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Influence of the altitude on the diversity and the dividing up of arborescent species of particular status: case of the district of Bangolo in the west of Côte d'Ivoire

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Abstract
Some ecosystems, hard to get access such as mountains areas and inselbergs which are particular ecological sites sometimes escape from degradation factors and thus represent the privileged shelter of some species of particular status. This research work deals with the influence of the altitude on the diversity of arborescent species of particular status in the district of Bangolo in the west of Côte d'Ivoire. The objective was to assess the impact of the altitude on the dividing up of arborescent species of particular status in the district of Bangolo. The inventory of the flora has been made thanks to the method of itinerant account and the one of squares of Gautier *et al* (1994). The inventory of thirty six (36) arborescent species of particular status has been made in those mountainous areas. Among those species 28 are vulnerable, two are at risk, 1 is endangered and 5 are threatened with extinction. This study shows that at altitude, the climate, the geomorphology and the pedology are some criteria of selection of species of particular status.

Keywords: Altitude, diversity, arborescent species of particular status, Côte d'Ivoire

1. Introduction
Biodiversity is the concern of numerous actors of development nowadays, particularly teams of researchers internationally famous. All of them orient their actions towards sustainable management of biodiversity. In fact, biodiversity is a main link, among many others, which influences the survival of the planet. Furthermore, in many African countries, the issue of population increase and availability of natural resources is really relevant. In Côte d'Ivoire, the reduction of natural areas and the gradual exhaustion of phylogenetic resources, fauna and water are caused by speedy urbanization in rural areas, high demography, the anarchic exploitation of natural resources, etc. The Ivorian flora faces an increasing degradation in course of years. That dynamic in plant structure enabled many research works on the flora. Those works have been oriented towards the characteristics of the flora in forest area. They are for example the ones of Alexandre (1989) [2], Devineau (1984) [5] and Kouassi (2008) [9]. In addition, the dynamic of the post-farming flora has been studied by Kouassi *et al* (2009) [10], in order to find the techniques of floristic regeneration of post-farming follows and degraded areas. Despite all those attempts, the flora degradation of forest area has increased in course of time. In such as a context, human activities contribute to weaken, to reduce and even to destroy much more the flora of the ecosystems. To mitigate that degradation and/or increasing destruction of the flora, the suggested solutions are mainly measures of sustainable and/or integrated management of natural resources. That management should be based on sensitization campaigns on reforestation to prevent the possible bio-eco-climatic imbalances. For that, the safeguard of riches and diversity of many agricultural countries should focus on the safeguard of the ecosystems, still rich in flora and species and fauna species. It's rightly that Lubini (1982) [12] and Reitsma (1988) [14] asserted that the study of plants classification constitute as well as the flora invention, one of the most important sources of data, particularly for researches about the biological diversity, the development of

systems of managements, the arrangement and conservation of the nature. We should also know the structure, the dynamic and the functioning of phytocenoses to consider a sustainable management. Mullenders (1954) [13] has pointed out that the knowledge of plants classifications is relevant since those classifications are the consequences of many factors of accommodation. In Côte d'Ivoire, the mountains and the inselbergs sometimes hard to get access constitute privileged shelters of plant and animal species. (Roland *et al*, 2014) [15]. Those ecosystems are very often diversified and contain numerous arborescent species of particular status (endemic, rare, threatened, vulnerable, at risk, endangered, etc…). This work is a contribution to researches on the diversity of mountain flora in Côte d'Ivoire. It deals with the arborescent species of particular status. The general objective is to determine the influence of the altitude on the diversity and dividing up of arborescent species of particular status in the mountainous areas of the district of Bangolo.

2. Materials and methods

2.1 Area of study

The district of Bangolo is located in the west of Côte d'Ivoire, at 7°4'60'' North and 7°19'60'' west (Figure 1). The climate is tropical and of transition one. (Climate of mountain) It is characterized by two reasons. A dry season which starts in November and ends in February of the next year. As far as the rainy season is concerned, it lasts eight months, from March to October. The annual average precipitation is 1449 mm with a minimum of 1500 mm and a maximum of 2200 mm (SANYU and JICA, 2001; Goula Bi, 2007) [17, 8]. The annual average temperature is 25 °C. The mountainous area is occupied by humid dense forest half-decidua or humid mountain dense forest. It breaks up into forest islet and forest gallery (Bakayoko *et al*, 2004) [3]. The forest of the site, formerly dense, humid, rich and diversified in terms of flora species is today fragmented in many areas. In fact even though some places still contain some well-conserved vegetations, the scattered agrarian landscape containing some parcels of income farming and food crops are much more represented. In addition, some remaining vestiges have been seriously exploited. The western area is characterized by a mountainous relief with steep slopes. The differences of altitudes are remarkable and mountains are more than 1000 m at their highest point. We can mention among others: the mount Sangbé (1072m), the mount Toura (1170m), the mount Tonkpi (1223m), the mount Momi (1302m) and the mount Nimba (1752m). The soils contain iron and they are washed out like in the main part of the Ivorian territory. They are particularly present in the west; they are soils on charnockites (Dabin *et al*, 1960) [4].

