zone, and e) zone 5 or the transitional forest between submontane and montane forests.

Each of these zones is peculiar by the mountain slopes and altitudinal ranges it covers. The transition zone between lowland and submontane forests stretches over altitudes 700 to 1000m and concerns four plots 1, 21, 28 and 29 established respectively in forest on the western, eastern and southern slopes of the mountain. The topography of the individual plot is either flat or gentle on the southern and eastern slopes while it is steep on the western side. The soil is loose on the western slope and rocky to lightly rocky respectively on the eastern and southern slopes.

Table 1. Most important plant families on Mount Kupe.

Zn 1	Families	Euphorbiaceae	Guttiferae	Sterculiaceae	Meliaceae	Burseraceae	Fabaceae
	FIV	39.3	40.5	37.1	28.9	45.1	37.1
	G	12	5	3	5	2	8
	S	13	8	8	6	2	8
Zn 2	Families	Euphorbiaceae	Guttiferae	Sapotaceae	Meliaceae	Burseraceae	Rubiaceae
	FIV	38.7	39.7	35.8	38.4	48	35.1
	G	8	4	6	5	2	9
	S	11	5	6	6	2	10
Zn3	Families	Euphorbiaceae	Moraceae	Caricaceae	Meliaceae	Olacaceae	Rubiaceae
	FIV	40.7	38.2	37.8	37.9	37.2	37
	G	12	3	1	6	1	11
	S	13	5	1	8	1	11
Zn 4	Families	Euphorbiaceae	Guttiferae	Sterculiaceae	Meliaceae	Burseraceae	Rubiaceae
	FIV	39.6	41	38.9	41.3	37.8	39.1
	G	10	4	2	5	2	9
	S	10	5	2	7	2	12
Zn 5	Families	Euphorbiaceae	Guttiferae	Sterculiaceae	Meliaceae	Rubiaceae	Fabaceae
	FIV	38.9	41	36.3	42.5	39.5	30
	G	5	2	1	1	6	1
	S	5	2	1	1	6	1

Legend: Zn: vegetation zone; FIV: Family Important Value; G: number of genera; S: number of species.

The flora is rich in lowland forest species and the majority of them form the tree stratum where the tallest like *Pycnanthus angolensis* (Welw.) Warb., *Pouteria pierrei* (A. Chev.) Baehni and *Entandrophragma angolensis* (Welw.) C.D.C can reach a height of 35 m.

Typical submontane forest species including *Allanblackia gabonensis, Garcinia lucida,* and *Santiria trimera* start to occur and their abundance increases with altitude. This forest is exclusively home for *Garcinia lucida, G. conrauana* Engl.*, Pentadesma grandifolia* and *Guarea mayombensis* Pellegr. From altitude 700m, *Garcinia lucida* forms stand in the understory and do not reach altitude 1100m. Altitude 1000m is regarded as an elevation many lowland forest species do not exceed and is considered as the upper limit of the transition between lowland and submontane forest zones.

The lower extend of this zone is altitude 700m because of the exposure of the southern slope to the monsoon that enables submontane forest species to occur.

The wet lower submontane zone is a forest with *Santiria trimera, Dacryodes klaineana*, and *Beilschmiedia* sp. is found from altitude 1000 to 1300 m and comprises five plots 2, 3, 4, 22 and 23 established only on the western and eastern slopes of the mountain on loose soil. The topography is flat in plots 2 and 3, gentle in plot 4 found respectively at 1100, 1200 and 1300m altitude on the western slope, and steep in plots 22 and 23 of the eastern slope.

Table 2. Important species on mount Kupe.

