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Floristic composition, diversity and structure of *Khaya senegalensis* stands in Benue Department, Cameroon

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Abstract

The present work has been done to provide basic data for a better conservation and valorization of *Khaya senegalensis* stands in Sudano-Sahelian zone of Cameroon. A 100 m x 50 m transect method was undertaken to measure floristic diversity through the use of species richness, Shannon index, Pielou equitability, Simpson index, importance value index and importance value family. The vegetation structure is determined by density, basal area and biovolume. The inventory included trees with a dbh ≥10 cm on an area of 1 ha per plot. A total of 6743 individuals distributed in 24 families, 33 genera and 54 species were inventoried in all *Khaya senegalensis* stands studied. Statistical analysis showed significant differences, Shannon index, Simpson index, Pielou equitability, density, basal area, biovolume, species richness, heights class, diameters class, circumferences class but does not certify a significant difference of importance value index among in the villages. The undergrowth of *Khaya senegalensis* stands is more diverse at Bamé with a Shannon diversity index (ISH=5.87 ± 0.12 bit). The greatest of Pielou equitability is observed at Bamé (EQ=0.80 ± 0.01). The largest of Simpson index is recorded at Bamé (D=0.098 ± 0.001). *Khaya senegalensis* Stands are denser at Bamé (194 ± 3.12 individuals/ha). The basal area and biovolume of *Khaya senegalensis* stands are very high at Bamé (BA=25.87 ± 0.06 m^2/ha and Biovolume =15.32 ± 0.012 m^3/ha). The species importance value is maximal in all the studied villages (SIV=300 ± 71.45). The importance value index of species revealed a clear dominance in the undergrowth of *Khaya senegalensis* stands are *Combretum adenogonium; Acacia senegal; Terminalia laxiflora; Guiera senegalensis; Acacia nilotica; Entada Africana*. The vertical structure has three aspects, like the L (Dbh), asymmetric (height) and dissymmetrical (circumference) structures attesting to a strong regeneration of the understory ligneous woods of *Khaya senegalensis* stands studied.

1. INTRODUCTION

Over these two decades, Sub-Saharan Africa is facing an accelerated degradation of its plant biodiversity following anthropogenic and natural activities (Ndjidda, 2001). Living populations in these countries are highly dependent on natural plant resources and often have relatively limited adaptive capacity (IPCC, 2006). According to the IUCN 2007 classification, human factors related to resource use practices are one of the causes of the loss of biodiversity. In Cameroon, human pressure has caused a gradual degradation of natural resources in Sudan and Sahel. Conservation remains a major challenge. There is indeed a strong anthropic pressure and an excessive and uncontrolled use of the wood resource in the savannah ecosystems in Northern region, Cameroon; these are the causes weighing on biodiversity. These major impacts on natural environments lead to the destruction of species and their habitat, including threatened plant species.

Khaya senegalensis is a large tree of the multi-purpose Meliaceae family, widespread in tropical dry Africa, which is used to control wind erosion, also used as fodder for livestock (Arbonnier, 2000, Gaoue &Ticktin, 2007). *Khaya senegalensis* is a sacred tree for some tribes. Its wood is more often used in construction, cabinet making, and carpentry and also as firewood. All parts are used in traditional pharmacopoeia (Arbonnier, 2000). Leaves, flowers, roots and young twigs are popular as decoctions, cooking; powder (Arbonnier, 2000). Also used in medico-magic (specially to fight against madness) (Gaoue & Ticktin, 2008). This species is importance of socio-economic and environmental. According to the

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IUCN Red List, *Khaya senegalensis* is listed in this list as a vulnerable species with special status (Gaoue & Ticktin 2008). Overexploited, threatened by fire, overgrazing and drought, this species is in sharp decline (FAO, 2001). In Northern Cameroon, the big feet of *Khaya senegalensis* are rare in Sudanian savannahs. However, in the Sudanian zone, particularly in Cameroon, knowledge about the floristic composition, diversity and structure of *Khaya senegalensis* stands is very limited, if not unavailable. However, biodiversity provides a lot of information about the functioning, ecological and economic productivity of ecosystems. It would therefore be important to have sufficiently accurate information on the floristic structure of the undergrowth of *Khaya senegalensis* stands. Hence the interest of this work is to contribute to the improvement of knowledge for a sustainable safeguard of biodiversity while improving the incomes of local communities.