2.2 Method

2.2.1 Choice of mountains

The vegetation of seven mountains (Figure 1) located in the south, in the centre and in the North of the district of Bangolo have been assessed. Those trainings have been chosen on the basis of criteria of selection such as the geographical position, the vegetation and the extent of the surface covered with the vegetation.

2.2.2 Inventory of the flora

The flora inventories took place in the rainy months (June-July). Two methods have been associated to assess the arborescent flora. It concerns here the methods of itinerant account and the one of the squares of Gautier *et al* (1994) [7]. The method of itinerant account consists in registering the species in an itinerant way by covering all the directions through the different species of plants of the site. That method of botanic account has been used by Aké Assi (2002) [1]. The method of squares consists in describing the vegetation in some « quadrats » considering the four cardinal points with a precise spacing. Figure 2 shows the disposition of squares of account on each mountain. On each mountain four (4) squares of one hectar (1 har) of surface have been demarcated. Those squares were 100 m apart and have been classified in order to cover the highest point and all the sides of each mountain. Some squares of 20m x 20m of 50 m apart have demarcated in each of the squares. The plant species of those squares have been assessed and classified taking into account their status (threatened, vulnerable, endangered, at risk, endemic etc…).

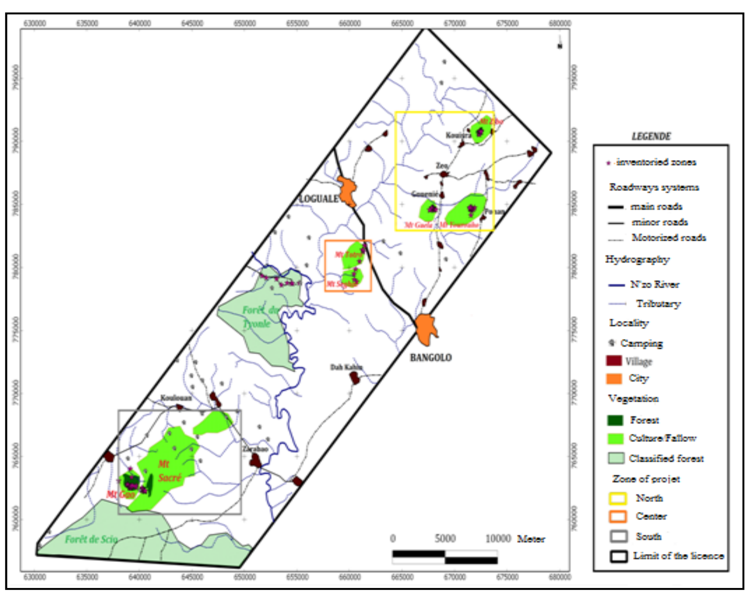

Fig 1: Localization of the district of Bangolo in Côte d'Ivoire and other assessed sites