	Vegetation zones				
Species	1	2	3	4	5
Allanblackia gabonensis	26.5	37.7	0	20.4	0
Beilschmiedia obscura	17.5	30.3	17	26.8	0
Carapa oreophila	0	27.6	18.0	39.4	37.0
Cola verticillata	25.7	28.0	17.2	39.1	36.2
Cyathea manniana	16.1	6.7	9.0	22.5	32.0
Cylicomorpha solmsii	25.4	6.7	39.0	0	0
Dacryodes klaineana	36.6	43.3	8.6	0	0
Garcinia lucida	30.9	0	0	0	0
Garcinia smeathmannii	0	20.9	0	29.1	52.5
Macaranga occidentalis	35.0	33.7	35.2	32.2	36.0
Pentadesma grandifolia	26.4	21.2	0	9.5	0
Santiria trimera	43.7	42.3	26.8	38.5	0
Schefflera mannii	0	6.7	0	9.9	29.9
Strombosia scheffleri	36.6	21.1	38.5	12.1	0
Symphonia globulifera	27.2	21.3	8.4	32	6.7
Zenkerella sp.	34.4	35.0	8.4	35.1	30.3

The height of the trees is between 25 and 30 m and the most common are *Dacryodes klaineana, Santiria trimera,* and *Allanblackia gabonensis* which are frequent and dominant in the tree layer. The dried lower submontane zone comprises a forest dominated by *Cylicomorpha solmsii* and it is represented by plots 12, 13, 14 and 15. This forest is found exclusively on the northern flank of the mountain where it does not exceed altitude 1300m.

Table 3. Diversity indices and structural parameters of the different vegetation zones.

	Vegetation zones				
	1	2	3	4	5
Diversity indices					
p	4	5	4	11	5
N	106	94	106	86	39
S	53	38	53	16	16
H	3.8	3.7	4.1	3.4	2.2
E	0.8	0.8	0.8	0.7	0.6
Structural parameters					
I	1117	1662	1020	3803	2002
I/ST	10.5	17.6	9.6	44.2	51.3
Basal area	26.1	23.4	25.7	24.7	16
Stem density	558.5	664.8	510	691.4	800.8

Legend: p = Number of plots. N = Total number of species in vegetation group; S = Species richness per ha; H = Shannon diversity index; E = Pielou's evenness; I = number of individuals in the vegetation group.

The topography is almost flat at 1000m while it is gentle between 1100 and 1300 and patches of cocoyam fields are found.

The soil between 1000 and 1100m is stony. In this zone, most of the species such as *Ficus mucuso, Schrebera arborea,* and *Albizia* spp. are typical of semi deciduous forest and the height of the upper tree stratum reaches 25m.

The canopy is scattered and the forest is rich with species of disturbed areas like *Neoboutonia mannii* Benth. & Hook. f, *Albizia adianthifolia* (Schum.) W. Wight, and *Cylicomorpha solmsii* as well.

Above Tape Etube village, there is a large stand of Marantaceae and Zingiberaceae developed on rocky soil and poor in trees. Many species like *Allanblackia gabonensis, Dacryodes klaineana, Beilschmiedia obscura* (Stapf) A. Chev. or *Englerophytum stelecanthum* Mildbr which are typical of wet forests are absent in this forest whereas they are found on other slopes.

The frequency and relative abundance of other submontane species like *Santiria trimera, Cola verticillata* (Thonn.) Stapf. *and Zenkerella* sp. drops considerably.