1.1. Study area

The study was conducted in North region, Benue Department, Cameroon. This region is located between latitude 9° 18' North and longitude 13° 23' East (Abdoulay, 2012) (Fig.1). The terrain is a wide pediplain Between the Mandara Mountains (1442 m) in the North and the plateau of the Adamawa to the south. The climate is Sudano-sahelian type with two seasons: a dry season of duration of six months (November-May) and a rainy season of duration of six months (June-October) (Abdoulay, 2012). The mean monthly temperature evolving from 26°C in August to 40°C in March.

The soil is ferruginous type characterized by an acidity (pH = 5.5 to 6), and a low cation exchange capacity (Noiha *et al.*, 2017). The vegetation is a savannah shrub Sudanian zone having an aspect of clear savannah and degraded around the villages (Letouzey, 1985). Agriculture is the main activity of the populations in the North region. The population practice subsistence farming (corn; peanut and mil).

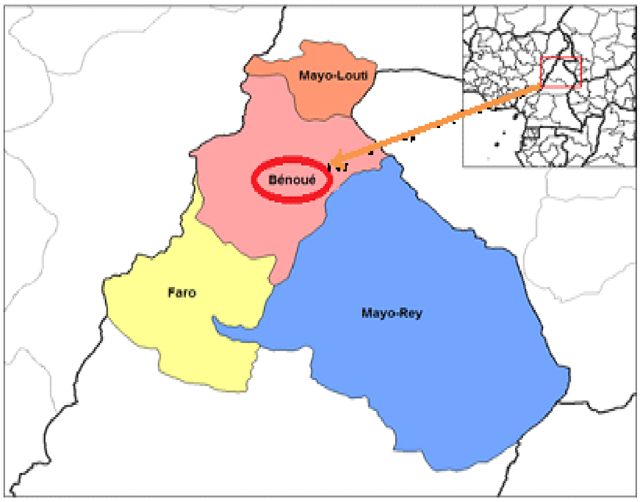

Figure 1: Map of study area location (Abdoulay, 2012).

2. MATERIALS AND METHODS

2.1. Data sampling

The experimental set-up consists of transects ranging from 100 m long to 50 m wide. These transects were arranged in a North-South direction to cover most or all of *Khaya senegalensis* stands in the six villages studied. The sampling tapes were established using the wires and the compass. At the ends of each strip, the milestones were marked equidistant 20 m from the base. At each distance of 20 m, all the trees have been inventoried. Geographic coordinates were collected using GPS for each tree in the sample to determine its geographical location on the ground. All the trees were systematically counted and measured. Dendrometric data were based on dbh (Diameter of Breast hearth), height and trunk size. For example, the circumferences of the trees were measured with a tape measure at 1.3 m from the ground for tall trees and at 50 cm from the ground for shrubs and shrubs.

2.2. Analysis of data

The data has been encoded in the Excel software and then analyzed thanks to software Statgraphics plus 5.0. Duncan's test to 5%.

2.3. Floristic diversity

-Species richness (N) indicates the number of species responsible for the observed diversity. It is given by the formula: $N = 2^H$; 2 is the basis of the logarithm used to calculate the Shannon diversity index (H).

-Shannon Diversity Index (ISH) (Frontier and Pichod-viale, 1992): $ISH = -\Sigma\ (ni/N)*\log_2\ (ni/N)$, with ni = number of species i, N = effective of all species; ISH is expressed in bit.

- Pielou equitability (EQ) (Pielou, 1969): $EQ = ISH/\log_2 N$.

- Simpson's index (Colinvaux, 1986): $D= 1-\sum\ (ni/N)^2$ (Begon *et al.,* 1998).

- Density (D): D=n /S; D: density (in trees/ha), n: number of trees present on the surface considered and S: basal area (m^2/ha).

- Basal area of a tree corresponds to the area occupied by the tree trunk at the level of the dhp. It is given by the formula: Basal area = $dhp^2 \times 0.25 \times 9$ (Dawkins, 1959).

- Biovolume is defined as the volume of wood provided by vegetation in a given area. It makes it possible to estimate the wood potential of the plant formation. It is given by the formula of Dawkins. (1959): V = 0.53 ågi x hi x ni with gi: basal area (m^2/ha). Hi: height of the barrel (m); ni: number of individuals; V: biovolume (m^3/ha). According to Roger and Rabarison (2000), biovolume is high when it is higher than 250 m^3/ha, average when it is between 50 and 250 m^3/ha, and low, when it is lower than 50m^3/ha.