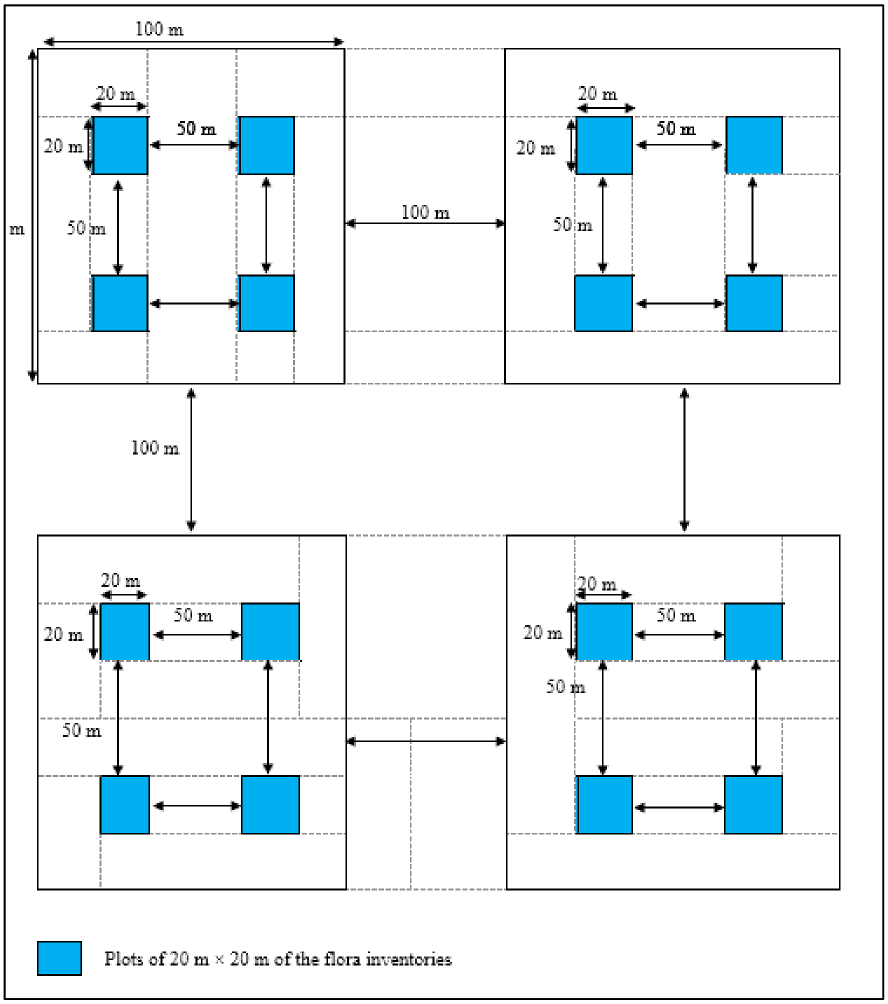

Fig 2: Configuration of the plots of the flora inventories one each mountain

2.2.3 Analysis of the flora data

The comparison between the flora of mountains and that of different highest points has been made through the coefficient of similarity Sφrensen (1948) [18]. The mathematic expression of the coefficient is as follows

$$Cs = 100 \times \frac{2c}{a + b}$$

In that formula, Cs is the coefficient of similarity of Sorensen where « a » represents the number of species registered in the site A, « b » represents the number of species registered in the site B and « c » represents the number of species common to the two sites (A and B) that we want to compare. That coefficient varies from 00% to 100% depending on the fact that the two sites have totally different (c= 0) or identical (a=b=c) flora compositions. For a coefficient of similarity superior or equal to 50%, the two sites concerned are considered as homogenous.

A Factorial Analysis of Correspondences (FAC) has been made through the data relating to arborescent species of particular status registered on the different altitudes in order to explain the diversity and the dividing up of the species according to the altitude and the conditions of the area. The software PAST (ver.2.17c) has been used for that.

3. Results

3.1 Richness of the arborescent flora of particular status

Thirty six (36) arborescent species of particular status have been assessed on the investigated mountains (table 1). Those species are classified in 19 families of which the most important are the Meliaceae with 7 species, the Caesalpiniaceae and the Sterculiaceae with 4 species.

Table 1: List of assessed arborescent species of particular status and corresponding status.

N°	Assessed arborescent species of particular status in different altitude	Family	Status
1	*Afzelia africana Sm*	Caesalpiniaceae	VUL, UICN (2015)
2	*Albizia ferruginea* (Guill. & Perr.) Benth	Mimosaceae	VUL, UICN (2015)
3	*Anopyxis klaineana* (Pierre) Engl.	Rhizophoraceae	VUL, UICN (2015)
4	*Antrocaryon micraster* A. Chev. & Guill	Anacardiaceae	VUL, UICN (2015)
5	*Cassia aubrevillei* Pellegr.	Mimosaceae	VUL, UICN (2015)
6	*Cleidion gabonicum* Baill	Euphorbiaceae	MEC, AKE ASSI (2002)
7	*Cordia platythyrsa* Bak	Boraginaceae	VUL, UICN (2015)