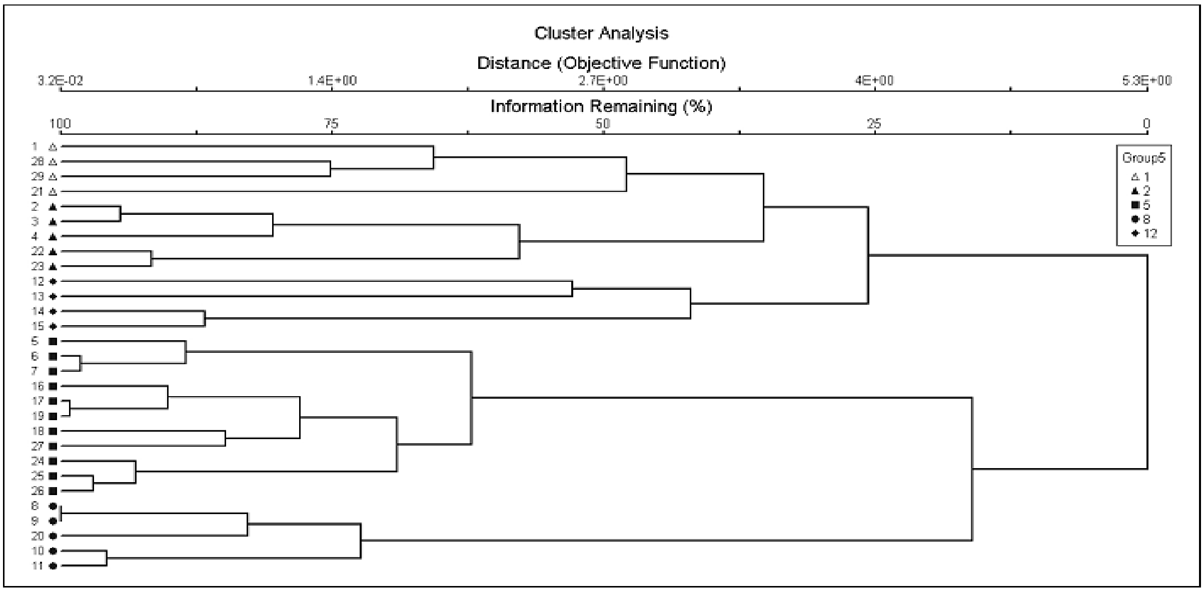


Fig. 2. Dendrogram showing the five vegetation zones.

Legend: Group1 = Zone 1; Group 2 = Zone 2; Group 5 = Zone 3 to which belongs plot 5; Group 12= Zone 4 (plot 12 is part of the zone) whereas Group 8 = Zone 5 (plot 8 belongs to this zone).

In the upper submontane zone represented by a set of 11 plots demarcated from altitude 1400 to 1700m on the northern, western and eastern slopes regularly covered by a thick fog, the forest is rich in Guttiferae. All categories of topography are concerned from flat to very steep. Tallest trees like *Ficus chlamydocarpa* (Mildbr.) Burr., *Symphonia globulifera* L.f. and *Entandrophragma angolense* (Welw.) D.C. can reach a height of 25m. Apart from *Garcinia conrauana, G. lucida* and *Mammea africana* Sab., all the species of Guttiferae recorded in this study are present in this forest type. Thus significant changes are noticeable both in terms of flora, structure and especially the physiognomy of the forest. Some species like *Allanblackia gabonensis, Dacryodes klaineana,* already present at low elevation become rare or do not occur at all in the plots. At the same time, other species amongst which *Ficus chlamydocarpa,* and *Draceana viridiflora*Engl. & K. Krause occur for the first time.

The abundance of species like *Polyscias fulva* (Hiern) Harms *and Psychotria camptopus* Verdc. increases with altitude, the former being represented by tall and big individuals. However the frequency and abundance of *Garcinia smeathmannii* which was present from altitude 1100m on western slope by isolated individuals increases considerably.

Five plots established from altitude 1700m to the summit form the transition between submontane to montane zones. Where the topography is steep, there is a frequent falling of trees due to a tin soil layer and its consequent shallow rooting and the outcropping of the bedrock. The resulting gaps are covered by subshrubs where the most common are *Discopodium penninervium* Hochst., *Piper capense* L.f., *P. umbellatum* L. and *Leea guineensis* G. Don. The height of the tree stratum is low and the tallest trees can reach 15m as is the case with *Polyscias fulva,* *Carapa oreophila* and *Syzygium staudtii* (Engl.) Mildbr. In the shrub stratum *Garcinia smeathmannii* is abundant and its individuals represent more than 2/3 of the stems in that stratum. The presence of montane species like *Podocarpus latifolius* Rendle, *Prunus africana* (Hook. f.) Kalkman, *Nuxia congesta* R. Br ex Fresen, and *Xymalos monospora* (Harv.) Baill. ex Warb. at this altitudinal elevation indicates the transition to the montane zone as is the case with *Xymalos monospora* and *Pittosporum viridifolium* Hook. f.