-Relative density = (total basal area for one species / total basal area of all species) × 100.

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-Relative density = (number of individuals of the species / total number of individuals all species combined) × 100.
Relative frequency = (frequency of species / sum of all frequencies of other species) × 100.
-Relative diversity = (number of species in the family / total number of species present) × 100.
- Species Importance Value (SIV) (Curtis and Macintosh (1950)): SIV = Relative Dominance (Species) + Relative Density (Species) + Relative Frequency (Species).
- Family Importance Value (FIV) = relative dominance + relative density + relative diversity.

2.4. Vertical structure

The distribution of woody individuals in class of diameter, height and circumference was performed. For diameter class distribution and circumference, trees were distributed by diameter class and stem distribution histograms were constructed to characterize the diametric structure of the vegetation. 7 to 10 diameter classes with amplitude equal to 10 cm have been established. From the results of the height measurements, the individuals were grouped in class of amplitude 4 cm all these classes were then simplified in large classes: regeneration, rods of futures, medium stems and big trees.

3. RESULT AND DISCUSSION

3.1. RESULT

3.1.1. Specific richness

A total of 6743 individuals distributed in 24 families, 33 genera and 54 species were identified in all the stands of Khaya senegalensis studied in the six villages. Khaya senegalensis stands in Bamé village are richer in terms of phytodiversity (Table1).

Table 1: Species richness in each village studied.

Villages	Nf	Ng	Ns	Ni
Sanguéré-Paul	11	12	23	1036
Bame	19	21	32	1564
Sanguéré -Ngal	11	13	21	1011
Bockli	10	12	30	1034
Djalingo	13	18	28	1512
Mayo-Djarendji	9	10	18	586
Total	24	33	54	6743

Nf: Number of families, Ng: Number of genera, Ns: Number of species, Ni: Number of individuals

3.1.2. Taxonomic abundance

In sangéré-paul, the Combretaceae are more represented (32.73 %) (Fig.2A). in Bamé, the Caesalpiniaceae are more represented (45 %) (Fig.2B). In Sanguéré-Ngal, the Fabaceae are more represented (46.4 %) (Fig.2C). In Bockli, found, the Anacardiaceae are more represented (81.56 %) (Fig.2D). In Djalingo, the Rubiaceae are more represented (31.52 %) (Fig.2E). In Mayo-Djarendji, the Loganiaceae are more represented (76.80 %) (Fig.2F).

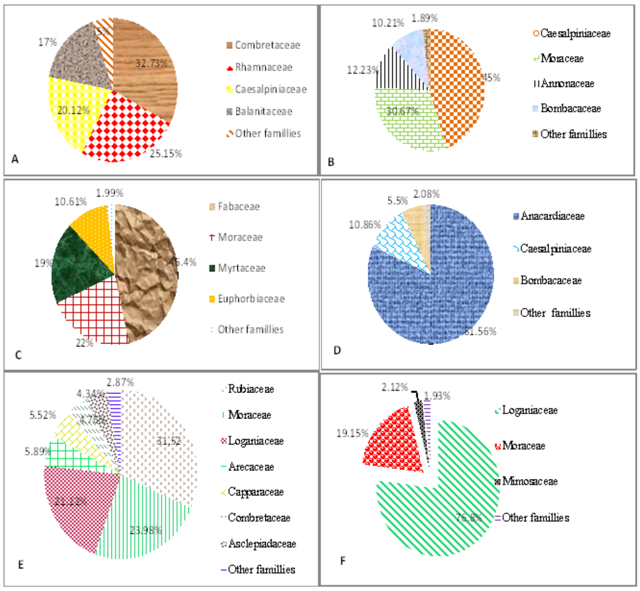

Figure 2: Taxonomic abundances of families in each studied village.

3.1.3. Species importance value index

Acacia sieberiana has the highest SIV in the Sanguéré-paul village with 178.60 %. On the other hand, in Bamé village, *Tamarindus indica* has the highest SIV with 183.21 %. *Faidherbia albida* has the highest SIV in Sanguéré-Ngal village with 146.86 %. *Guiera senegalensis* has the highest SIV in Bockli village with 70.39 %. *Acacia nilotica* has the highest SIV in Djalingo with 150.45 %. On the other hand, in Mayo-Djarendji village, *Acacia polyacantha* has the highest SIV with 100.55 % (Table 2).

