



Ecological characterization of the Gaban Tissilé and Kilguim hills in Far North, Cameroon

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Abstract

The study took place on the hills of Gaban Tissilé and Kilguim in the Mayo-Kani Division of the Far North Region of Cameroon. The objective of the work is to characterize from a floristic and structural point of view the phytodiversity of these hills. For this, the methods used for data collection were the inventory of ligneous plants and observation in the field. The inventories were carried out in plots of 40 m x 30 m each arranged from the bottom to the top of each hill on each of the EAST and WEST slopes and separated by 10 m intervals. The vegetation of these hills presents a wealth of 3269 woody individuals which have been inventoried, divided into 32 woody species with 25 genera and 16 botanical families. The subjects of size between] 0-4m [are the most represented with 41.87 % of the floristic background of the studied mountains, the trees of diameter] 0-10 cm [are the most important (42.34%). The most represented families are the Combretaceae, Mimosaceae, Cesalpiniaceae, Anacardiaceae and Moraceae. The Shannon site vegetation diversity index is 1.29 bit on Kilguim Hill and 1.23 bit on Gaban Tissilé Hill. Three species show values of the Ecological Significance Index *Terminalia brownii*, *Ficus abutilifolia* and *Lannea barteri*. The distribution of vegetation on the two hills shows that the WEST slopes of the two hills are more diversified than the EAST slopes. The results obtained contribute to ensuring responsible community and citizen participation in the management of the natural resources of the hills of the locality of Kaélé.

Keywords: phytodiversity, hills, Kaélé, Gaban Tissilé and Kilguim

INTRODUCTION

Deforestation affects ecosystems, degrades water and agricultural land resources, compromises food security and worsens poverty in communities (Haiwa et al., 2017). Each year, we observe more than 50 to 100 times the rate of species extinction in the world - this is higher than the natural rate of extinction (CBD, 2000). Strong population growth puts pressure on natural vegetation through an increase in different forms and intensities of anthropogenic activities (Yaya et al., 2017). Thus, plant cover the world in general and that of Cameroon in particular which is confronted with deforestation accentuated by climatic variations (Ndih, 2008). Indeed, the analysis of the current factors of degradation shows the extent of the impact of man on the ecosystems of the Kaélé hills, perceptible everywhere through the vegetation (Chérif et al., 2011). The ecosystems of the hills of the Sahelian zones are characterized by particularly severe climatic conditions manifested by a long period of drought, intense evaporation and low rainfall (Oumorou 2003). The Hills of the Kaélé area are of real interest for their geographic and ecological components. Its environmental and socio-economic role deserves to be pointed out and studied. Preserving the biological diversity of these hills is therefore an imperative necessity. The major interest of this study is to be able to best strengthen the state of ecological and socio-economic knowledge of the hills of Gaban Tissilé and Kilguim.

Material and methods

Presentation of the study area

The investigations took place on the hills of Gaban Tissilé and Kilguim located in the district of Kaélé, Department of Mayo-Kani, region of the Far North, Cameroon (Figure 1). Extending over an area of approximately 2000 km² (Beauvilain, 1995) and located between 10 ° 02 'and 10 ° 23' North latitude and 14 ° 03 'and 14 ° 42' East longitude (Donfack et al., 1998), the district of Kaélé is dominated by the plain of Kaélé which is bordered by Chad in the north-east, by the district of Figuil in the south-west, by the district of Mindif in the North, by the district of Moutourwa in the West, by the district of Moulvoudaye in the North East and by the district of Guidiguiss in the East. The relief of the Municipality of Kaélé is made up of 95 % of the plains, 1 % of the plateaus and 4 % of the mountains (PCD, 2013).

From a climatic point of view, the study area belongs to the Sudano-Sahelian zone, characterized by an alternation of a long dry season from October to June and a short rainy season between July and September. The months of August and September, which record the maximum rainfall, are considered to be the wettest months (Fotsing, 2009). Precipitation regression is recorded over the years and over the length of the rainy season and the height of the rains (Lienou et al., 2003).