Vegetation zones on tropical mountains are tributary of local environmental conditions prevailing on the sites. Between altitude 700 and 1000m, the floristic composition of the forest changes with occurrence of submontane forest species. Many authors (Portères, 1946; Schnell, 1952; Achoundong, 1995, 1996) had identified altitudinal range of 800 to 1000m as the point where lowland vegetation changes. On mount Kupe, this transition zone is floristically similar to that observed by Achoundong (1995, 1996) on the Nta Ali and the hills above altitude 1000m in the Yaounde area.

The only difference concerns the behavior of *Garcinia lucida* which on Mbam-Minkom in the Yaounde area, starts to appear in few stems at altitude 900m then forms stand at 1000m and disappears at 1150m (Achoundong, 1996). This difference can be explained by the air moisture which is higher on Kupe than on the hills on Yaounde area. However, the authors had found *Garcinia lucida* growing to altitude 1550m at Kodmin on the Bakossi Mountains, situated at the West of mount Kupe.

The difference in the behavior of this species can be explained by the high annual rainfall and air moisture in the Kupe-Bakossi region which had lowered the inferior limit of this zone from 800-1000m to 700m. The altitudinal delimitation of the transition zone on mount Kupe is consistent with results of other studies (Boughey, 1955; Jaeger and Adam 1971; Schnell, 1971; Jacobs, 1981; Letouzey, 1985) which had shown that on tropical mountains and around altitude 800 to 1200m, vegetation changes from lowland to a submontane type.

The different faces of the submontane vegetation above the transition zone are not only due to altitude, but by others factors like moisture, nature of the soil, exposure etc. (Morton, 1986; Engler, 1908). Thus the wet lower submontane forest is narrowly linked to slopes under influence of the monsoon and high precipitations. This situation concerns the ark circle from Nyasoso on the western slope, Tombel and Kupe village on the southern slope to N'lohe on the eastern side of the mountain.