Table 2: Representations of the most important species in terms of ecological index.

Villages	Espèces	DoRe	DeRe	FeRe	IVI
Sanguéré -Paul	*Anacardium occidentale*	0.04	5.16	5.16	10.37
	Acacia sieberiana	80.41	49.09	49.09	178.60
	Jatropha curcas	4.51	2.84	2.84	10.19
	Balanites aegyptiaca	2.93	12.24	15.24	30.42
	Ficus glomusa	0.04	5.07	5.07	10.19
Bamé	*Hexallobus monopetalus*	0.13	7.73	8.73	16.61
	Tamarindus indica	97.13	45.54	40.54	183.21
	Acacia senegal	0.49	13.85	13.85	28.20
	Diospyros mespiliformis	0.32	9.17	9.17	18.66
Sanguéré -Ngal	*Ximenia amaricana*	0.07	5.52	5.52	11.13
	Faidherbia albida	84.02	32.41	30.41	146.86
	Terminalia laxiflora	2.10	14.19	14.19	30.49
	Terminalia schimperiana	1.25	6.87	8.85	16.98
	Piliostigma thonningii	78.78	10.89	12.87	104.55
	Guiera senegalensis	4.44	30.48	35.46	70.39

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Bockli	*Prosopis africana*	3.82	4.53	6.51	14.86
	Vitellaria paradoxa	1.33	7.54	9.52	18.40
	Burkea africana	1.41	5.62	5.60	12.63
	Vitex doniana	0.33	11.11	11.11	22.56
Djalingo	*Gardenia aqualla*	0.07	5.52	5.52	11.13
	Acacia nilotica	88.02	30.41	31.02	150.45
	Sclerocari abirrea	2	14.19	14.19	30.39
	Strychnos spinosa	1.25	6.87	8.85	16.98
Mayo-Djarendji	*Acacia polyacantha*	72.78	10.89	10.87	100.55
	Detarium microcarpum	0.44	33.48	30.46	64.39
	Sclerocaria birrea	3,82	4.53	4.51	12.86
	Boswellia papyrifera	1.33	7.54	9.52	18.40
	Commiphora pedunculata	0.41	5.62	7.60	11.63

Relative dominance (DoRe), relative density (DeRe), relative frequency (FeRe), Species importance value (SIV).

3.1.4. Family importance value index

The most representative families in the undergrowth of *Khaya sengalensis* stands with a high FIV value are Sapotaceae in Sanguéré-Paul village (IVF = 40.19); Meliaceae in Bamé village (FIV = 98.21); Fabaceae in Sanguéré-Ngal village (FIV = 146.86); Caesalpiniaceae in Bockli village (FIV=118.40); Verbenaceae and Asclepiadaceae in Djalingo village with respectively (FIV = 150.45 and 111.55); Moraceae in Mayo-Djarendji village (FIV = 150) (Table 3).

Table 3: Representations of the most important families in terms of ecological index.

Villages	Familles	FIV	Familles	FIV
Sanguéré - Paul	Meliaceae	10.37	Myrtaceae	20.37
	Anacardiaceae	12.60	Rubiaceae	138
	Annonaceae	8	Sapotaceae	40.19
	Asclepiadaceae	20.11	Scleropiadaceae	29.42
	Bombacaceae	10.19	Other families	6.75
Bamé	Burseraceae	16.61	Loganiaceae	16.61
	Caesalpiniaceae	33.21	Meliaceae	98.21
	Capparaceae	30.28	Verbenaceae	48.20
	Celastraceae	18.66	Mimosaceae	18.66
	Combretaceae	11.43	Other families	9.13
Sanguéré - Ngal	Fabaceae	146.86	Arecaceae	4.86
	Sterculiaceae	30.49	Apocynaceae	4.49
	Connaraceae	16.98	Malvaceae	6.98
	Euphorbiaceae	13.01	Moringaceae	4.55
	Bignoniaceae	70.39	Other families	1.39
Bockli	Rhamnaceae	15	Myrtaceae	98.01
	Caesalpiniaceae	118.40	Meliaceae	18.40
	Sapotaceae	12.44	Anacardiaceae	12.63
	Mimosaceae	22.56	Other families	2.56
Djalingo	Meliaceae	11.61	Asclepiadaceae	111.55
	Verbenaceae	150.45	Bombacaceae	23.45
	Mimosaceae	50.55	Other families	3.39
Mayo-Djarendji	Sapotaceae	25	Sterculiaceae	30.98
	Moraceae	150	Connaraceae	30
	Scleropiadaceae	19.02	Balanitaceae	9.40
	Fabaceae	11	Bignoniaceae	5.44
	Anacardiaceae	14.60	Other families	4.56