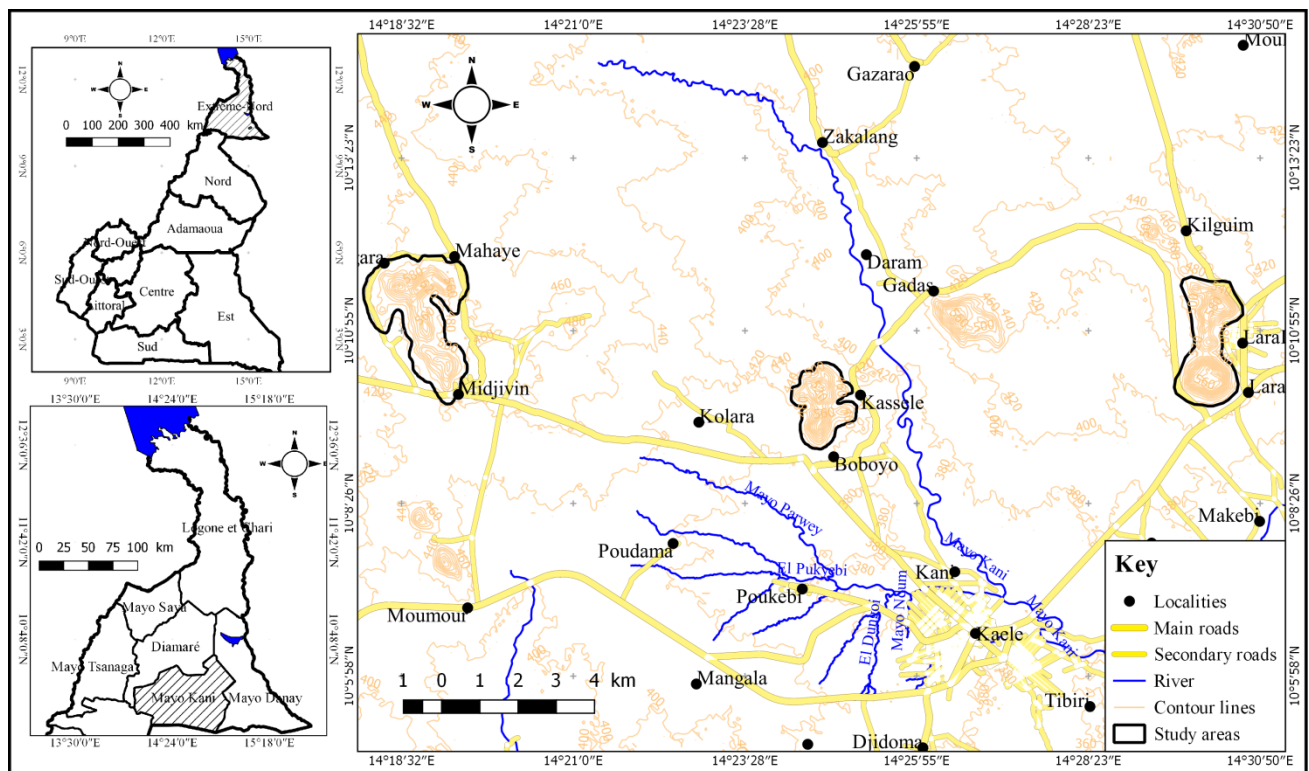


Figure 1: Location map of the study site

METHODOLOGY

Floristic inventory

To determine the composition and structure of the vegetation of the Kaélé hills, a floristic inventory of woody plants was carried out in plots of 40 mx 30 m, established from the base to the top (down-up) of the hills and from left to right, with an interval of 10 m between them and on each of the two facades (East and West). On the whole, 72 plots (2 hills X 2 slopes X 18 plots) were performed. The plot method was used over the transect method because of the characteristics of the sites. According to Bowman (1997), the most suitable inventory method for hills is that of plots, because the transects cannot be carried out due to the roughness of the environment and the rocks. The experimental set-up is a 3-repeat split-plot. The main treatments are the hills, the secondary treatments are the slopes and the plots are the replicates. A total of 72 plots (2 hills x 2 slopes x 9 plots) have been inventoried. All individuals were listed; their diameter at breast height (dbh), crown diameter and height measured using a tape measure and a graduated pole, respectively. For multi-stemmed individuals, the diameter of the largest, middle, and smallest rod are measured. The scientific names of the species were determined in the field, and using the germination keys. For the choice of slopes, this method is inspired by the work of Achoundong (1996) on the study of the influence of slopes on the distribution of the plant population on the hills of Yaoundé.

The ecological profile of the vegetation of these hills was produced using taxa quantification parameters (absolute abundance, frequency, relative density, frequency, basal area,) which are calculated according to the following formulas:

- Absolute abundance is the total number of individuals of the species out of the total number of individuals. Relative abundance is the ratio of absolute abundance to the total number of individuals in the community;
- The relative density which is the ratio between the number of individuals of a species and the total number of all individuals encountered on a given surface multiplied by 100. ($DeR = N_i / N \cdot 100$);
- The frequency which designates the number of times that a species appears on the total of surveys carried out multiplied by 100.

Basal area

It is given by the formula: $G_i = \frac{c^2}{4\pi}$

Where G_i is the basal area of species i , C = tree circumference 1.30 m above the ground.

Species Ecological Significance Value Index (IVIEE)

The Ecological Importance Value Index of Species (IVIE) is calculated using the following formula (Akoègnion, 2004, Adjakpa, 2006):

$$IVIE = 100 * \left[\left(\frac{N_i}{\sum N_i} \right) + \left(\frac{G_i}{\sum G_i} \right) + \left(\frac{F_i}{\sum F_i} \right) \right]$$

Where N_i is the number of individuals of species i , G_i is the basal area of species i , F_i is the frequency of species i . Species with $IVIE \geq 10$ are ecologically important.

The floristic diversity of the hills was assessed using the Shannon-Weaver (H'), the Piélou fair and the Simpson index (D),

- The Shannon Weaver diversity index (H'), which considers both abundance and species richness, is well suited to the comparative study of stands because it is relatively Independent of the sample size (Ramade, 2003). The Shannon-Weaver Index, expressed in bits, is given by the following formula:

$$ISH = - \sum_{i=1}^S (N_i/N) \log_2 (N_i/N)$$

N_i = the number of species i ; N = total number of species. This H index 'is minimal if all the individuals in the stand belong to one and the same species; it is greatest when all individuals are evenly distributed over all species (Frontier, 1983). From the Shannon diversity index, we determined the fairness index.