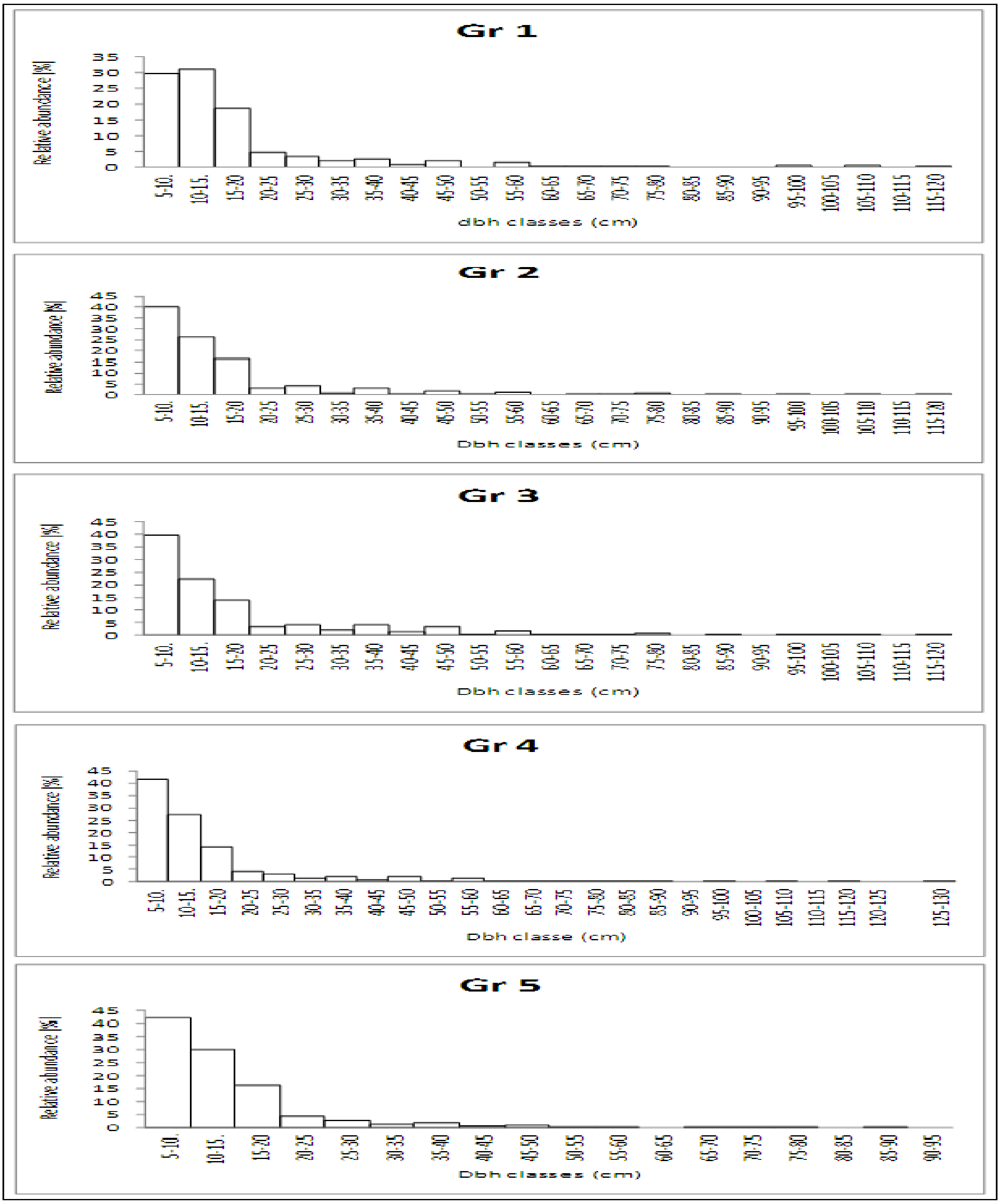
The presence on the northern slope of a dried lower submontane zone is due to the foehn effect. The cold winds coming from the Atlantic Ocean land first on the western and southern slopes of the mountain where precipitations are high with annual rainfalls of 4002 mm at Nyasoso and 4891 mm at Kupe village (Suchel,1972). Before reaching the low altitudes on the opposite northern flank, they have lost an important part of their moisture and become dry.

This contrasting situation between the windward and the leeward leads to a deep difference in the flora of the two slopes. This phenomenon is well known even on mountains of moderate altitude like those of Yaounde area (1000m) where Achoundong (1996) found evergreen and semi-deciduous forests respectively on the wet and dry slopes. This rain shadow effect coupled to forest encroachment by man is responsible of the predominance of species typical of semi deciduous forests in the dried lower submontane zone.

It also explains the absence of submontane hygrophilous species and the decrease of relative abundance and frequency of some of them. The upper submontane zone takes place at altitude 1400m and corresponds to "the Nebelwald (Engler, 1908; Letouzey, 1985), the "highland zone" (Boughey 1955) the "montane zone" (van Steenis 1934), or the lower montane zone (Hemp 2005).

These authors had identified altitude 1500m as the point where the vegetation of tropical mountains changes in both flora and structure. The early occurrence of this zone on mount Kupe can be explained by the combination of the altitude, the annual rainfall and the permanent presence of fog. The last factor creates a lowering of the temperature and increase of air moisture that favors hygrophilous species to establish in the forest.

The cold microclimate reigning in this environment leads to the abundance of some species like the tree fern *Cyathea manniana*.