8	*Cryptosepalum tetraphyllum* (Hook.f.) Benth.	Caesalpiniaceae	VUL, UICN (2015)
9	*Didelotia idae* J. Léonard, Oldeman & de Wit	Caesalpiniaceae	VUL, UICN (2015)
10	*Diospyros vignei* F. White	Ebenaceae	MEC, AKE ASSI (2002)
11	*Entada gigas* (Linn.) Fawc&t &-Rendle	Mimosaceae	MEC. AKE ASSI (2002)
12	*Entandrophragma angolense* (Welw.) C. DC	Meliaceae	VUL, UICN (2015)
13	*Entandrophragma candollei* Harms	Meliaceae	VUL, UICN (2015)
14	*Entandrophragma cylindricum* Sprague	Meliaceae	VUL, UICN (2015)
15	*Entandrophragma utile* (Dawe & Sprague)	Meliaceae	VUL, UICN (2015)
16	*Eribroma oblongum* (Mast.) Pierre ex A. Chev	Sterculiaceae	VUL, UICN (2015)
17	*Garcinia afzelii* Engl	Guttiferae	VUL, UICN (2015)
18	*Garcinia kola* Heckel	Guttiferae	VUL, UICN (2015)
19	*Gilbertiodendron splendidum* (A. Chev. ex Hutch. & Dalz.) J. Léonar	Caesalpiniaceae	VUL, UICN (2015)
20	*Guarea cedrata* (A. Chev.) Peliegr.	Meliaceae	VUL, UICN (2015)
21	*Guarea thompsonii* Sprague & Hutch.	Meliaceae	VUL, UICN (2015)
22	*Gymnostemon zaizou* Aubrév. & Pelleg	Simaroubaceae	VUL, UICN (2015)
23	*Hallea ledermannii* (K. Krause) Verdc.	Rubiaceae	VUL, UICN (2015)
24	*Irvingia gabonensis* (Aubry-Lecomte ex O'Rorke) Baill	Irvingiaceae	RIS, UICN (2015)
25	*Khaya grandifoliola* C.DC.	Meliaceae	VUL, UICN (2015)
26	*Lannea nigritana* (Sc. Elliot) Keay var. nigritana	Anacardiaceae	MEC, AKE ASSI (2002)
27	*Lophira alata* Banks ex Gaertn.f	Ochnaceae	VUL, UICN (2015)
28	*Milicia excelsa* (Welw.) Benth.	Moraceae	VUL, UICN (2015)
29	*Nesogordonia papaverifera* (A. Chev.) R. Capuron	Sterculiaceae	VUL, UICN (2015)
30	*Placodiscus boya* Aubrév. & Pellegr.	Sapindaceae	VUL, UICN (2015)
31	*Placodiscus pseudostipularis* Radlk	Sapindaceae	DAN, UICN (2015)
32	*Pterygota macrocarpa* K. Schum.	Sterculiaceae	VUL, UICN (2015)
33	*Rhodognaphalon brevicuspe* Sprague	Bombacaceae	VUL, UICN (2015)
34	*Solanum terminale* Forrsk	Solanaceae	MEC, AKE ASSI (2002)
35	*Terminalia ivorensis* A. Chev.	Combretaceae	VUL, UICN (2015)
36	*Triplochiton scleroxylon* K. Schum.	Sterculiaceae	RIS, UICN (2015)

NB: DAN: Endengered species UICN (2015); MEC: Species endangered with extinction; RIS: Species at risk UICN (2015); VUL: Vulnerable species UICN (2015); UICN: International union of the conservation of nature.

3.2 Quantitative distribution of arborescent species of particular Status on the different altitudes.

The number of arborescent species of particular status reduces from 350m to 400m and from 550m to 600m of altitude. However, that number increases between 450m and 500m (table 2)

Table 2: Quantitative evolution of arborescent species of particular status depending on the altitude.

Altitude (m)	number of arborescent species of particular status registered per altitude
350	13
400	8
450	12
500	11
550	9
600	5

3.3 homogeneity of the flora

The estimation of the similarity of the flora between the highest points has shown a significant difference between some highest points. The values in the chart 3 show that four (4) among them give values which are superior to 50%. The highest coefficient (60%) is obtained between an altitude of 500 m and 550 m. however, the other values are inferior to 50% and the weakest coefficient (00%) is obtained between an altitude of 550m and 600m (table 3)

Table 3: Coefficients of similarity of Sorensen between the different altitudes.