Jaccard similarity coefficient

The Jaccard similarity coefficient (Le Ffloch, 2007) makes it possible to compare the different plots and to evaluate the diversity β . It is given by the formula:

$$PJ = \frac{c}{a + b - c} * 100$$

Where PJ is the Jaccard index, a , the number of species from list a (Medium 1), b , the number of species from list b (Medium 2) and c , the number of species common to two backgrounds. Similarity between habitats is expressed by the high value of this index.

The Hamming distance proposed by Daget *et al.*, (2003) cited by Floch (2007) is added to this index to compare the floristic records according to the formula:

$$H = 100 - PJ$$

Where H is the Hamming distance and PJ is the Jaccard index. The thresholds used are shown in Table I.

Table I: Criteria of the species classification

Indices	Frequencies	Type of species
I	$F < 20$	Accidental species
II	$20 < F < 40$	Accessory species
III	$40 < F < 60$	Fairly frequent species
IV	$60 < F < 80$	Frequent species
V	$80 < F < 100$	Very frequent species

F = Frequency indices, Braun-Blanquet

Specific richness

It was evaluated from the tale specific richness and the average specific richness. The total specific richness (S) is the total number of species in the stand considered in a given ecosystem (Ramade, 2003). The average specific richness corresponds to the average number of species per survey for a given sample of parks.

RESULTS

Floristic procession of the hills

Table II indicates the woody stands of the hills studied have a composition and an abundance which are not nearly similar according to the situation and the characteristics of the sites. A total of 3269 woody individuals have been inventoried, divided into 32 species, 25 genera and 16 botanical families have been recorded in all of the hills. The most represented families are the Combretaceus, with 7 species and Mimosaceus, Caesalpiniaceus and Anacardiaceus each with 3 different species. However, the distribution of species on the hills varies from one to another indeed, there are 774 individuals distributed in 30 species, 23 genera and 16 families on the hill of Gaban Tissilé and 755 individuals distributed in 28 species, 23 genera and 16 families on Kilguim Hill.

Table II: Floristic procession of the hills

Species	Family	Number of individuals			Species	Family	Number of individuals		
		Gaban Tissilé	Kilgui m	Tot al			Gaban Tissilé	Kilgui m	Tot al
<i>Acacia albida</i>	Mimosaceou s	3	0	3	<i>Diospirios mespiliformis</i>	Ebenaceous	27	5	32
<i>Acacia ataxacantha</i>	Mimosaceou s	8	12	20	<i>Entada africana</i>	Cesalpiniace ous	10	12	22
<i>Acacia sieanena</i>	Mimosaceou s	2	0	2	<i>Ficus abitilifolia</i>	Moraceous	77	67	144
<i>Allophylus africana</i>	Sapindaceou s	39	17	56	<i>Ficus ingens</i>	Moraceous	29	11	40
<i>Annona senegalensis</i>	Annonceous	5	1	6	<i>Grewia bicolor</i>	Tiliaceous	49	24	73
<i>Anogeissus leiocarpus</i>	Combretace ous	16	15	31	<i>Grewia cissaides</i>	Tiliaceous	21	22	43
<i>Azadirachata indica</i>	Meliaceous	12	0	12	<i>Haemastostaphis barteri</i>	Anacardiace ous	44	32	76
<i>Bombax costatum</i>	Bombacaceo us	12	21	33	<i>Hexalobus monopetalus</i>	Anacardiace ous	1	2	3
<i>Combretum collnum</i>	Combretace ous	33	28	61	<i>Lannea barteri</i>	Anacardiace ous	78	85	163
<i>Combretum fragans</i>	Combretace ous	11	12	23	<i>Phyllanthus muellerianus</i>	Euphorbiace ous	8	9	17
<i>Combretum glutinosum</i>	Combretace ous	29	37	66	<i>Piliostigma reticulatum</i>	Cesalpiniace ous	5	3	8
<i>Combretum molle</i>	Combretace ous	15	16	31	<i>Sterculia setigera</i>	Sterculiaceo us	0	3	3
<i>Commiphora africana</i>	Burseraceou s	72	59	131	<i>Strychnos innocua</i>	Loganiaceou s	13	30	43
<i>Crateava adansoni</i>	Capparaceo us	2	17	19	<i>Terminalia brownii</i>	Combretace ous	95	160	255
<i>Croton pseudopulchellus</i>	Combretace ous	36	37	73	<i>Ximenia americana</i>	Loganiaceou s	0	8	8
<i>Detarium microcarpum</i>	Cesalpiniace ous	19	10	29	<i>Ziziphus mauritiana</i>	Rhamnaceo us	3	0	3
					Total		774	755	1529