The enrichment of forest flora with montane species around 1700m marks the transition to montane zone. Portères (1946) described a montane vegetation zone on Bambuttos Mountains between altitudes 1650 to 2600m, but this figure cannot work on mount Kupe since from 1650 to 2000m altitude, the flora is still rich in submontane forest species. *Pittosporum viridifolium* and *Xymalos monospora* which are present in this forest are best regarded as a species marking the transition to montane zone (White, 1983) since they do not grow at low altitude. Out of the five montane tree species Letouzey (1985) recognized as characteristic of the montane zone in Cameroon, four occur on mount Kupe: *Syzygium staudtii, Prunus africana, Nuxia congesta* and *Podocarpus latifolius*. With regard to the last species, it had been collected at low altitude in Cameroon and in Congo (Letouzey, 1985; Maley *et al.*, 1990). The author had the opportunity to find a good population of this plant at altitude 800m at Ebo forest situated at about 125 km North East of mount Kupe.

Its mountain character is well evidenced by the pure stands it forms above altitude 2200 on mount Oku situated at about 180km NNW of mount Kupe. It is part of character and dominant species of the upper montane zone defined between altitudes 2800 to 3200m on Kilimanjaro Mountain as well as *Prunus africana* (Hemp, 2005). The presence at low altitude of *Podocarpus latifolius* can be regarded either as the consequence of the “Massenerhebung effect” (Grubb, 1977) or evidence of a cool paleoclimatic environment different from the present period (Maley *et al.*, 1990).

Floristic characteristics of the zones

Diversity of families and genera

A total of 198 species belonging to 143 genera and 51 plant families were recorded and 11 of these plant families are the most diverse at both generic and specific levels. They account for 54% and 61% respectively to the total number of genera and species. The Rubiaceae are the most diverse with 20 genera and 26 species mostly found in the understory. They are followed by the Euphorbiaceae, 16 genera and 20 species, the Meliaceae and Sterculiaceae with respectively seven and three genera but 11 species each. Leguminosae are represented by nine genera and 10 species. All these families and five others are those with high family important value (Table 1). However, despite their low diversity, the Burseraceae play important role since their FIV is high in three vegetation zones. The Caricaceae, Moraceae and Olacaceae are most important in the forest dominated by *Cylicomorpha solmsii*. Most of the families are poorly diverse. 23 of them like Loganiaceae, Melianthaceae and Simarubaceae are each represented by a one genus and one species.

At generic level *Cola* with eight species all found in the transition zone between lowland and submontane forests, is the most diverse genus whereas in the other vegetation zones, it is only represented by *Cola verticillata*. Beside *Cola* Schott & Endl., the other most diverse genera comprise *Ficus* L., *Garcinia* L. and *Oncoba* Forssk. with five species each.

Many of the most important families and genera found on mount Kupe are reported to play an important role on other mountains and hills of Cameroon above altitude 1000m (Letouzey 1985, Achoundong 1995, 1996). Letouzey (1985) pointed out that the forests of Congo Guinean region in Cameroon comprise the lowland forest and the submontane forest zones. Despite the altitudinal change of the flora with altitude, most of the important families and genera on mount Kupe are endemic to the Congo Guinean centre of endemism (White 1983). Their predominance on mount Kupe is therefore tributary to the fact that they are endemic to the phytochoria. Furthermore, the major importance of the Guttiferae had been reported in other studies elsewhere ([Achoundong & Tchatat 1988, Thomas & Achoundong 1994, Schnell 1952, Noumi 1998). Letouzey (1968a) characterized the submontane zone in Cameroon as a zone with Guttiferae. On many other mountains (Nlonako, Lebialem, Bakossi) and hills (Ebo forest) of Cameroon, the author had the opportunity to find that *Garcinia* spp., *Allanblackia gabonensis*, and *Pentadesma grandifolia* are very common. For other group of plants, it is either the same species like *Garcinia smeathmannii, Santiria trimera* that abound on mountain slopes, or species from the same genus as is the case of *Carapa procera* in West Africa and *Carapa oreophila* in Cameroon (Kenfack 2008). Beside the Congo Guinean species, the presence of those of the afro montane archipelago (White 1983) such as *Podocarpus latifolius, Xymalos monospora, Syzygium staudtii,* and *Prunus africana* well illustrates the transition to montane zone.