Altitude(m)	350 m	400 m	450 m	500 m	550 m	600 m
350 m		47,62%	56.00%	58.33%	45.45%	33.33%
400 m			30.00%	52.63%	47.06%	15.38%
450 m				34.78%	38.10%	35.30%
500 m					60.00%	25.00%
550 m						00.00%
600 m						

3.4 Projection of arborescent species of particular status on the different altitudes.

The projection of arborescent species of particular status on the different altitude has enabled us to make out 4 groups of plant species divided into (Figure 3). The factorial guide mark constituted by the first two components (axis 1 and axis 2). Those components explain 55.12% of the variability observed of which 31. 72% are applied to axis 1 and 23.4% to axis 2. The plant species composing group 1 (altitudes of 350m and 500m) present a larger classification on axis 1 and

2. The Group 2 composed of plant species with altitudes of 450m and 550m have a very classification on axis 2. The group 3 negatively located on axis 1 and 2 present a less large classification. The Group 4 positively located on axis 1 and negatively located on axis 2 have a very weak classification.

Four (4) ecological groups are noticeable through that classification. The first group established on brown-black soils of slopes, presenting larger classification gathers, arborescent species of particular status from primary humid forests such as que *Placodiscus pseudostipularis* Radlk (Sapindaceae), *Guarea cedrata* (A. Chev.) Peliegr (Meliaceae), *Milicia excelsa* (Welw.) Benth (Moraceae), some arborescent species of particular status from secondary forest of which *Pterygota macrocarpa* K. Schum (Sterculiaceae), *Terminalia ivorensis* A. Chev (Combretaceae), *Triplochiton scléroxylon* K. Schum (Sterculiaceae), and arborecent species of particular pioneering status like *Solanum terminale* Forrsk (Solanaceae). The second group is composed of arborescent species of particular status from secondary forests such as: *Entandrophragma cylindricum* (Sprague) Sprague (Meliaceae) et *Entandrophragma utile* Dawe & Sprague (Meliaceae). Those species are often associated with some species from primary forest of the plains and plateaus such as: *Diospyros vignei* F. White (Ebenaceae), *Nesogordonia papaverifera* (A. Chev.) R. Capuron (Sterculiaceae) *et Afzelia africana* Sm (Caesalpiniaceae). The third group contains the species of primary humid forest humid *Garcinia afzelii* Engl (Guttiferae), associated with *Cordia platythyrsa* Bak (Boraginaceae), a secondary forest species and *Albizia ferruginea* (Guill. & Perr.) Benth (Mimosaceae). The fourth group is composed of only arborescent species of particular status from primary forest of which *Cleidion gabonicum* Baill (Euphorbiaceae), *Entandrophragma angolense* (Welw.) C. DC (Meliaceae), on brown black soil of plains, plateaus, slopes and hollows of dense humid forests.

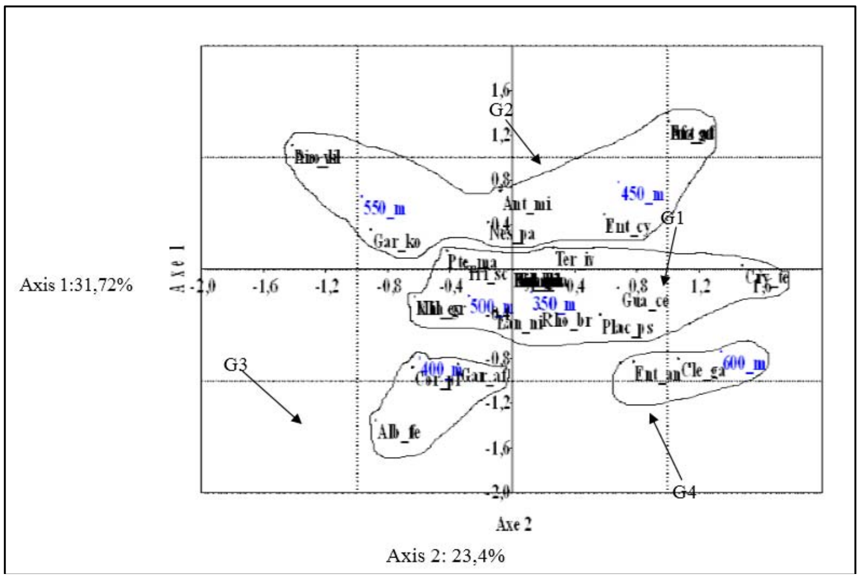

Fig 3: Factorial Analysis of Correspondences relative to the diversity of arborescent species of particular status registered in the different altitudes.