Ecological characteristics of taxa

The data from the vegetation surveys carried out in each of the two hills made it possible to study a certain number of structural parameters of the woody vegetation of the palm groves and the results obtained are shown in Table III. The relative density of woody species varies from hill to hill. Indeed, these parameters vary from (0.26%) to (12.27%) on the hill of Gaban Tissilé and from (0.26%) to (21.19%). The species with the highest relative density on the two hills are *Termialia brownii* (12.27%) on Gaban Tissilé hill and (21.19%) on Kilguim hill, *Lannea barteri* (10.08%) on Gaban Tissilé hill and (11.26%) on Kilguim hill and *Ficus abutilifolia* (9.95%) on Gaban Tissilé hill and (8.87%) on Kilguim hill. The relative dominance of the species also varies according to the hills, (0.06%) to (15.19%) on the hill of Gaban Tissilé and from (0.10%) to (35.70%) hill of Kilguim. The species with the important dominance are *Termialia brownii* with 35.70% on the hill of Kilguim and 15.10% on that of Gaban Tissilé then the species *Lannea barteri* with (11.26%) on the hill of Kilguim and (10.08%) in Gaban Tissilé and *Commiphora africana* with (7.81%) on the hill of Gaban Tissilé and (8.30%) in Kilguim. The frequency of occurrence of species also varies depending on the hills, eight species have the highest frequency (> 5.00%) among which: *Termialia brownii* (16.73%), *Lannea barteri* (10.67%), *Ficus abutilifolia* (9.41%) and *Commiphora africana* (8.56%).

Table III: relative density, dominance and relative frequency

Species	Relative density		Dominances		Frequency	
	Gaban Tissilé	Kilguim	Gaban Tissilé	Kilguim	Gaban Tissilé	Kilguim
<i>Acacia albida</i>	0.39	-	0.06	-	1.22	-
<i>Acacia ataxacantha</i>	1.03	1.59	0.56	1.58	2.44	3.90
<i>Acacia sieanena</i>	0.26	-	0.09	-	1.22	-
<i>Allophylus africana</i>	5.04	2.25	2.69	1.07	3.66	5.19
<i>Annona senegalensis</i>	0.65	0.13	0.44	-	2.44	1.30
<i>Anogeissus leiocarpus</i>	2.07	1.99	0.73	2.90	3.66	3.90
<i>Azadirachata indica</i>	1.55	-	0.40	-	3.66	-
<i>Bombax costatum</i>	1.55	2.78	0.31	2.54	1.22	3.90
<i>Combretum collimun</i>	4.26	3.71	9.09	1.82	4.88	3.90
<i>Combretum fragans</i>	1.42	1.59	0.68	0.52	2.44	2.60
<i>Combretum glutinosum</i>	3.75	4.90	1.19	1.26	4.88	5.19
<i>Combretum molle</i>	1.94	2.12	7.27	0.58	3.66	3.90
<i>Commiphora africana</i>	9.30	7.81	4.65	3.03	4.88	5.19
<i>Crateva adansoni</i>	0.26	2.25	0.09	1.06	4.88	2.60
<i>Croton pseudopulchellus</i>	4.65	4.90	1.49	3.16	3.66	5.19
<i>Detarium microcarpum</i>	2.45	1.32	1.63	1.12	3.66	2.60
<i>Diospiros mespiliformis</i>	3.49	0.66	2.27	0.27	2.44	3.90
<i>Entada africana</i>	1.29	1.59	0.13	0.77	4.88	2.60
<i>Ficus abutilifolia</i>	9.95	8.87	15.34	17.01	4.88	5.19
<i>Ficus ingens</i>	3.75	1.46	11.82	1.97	4.88	2.60
<i>Grewia bicolor</i>	6.33	3.18	6.92	2.04	3.66	3.90
<i>Grewia cissoides</i>	27.1	2.91	1.82	3.23	4.88	3.90
<i>Haemastostaphis barteri</i>	5.68	4.24	5.66	3.27	1.22	5.19
<i>Hexalobus monopetalus</i>	-	0.26	-	0.10	-	1.30
<i>Lannea barteri</i>	10.08	11.26	8.04	11.32	1.22	5.19
<i>Phyllanthus muellerianus</i>	1.03	1.19	0.48	0.54	2.44	2.60
<i>Piliostigma reticulatum</i>	0.65	0.40	0.20	0.24	2.44	1.30
<i>Sterculia setigera</i>	-	0.40	-	0.12	-	1.30
<i>Strychnos innocua</i>	1.68	3.97	0.80	2.29	3.66	5.19
<i>Termialia brownii</i>	12.27	21.19	15.10	35.70	4.88	5.19

<i>Ximenia americana</i>	-	1.06	-	0.48	-	1.30
<i>Ziziphus mauritiana</i>	0.39	-	0.04	-	1.22	-
Total	100.00	100.00	100.00	100.00	100.00	100.00

The Ecological Significance Value Indices of species

Table IV shows the Ecological Significance Value indices showing the ecological role that these plant species play in their environment since they have a wider ecological plasticity. Three (3) species have the highest IVIE values on all the hills with a value greater than 20. These are *Terminalia brownii* (47.17 %), *Ficus abutilifolia* (30.62 %) and *Lannea barteri* (23.56 %). The species with the lowest IVIE values, i.e. less than 1, are: *Ziziphus mauritiana* (0.82 %), *Acacia albida* (0.83 %) and *Hexalobus monopetalus* (0.90 %). The other species have intermediate value of IVIE.