The zonation of the vegetation is the consequence of that of species. Dominant species are either exclusive to one vegetation zone or they overlap in not more than two zones and disappear afterwards. Only species with large ecological spectra are found from altitude 1000m to almost the top of the mountain.

The Importance value index is of great importance in ecology. It enables to perceive the real influence and weight of any species in a given plant communities. Species with high IVI in each vegetation zone are those which are at the same time abundant, dominant and frequent in the plots. With increase altitude, the requirements of the species undergo changes until the species do not occur at all in the plots. The abundance or frequency of a species may be low at the beginning, then increases to a maximum and drops thereafter. Dominant species often overlap from one vegetation zone to another.

Dominant species

Species with high value of IVI are considered as leading dominant species in the different zones in which they are found. Dominant species in the transition forest between lowland and submontane zones (Table 2) are *Santiria trimera* (43.73%), *Garcinia lucida* (30.87%), *Dacryodes klaineana* (36.64%), and *Strombosia scheffleri* Engl. (36.61%). *Garcinia lucida G. conrauana* and *Guarea mayombensis* occur exclusively in this forest especially in the western and eastern slopes. *G. lucida* forms stand in the shrub layer.

The lower submontane zone is dominated by submontane forest species. Their frequency and their abundance are high and increase with altitude. The Burseraceae and Guttiferae are dominant in the tree stratum. Thanks to increase of air moisture correlated to altitude, *Dacryodes klaineana* and *Santiria trimera* become abundant in this altitudinal range with IVI of 43.35% and 42.36% respectively.

The other tree species *Beilschmiedia* sp. has an IVI of 30.32%. The Guttiferae are well represented in this zone and the most abundant and frequent species of this family are *Symphonia globulifera* (21.36%), *Pentadesma grandifolia* (21.2%), and *Allanblackia gabonensis* (37.74%) in the tree stratum whereas *Garcinia smeathmannii* (20.9%) occurs in the shrub layer. This zone is home for endemic species such as *Rhaptopetalum depressum* and *Coffea montekupensis* Stoff., Cheek, Brids. & Robbr.

In the *Cylicomorpha solmsii* forest where the canopy is more opened than in the wet lower submontane forest zone, the most important species are *Cylicomorpha solmsii* with an IVI of 39.1% followed by *Strombosia scheffleri* 38.47%, *Macaranga occidentalis* (Müll. Arg.) Pax ex K. Hoffm. 35.21% and *Ficus sur* Forssk. 34.8%. The importance of *Santiria trimera* drops to 26.8%. Most of the dominant species in this forest type are those of disturbed areas. The top 5 dominant species in the upper submontane zone are *Carapa oreophila* (39.4%) *Cola verticillata* (39.1%) *Santiria trimera* (38.5%), *Leptonychia multiflora* K. Schum. (37.8%). and *Tabernaemontana ventricosa* Hochst. ex A. D.C. (36.3%). In this forest, *Cyathea manniana* Hook. which is one characteristic species of cloud forest reaches its highest relative abundance of 11%.

Garcinia smeathmannii is the most dominant species (52.5%) in the transition forest between submontane and montane zones followed by *Carapa oreophila* (45.6%), *Syzygium staudtii* (37.5%), *Cola verticillata* (36.2%) and *Macaranga occidentalis* (36%). This zone is also peculiar by the presence of species like

Xymalos monospora, Schefflera mannii (Hook. f.) Harms*, Maesa lanceolata* Forssk. that do not ecologically have any relationship with lowland flora. *Garcinia smeathmannii* becomes more abundant and represents almost the 2/3 of the shrubs in the understory.