4. Discussion

4.1 Distribution of arborescent species of particular species on mountains

The presence of arborescent species of particular status shows the good conservation of biodiversity on the study site. Indeed on the whole site 36 species of particular status have been assessed. Those species are all as abundant as diversified on the whole site. The number of arborescent species of particular status decrease when we rise. According to Tchouto (2004) [19] and Van (2004) [21], the species of particular species are the privilege targets of loggers because of the numerous uses. It is therefore possible that human activities of which the consequence is the destruction of forest does not enable the survival of those species which need a particular micro climate to thrive as pointed out by Sangne (2009) [16]. However the presence of some species of particular status in the cocoa fields located at altitudes of 350m, 400m, 450m, and 500m augur a will of an empirical protection of those rare essences by some produces. Furthermore, that protection could be linked to cultural practices aiming at protecting the young cocoa plants from damaging sun rays, as Koulibaly (2008) [11] mentioned (2008). In addition, some plant species taking advantages of that protection are found in the field thanks to their medicinal virtues. It is the case of *Euadenia eminens Hook. f* (Capparidaceae) let in the farming for its medicinal virtues, as underlined by Dickson *et al* (2012) [6]

4.2 Richness of the flora

At altitudes of 350m and 500m the arborescent species of particular status are abundant. That abundance can be linked to the protection of which those species take advantage against any activity of destruction of those altitudes. At an altitude of 600m those species are less abundant and less diversified. That weak presence of species is linked to climatic conditions not adapted to the development of those plants at that altitude.

4.3 Homogeneity of the flora at highest points

The strong similarity (60%) of arborescent species of particular status at an altitude of 500m and the one of species at 500m is due to the nature of the soil and the good geomorphology, are additional elements which facilitate the fittings of the survival of those species at this level. The non-existence of similarity between the species at 550m and those 600m would be linked to soil erosion at 600m. That erosion gradually brings about a gradual loss of mineral substances, necessary for the development of plant species. What is more, it provokes the degradation of superior horizon of the soil. Thus the soil becomes less fertile and less humid and unsuited to the optimal development of those arborescent species.

4.4. Distribution of ecological groups

Generally, speaking the dividing up of arborescent species of particular status, on the different highest points has enabled us to discover three trends. The first trend is composed of the repeated association of arborescent species of particular status from primary forest, from secondary forest and pioneer species. The arborescent species of particular status, pioneers depend almost exclusively on the light. That trend is found in two ecological grougs (G1, G3). The second trend is the association of arborescent species of particular status from primary forest and from secondary forest. The last trend is the one of arborescent species of particular status from primary forest.

The distribution of arborescent species of particular status from primary humid forest such as *Placodiscus pseudostipularis, Milicia excelsa, Diospyros vignei, Nesogordonia papaverifera, Afzelia africana, Garcinia afzelii, Cleidion gabonicum* Baill (Euphorbiaceae), *Entandrophragma angolense* is guided essentially by the gradual growth of the quantity of precipitations. The species of particular status from secondary forests such as *Pterygota macrocarpa* K. Schum (Sterculiaceae), *Terminalia ivorensis* A. Chev (Combretaceae), *Triplochiton scleroxylon, Entandrophragma cylindricum* Sprague (Meliaceae), *Entandrophragma utile, Cordia platythyrsa* Bak (Boraginaceae), have almost the same ecological needs as those of the primary forest. The pioneer species like *Solanum terminale, Albizia ferruginea* (Guill. & Perr.) Benth (Mimosaceae), have as favorable areas, the open ones at an altitude of 350 m, 400 m and 500 m, irrespective of the rate of humidity of those highest points.

5. Conclusion

The assessed flora contains thirty six (36) arborescent species of particular status, classified in 30 genres and 19 families dominated by the Meliaceae. That number decreases depending on the altitude. Those species are diversified at low altitudes but are rather submitted to anthropic pressures. That number decreases significantly at an altitude of 600 m because of the climate, the geomorphology, the fall of the soil fertility, etc…

The estimation of coefficients of similarity of different altitudes, have revealed that altitudes of 500 m and 550 m are homogenous in term of flora (with a coefficient of similarity of about 60%) whereas the floras of the altitudes of 550 m and 600 m are different. In their components, those species are classified in four (4) ecological groups oriented towards three trends. The first and the third group contain species from primary forest, species from secondary forests and pioneer species. The second group contains species of primary forests and secondary forests. The fourth groups is composed of species of primary forests. Furthermore, that study has shown that at altitude, the climate, the geomorphology and the pedology are some criteria of selection of arborescent species of particular status.

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