Table IV: Ecological Significance Value Indices of Species (IVIE)

Spices	Gaban Tissilé	Kilguim	Average	Spices	Gaban Tissilé	Kilguim	Average
<i>Acacia albida</i>	1.66	-	0.83	<i>Diospirios mespiliformis</i>	8.20	4.83	6.52
<i>Acacia ataxacantha</i>	4.03	7.07	5.55	<i>Entada africana</i>	6.30	4.96	5.63
<i>Acacia sieanena</i>	1.56	-	0.78	<i>Ficus abitifolia</i>	30.16	31.08	30.62
<i>Allophylus africana</i>	11.38	8.51	9.95	<i>Ficus ingens</i>	20.45	6.03	13.24
<i>Annona senegalensis</i>	3.53	1.43	2.48	<i>Grewia bicolor</i>	16.91	9.11	13.01
<i>Anogeissus leiocarpus</i>	6.46	8.78	7.62	<i>Grewia cissaides</i>	9.41	10.04	9.73
<i>Azadirachata indica</i>	5.61	-	2.81	<i>Haemastostaphis barteri</i>	12.56	12.70	12.63
<i>Bombax costatum</i>	3.08	9.22	6.15	<i>Hexalobus monopetalus</i>	013	1.67	0.90
<i>Combretum collinum</i>	18.23	9.42	13.83	<i>Lannea barteri</i>	19.34	27.77	23.56
<i>Combretum fragans</i>	4.54	4.70	4.62	<i>Phyllanthus muellerianus</i>	3.95	4.33	4.14
<i>Combretum glutinosum</i>	9.82	11.36	10.59	<i>Piliostigma reticulatum</i>	3.28	1.94	2.61
<i>Combretum molle</i>	12.87	6.59	9.73	<i>Sterculia setigera</i>	-	1.82	0.91
<i>Commiphora africana</i>	18.83	16.04	17.44	<i>Strychnos innocua</i>	6.14	11.46	8.80
<i>Crateava adansoni</i>	5.23	5.91	5.57	<i>Terminalia brownii</i>	32.25	62.08	47.17
<i>Croton pseudopulchellus</i>	9.80	13.26	11.53	<i>Ximenia americana</i>	-	2.84	1.42
<i>Detarium microcarpum</i>	7.74	5.04	6.39	<i>Ziziphus mauritiana</i>	1.65	-	0.82
				Total	300.00	300.00	300.00

Shannon Diversity Index

Species richness alone, which is the total number of species in a stand, is insufficient to compare the species diversity of two stands. This is how the Shannon Diversity Index was calculated. This not only takes into account the specific richness but also the abundance of each species and is independent of the size of the sample. It can be seen from this table V that the Shannon diversity index is 1.23 bits on Gaban Tissilé hill and 1.29 bits on Kilguim hill. Pielou's Equitability is 0.45 on Gaban Tissilé Hill, 0.43 on Kilguim Hills.

Table V: Shannon diversity index, Pielou equitability, density

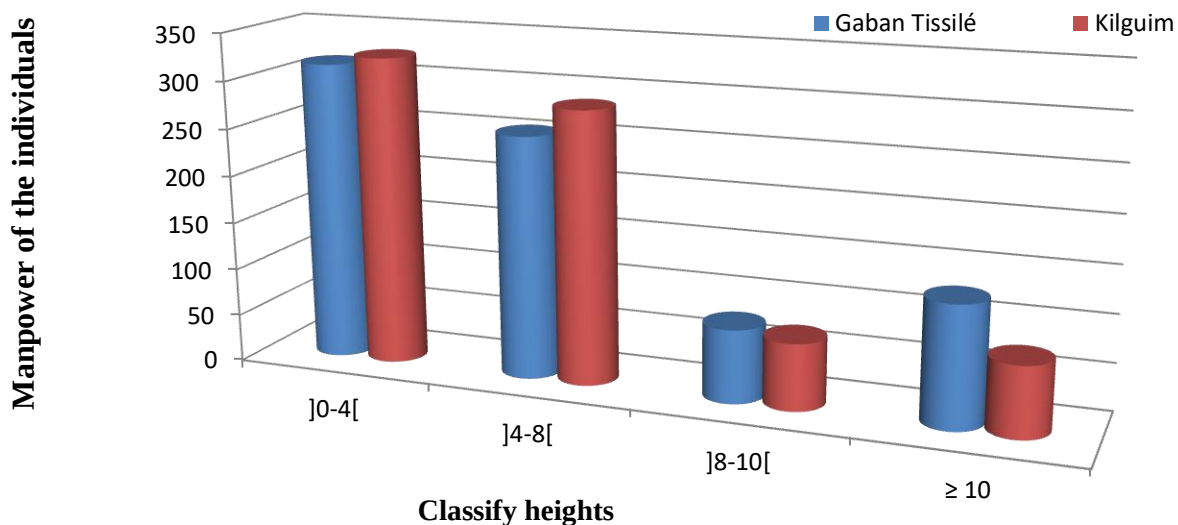
	Gaban Tissilé	Kilguim	Moyenne $\pm$ écart-type
Ni	774	755	764.50 $\pm$ 13.44
ISH	1.23	1.29	1.26 $\pm$ 0.04
EQ	0.43	0.45	0.44 $\pm$ 0.01
D	0.23	0.22	0.23 $\pm$ 0.01

Distributions of diameter and height classes of vegetation pressure exerted on the resource either by

The study of the distribution of phytodiversity, according to Onana and Devineau (2002), can be done around two important factors which are on the one hand, the distribution of individuals in size or diameter classes as an indirect indicator of the level of it balance of age groups and as a witness of the phases experienced by the population in terms of disturbance or regeneration, and on the other hand, the intensity of regeneration, symbol of the renewal of the population in the long term. A possible third element, the poor general condition of the stands, which unfortunately was not taken into account in this study.