Diversity indices and structural parameters

Diversity indices decrease as the altitudinal ranges of the vegetation zones increases (Table 3). The highest values of species richness and Shannon index are found in zones 1 and 3 between lowland and submontane forest and also in the dried submontane zone whereas the upper submontane zone and the transition between submontane and montane zones exhibit the lowest. The values of the Pielou's evenness are similar (0.8) in zones 1 and 3 whereas the lowest (0.6) is found in the transition to montane and that of the upper submontane zone (0.7) is between the two values.

The forest with *Cylicomorpha solmsii* has the lowest values of the ratio I/s_T and stem density while the transition forest to montane zone exhibits the highest. When considering the basal area, its value is high in the transition forest to submontane zone and very low in the transition to montane zone. With regard to the number of stem individuals, the highest value is found in the upper submontane zone while the lowest is in the forest with *Cylicomorpha solmsii.*

The distribution of tree size classes shows that the size classes well represented are those with dbh values between 5 and 25 cm (fig. 3). Trees with dbh greater than 50cm are rare especially in zone 5 where they represent less than 1% of the individuals recorded. The largest tree is an individual of *Santiria trimera* that has a dbh of 130cm and it is found on the northern slope between altitude 1400 and 1500m. Altitudinal variation of diversity indices follows a trend well described in literature. Diversity is high when environmental gradients are in their middle range (Odum 1963, Grime 1973) as is the case in the transition between lowland and submontane zones. The low values observed in the transition forest to montane zone is due to the fact that the increase of altitude induces low temperature and high air moisture, condition under which only few species can develop. In such an environment, some species tend to form stand as is the case with *Garcinia smeathmannii* in the understory and the abundance of *Carapa oreophila, Syzygium staudtii,* and *Cola verticillata* in the tree stratum. However, the Pielou's evenness which stretches between 0.6 and 0.8 can be interpreted as the sign of stability of the forest, a favorable condition to speciation. The steep slopes of mount Kupe had been an obstacle local villagers could not overcome to encroach in the forest at higher altitudes as seen elsewhere like on the Lebialem highlands where farmlands (Harvey *et al.* 2010).

Basal area, stem density and distribution of dbh classes are parameters that govern the structure of the vegetation. In the transition forest to submontane zone, where tree individuals with large dbh like *Pouteria pierrei* or *Pycnanthus angolensis* are still present, the basal area is high and the values approach that of the mature lowland tropical forest (Swaine *et al.* 1987, Kammesheidt 1992).

The low values of stem density and the ration I/s_T in the *Cylicomorpha solmsii* forest can be explained by the anthropogenic disturbance and the presence of a Marantaceae and Zingiberaceae thicket poor in trees. Few species recorded in this forest are represented by large number of individuals. Although some diagnostic species of cloud forest like *Cyathea manniana* grow in clumps, they do not develop large dbh.

The number of stem individuals increases with altitude and at the same time the basal area becomes low. Basal area is determined by both the number of tree and shrub individuals that is stem density and by the dbh of these individuals. The distribution of dbh classes have a reverse J shaped and means that the forest is in good way for its regeneration. Most of the trees found in the canopy have their juveniles in the understory.

Conclusion

As most of the tropical mountains, mount Kupe is a fragile ecosystem and its habitat is highly threatened on lower slopes by agriculture.

It is home for many endemic plant and animal species. Although many local populations live around these important areas, its forest must be protected and the valuable biological resources shall be conserved for future generation. From altitude 700m to 2000m, vegetation changes gradually from one zone to another following an ecological continuum as already found on other tropical mountain in Africa (Hamilton 1975, Hemp 2005). With its steep slopes that discourage local villagers to encroach at high altitudes as they can, mount Kupe is clothed with one of the best submontane forests in Cameroon. On conservation point of view, the site must be granted an official legal protection status since it is home of many rare and endemic species.

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