Vertical structure

The woody subjects measured during the vegetation surveys were distributed according to height classes. The results obtained are shown in Figure 2. Analysis of the figure shows that in the two hills as a whole, 77.29% of the individuals listed have a height of less than 8 m and therefore consist of young shoots. It should be noted that the most important hill height classes are classes [0-4 [with (41.87%) and class [4-8 [with (35.41%) of the individuals inventoried on the hills. Kaélé hills. The least represented classes are classes [8-10 [with (9.61%) and class ≥ 10 with (13.10%) of the flora background of the vegetation of the three hills.

**Figure 2:** Distribution of vegetation by height classes

Diameter class distributions

Overall on the hills studied, we notice a preponderance of young individuals of small circumferences. However, it emerges from figure 3 that the class of] 0-10 [is dominant and represents approximately 42.34% of the individuals in the whole of the hills then the class of] 10-20 [with 31.72%, the class] 20-30 [with 15.68% of individuals and the class ≥ 30 cm with 10.25% of individuals inventoried on the hills.

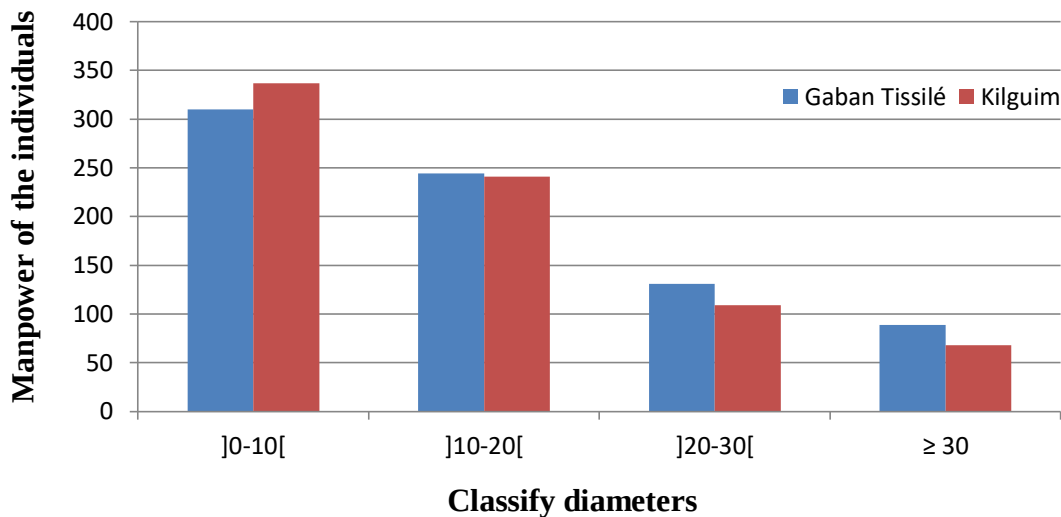


Figure 3: Distribution of vegetation by diameter classes

Distribution of vegetation according to the slopes and altitude of the hills

Figure 4 shows the altitude distribution of the vegetation is influenced by several factors acting as limiting factors. Examination of the figure shows that at the level of the hills, the distribution of the population shows small proportions at the bottom of the hills. At the level, between (420-520 m altitude) there is an average of 726 individuals for the two hills distributed as follows: 376 individuals on the hill of Gaban Tissilé and 350 individuals on the hill Kilguim and on the summit (> 520m) we have an average of 804 individuals distributed as follows: 399 individuals on the hill of Gaban Tissilé and 405 individuals on the hill Kilguim. The density of vegetation on the hills of Lara and Boboyo increases to an optimum. Depending on the slopes, we have on the EAST coast a total of 726 individuals for the two hills, with 376 individuals on the Gaban Tissilé hill and 350 individuals on the Kilguim hill. However, on the denser WEST slope, a total of 803 individuals are inventoried, distributed as follows: 398 individuals on the hill of Gaban Tissilé and 405 individuals on that of Kilguim.

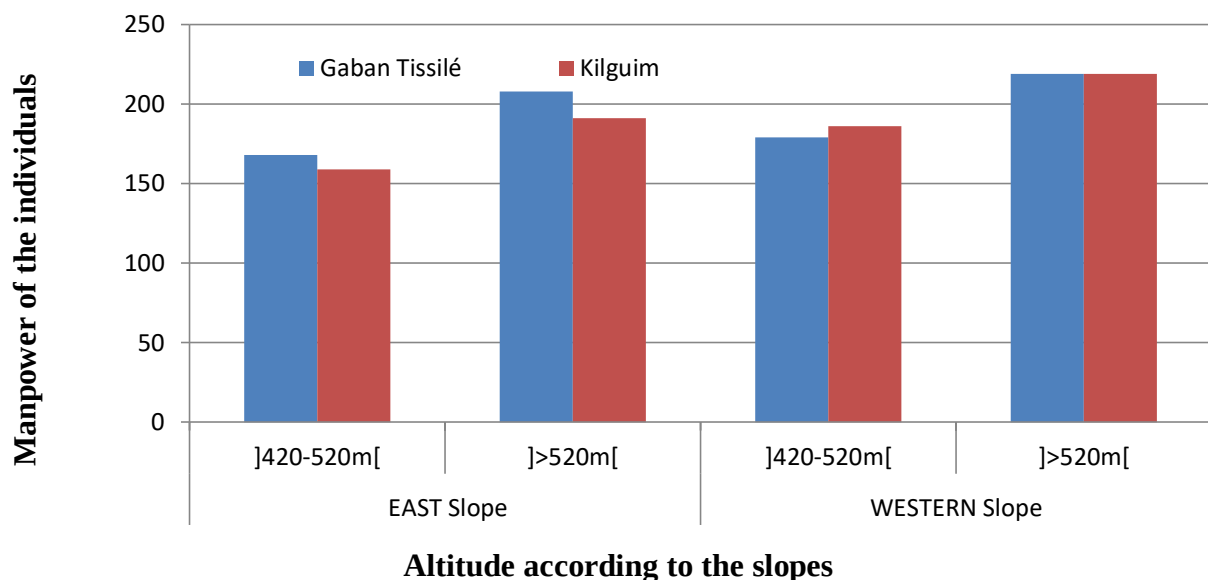


Figure 4: Distribution of vegetation according to slopes and altitude

Comparison between slopes or influence of slopes

When evaluating the homogeneity or heterogeneity of the different plant formations of the different study sites by the Jaccard test, this comparison is recorded in Table VI. The jaccard index and the Hamming distance vary on all slopes of. On Gaban Tissilé hill, the Jaccard similarity index is (80.00%) between slopes and is higher than on Kilguim hill which is (71.42%) and Hamming distances are (20.00%) low than on the hill of Kilguim which is (28.58%). The floristic

difference between certain slopes on the one hand and the similarity between certain slopes in the villages would be the consequence above all of the nature and depth of the soil, the topography of the soil on the slopes and the slope of each slope. These results are similar to those of Ntoupka (1999) in the Sudano-Sahelian zone who showed that the Hamming distances between the different plant formations are unevenly varied.

Table VI: Jaccard similarity indices and Hamming distance for plants from the hills

hill	Slopes	EAST Slope		WESTERN Slope	
		PJ	H	PJ	H
Gaban Tissilé	EAST	100	0		
	WESTREN	80.00	20.00	100	0
Kilguim	EAST	100	0		
	WESTREN	71.42	28.58	100	0

DISCUSSION

Floristic wealth

The vegetation surveys carried out made it possible to identify 3269 woody individuals were inventoried, divided into 32 species, 25 genera and 16 botanical families, this shows us that the hills studied contain a low flora diversity with a Shannon diversity index reflecting the existence of subjects belonging to regeneration. These results are similar to those of Beidi *et al.*, (2020) on Characterization of woody plants from the Kaélé hills in the same zone and what Donfack (1998) observed in the fallow vegetation of North Cameroon, the values of the population wealth obtained in the hills of the Sudano-Sahelian zone are low. But they differ from those reported Nyasiri (2018) on the vegetation of the cliff of Ngaoundéré (Adamaoua-Cameroon), he identified 66 genera, 87 species, 39 families. This difference would be due to climatic and edaphic factors given that the forest landscapes of the cliff belong to the South Guinean type climate, unlike our study area which is located in the Sahelian zone. Tchoua and Noumi (2016) have also shown that the climatic and edaphic factors of the sub-montagnatrd environments of the sub-montane forest of Kupe considerably increase the number of species. Three species show values of the Value of Ecological Significance Index *Terminalia brownii*, *Ficus abutilifolia* and *Lannea barteri*. These three species represent the species that can be found on all the hills of the Kaélé area. This result would be similar to that obtained on the hills of Lara, Boboyo and Midjivin in the district of Kaélé by Beidi *et al.*, (2020). This shows the importance that these species play in the environment with their more ecological plasticity large.

Vertical structure

Intense logging on the same plot results in a large number of seedlings of size less than 4 m which shows that the stands are viable. In addition, these undivided co-owners are more represented in low-altitude areas and therefore more accessible to the population. This can be explained either by the pressure exerted on the resource or by the destruction of the habitat. This would justify the "L" structure of the histogram representative of the vegetation. These results are in agreement with those of Tchobsala (2011) in the peri-urban savannah of Ngaoundéré. These results are in disagreement with those of Tchoua and Noumi (2016) on the structure of the vegetation of Mount Kupe who found that individuals of heights between 10 and 20 m are more represented. In addition, the analysis of variance notes that there is a significant difference between the height classes (P -value = 0.000), while there is no significant difference between the hills ($P > 0.05$). The collection of stones or gravel on the buttocks of the hills associated with the search for cultivated land at the level of the hills leads to a massive destruction of nature on the Kaélé hills leading to the fragmentation of the natural habitat of some species. This explains the low proportion of tall individuals, Keita and Ouattara (1995).

Diameter of class distributions

The horizontal distribution of the vegetation of the hills with a structure of the vegetation is in "L", sign of the strong exploitation of the vegetation. We note these results express the fragility of the vegetation. The dominance of small diameter individuals (young individuals) shows constant regeneration of species in the area. Despite the strong representativeness of these young individuals, they do not very often reach maturity and do not allow the ecological resilience of the vegetation, due to anthropogenic pressures. This result is in agreement with those Hamawa *et al.*, (2010) on the altitudinal distribution of *Vepris heterophylla* in the Sudano-Sahelian zone of Cameroon. Neuenschwander *et al.*, (2011), find that "In Benin, the ecological factors which determine the distribution of vegetation types are: climate, soil and geomorphology". The structure of the vegetation is therefore also a result of topographical and edaphic conditions, which also constitute an expression of the floristic diversity of an environment. By studying the floristic diversity of the vegetation of the Atacora range, Wala (2010) concludes that "the major ecological factors which explain the distribution of plant groups on said chain are soil moisture, topography, substrate, edaphic and anthropogenic activities". The

analysis of variance reveals a very highly significant difference between the classes (P-value 0.001 < 0.01 F-ratio 61.18) on the one hand and there is no difference between the hills. So that the vegetation is reconstituted.

Distribution of vegetation according to the slopes and altitude of the hills

The altitude distribution of the vegetation is influenced by several factors acting as limiting factors. At the level of the hills, the distribution of the population presents small proportions on all the hills. These results are explained by anthropogenic pressures. Indeed, the base of the hills is under the action of intense agricultural activities by the neighboring populations. The low altitude is more accessible to riparian populations than the median and summit levels, Kémeuzé *et al.*, (2009). This thus contributes to the destruction of vegetation and the fragmentation of the habitat of living beings. Hamawa *et al.*, (2010) reported similar facts in northern Cameroon and maintained that the intense exploitation of *V. heterophylla* led to its disappearance at low altitudes, as would be the case for many other species used by the population for various needs. .

The establishment of individuals on the slopes of a hill is influenced by the various parameters (nature of the soil, wind speed, slope of the slope, orientation with respect to the sun) which prevail on this slope (Jenik and Hall, 1966). On the hills of Gaban Tissilé and Kilguim, one undoubtedly notices that the EAST slope is less abundant in individuals than the WEST slope. These results are not in agreement with those of Achoundong (1996) on the study of the influence of slopes on the distribution of the plant population on the hills of Yaoundé and with those of Avohou and Sinsin (2009) reported within the framework of the study of plant biomass on the Attacora mountain (Benin) that the biomass is greater on the NORTH slope than on the SOUTH slope. The analysis of variance finds a statistically significant difference between the different hills P-value = 0.0002, F-ratio = 121.57 but there is not a significant difference between the different altitude classes.

Comparison between slopes or influence of slopes

The highest floristic difference between the WEST and EAST slopes which corresponds to the very strong comparison threshold (80%) on the hill of Gaban Tissilé and of (17.42%) and strong on that of Kilguim. This floristic difference would be the consequence especially of the nature and depth of the soil, the topography of the soil on the slopes and the slope of each slope. These results are similar to those of Ntoupka (1999) in the Sudano-Sahelian zone who showed that the Hamming distances between the different plant formations are unevenly varied. The analysis of variance reveals a statistically significant difference between the different hills P-value = 0.0063, F-ratio = 21.44 but there is not a significant difference between the slopes.

CONCLUSION

The objective of this study was to contribute to the characterization of vegetation and the distribution of the phytodiversity of the Lara, Boboyo and Midjivin hills, with a view to developing appropriate strategies for the sustainable management of biodiversity and for socio-economic development of their population. In this modest study, the results show us that the structure of the plant stand is dominated by young individuals. The height class of [0-4 [with is the most representative, with 41.87% and the class [4-8 [with 35.41% of the floristic font of the studied mountains. The least represented classes are the [8-10 [with (9.61%) and class ≥ 10 with (13.10%) of the floristic procession of the vegetation of the three hills. The diametrical structure of the vegetation of the three hills shows a predominance, individuals with a diameter of less than 20 cm represent 74.07% of the vegetation. On all the hills studied, individuals belonging to the class with a diameter greater than 20 cm are remarkably small, they represent 25.93% of the population. The most important species in terms of density, diversity and dominance were *Terminalia brownii*, *Ficus abutilifolia*, *Lannea barteri* and *Commiphora africana*. The distribution according to the slopes showed that the WEST slope is denser than the EAST slope and the population distribution presents small proportions at the bottom of the hills. The distribution at the low altitudes between (420-520 m altitude) there is an average of 726 individuals and on the top part (> 520m) there is an average of 804 individuals, the evaluation of the influence of the habitat on the morphological characters shows that the altitude and the slopes have a significant influence on the height and the diameter. In view of all these results showing a low population density and strong anthropogenic pressure, maintaining the ecosystem functions of these hills poses a problem of conservation and management of biodiversity. It therefore appears necessary to better conserve and above all to improve the management and exploitation of resources, but also to intervene more intensely in the protection of the natural regeneration of Gaban Tissilé and Kilguim.

Author contribution

Beidi Eugène wrote the original draft of the manuscript; Souare Konsala and Adamou Ibrahima conceived and designed the experiments, contributed to the explanations and discussions on results.

Declaration of Competing Interest

Authors declare that they have no conflict of interest with regards to the manuscript.

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