3.1.5. Analysis of diversity indices and similarities between sites

Analysis of variance reveals that there are significant differences ($p < 0.05$) for species richness of trees with a higher value in Bamé village (52 ± 0.11) (Table 4). The Shannon diversity index in Bamé village (5.87 ± 0.12 bits) shows the greatest diversity in this site. This Shannon index varies significantly ($p < 0.05$) between stands (Table 4).

Analysis of variance reveals that there are significant differences ($p < 0.05$) in this Pielou equitability between the sampled stands. The Pielou equitability is maximal in Bamé village (0.80±0.01) (Table 4). The average circumference of the individuals is important in Bamé Village stands (68 ± 0.11 cm). Variance analysis reveals that there are significant differences ($p < 0.05$) in the average circumferences of individuals between sampled stands (Table 4). Simpson's index is higher in Bamé village (0.098 ± 0.001) and varies significantly ($p < 0.05$) between sites (Table 4).

For the mean DBH, the analysis shows that there is a significant difference ($p < 0.05$) between sites with a higher value in Bamé village (54.12 ± 0.21) (Table 4). Considering the sites, there are very significant differences ($p < 0.05$) for the density. The highest average tree trunk density is recorded in Bamé village (194 ± 3.12 individuals/ha) (Table 4). For mean basal area, the analysis shows that there is a significant difference ($p < 0.05$) between sites with a higher value in Bamé village (25.87 ± 0.06 m^2/ha) (Table 1).

Statistical analysis shows a significant difference to biovolume between sites ($P < 0.05$). The highest average biovolume was recorded in Bamé village (15.32 ± 0.012m3/ha) (Table 4). Statistical analysis does not indicate a significant difference importance value index between villages ($P > 0.05$). It is worth (IVI=300 ± 71.45) in all villages (Table 4).

Table 4: Floristic diversity and structural characterization.

Diversity parameter	Sanguéré -Paul	Bamé	Sanguéré -Ngal	Bockli	Djalingo	Mayo-Djarendji
Specific richness (Rs)	23±0.02^{b}	52±0.11^{c}	21±0.01^{a}	30±0.10^{d}	28±0.03^{f}	18±0.011^{e}
Shannon index (ISH)	2.98±0.01^{b}	5.87±0.12^{c}	2.15±0.02^{a}	3.54±0.02^{d}	3.07±0.03^{f}	1.87±0.00^{e}
Pielou's equitability (EQ)	0.42±0.01^{a}	0.80±0.01^{b}	0.31±0.01^{c}	0.51±0.01^{d}	0.45±0.01^{a}	0.30±0.01^{c}
Simpson index (DS)	0.061±0.00^{b}	0.098±0.001^{c}	0.045±0.003^{a}	0.084±0.004^{d}	0.078±0.006^{f}	0.038±0.00^{e}
Average diameter (cm)	11.67±0.03^{b}	54.12±0.21^{c}	34.56±0.05^{a}	28.12±0.12^{d}	21.76±0.01^{f}	26.76±0.05^{e}
Average circumferences (cm)	31±0.08^{b}	68±0.11^{c}	28±0.15^{a}	56±0.83^{d}	49±0.31^{f}	20±0.01^{e}
Density (tiges/ha)	126±2.89^{b}	194±3.12^{c}	110±1.76^{a}	174±1.01^{d}	143±4.01^{f}	98±0.09^{e}
Basal area (m²/ha)	16.94±0.03^{b}	25.87±0.06^{c}	12.56±0.01^{a}	18.01±0.02^{d}	14.23±0.01^{f}	9.23±0.00^{e}
Biovolume (m²/ha)	6.45±0.01b	15.32±0.012c	2.06±0.001a	8.01±0.013d	3.96±0.011f	1.29±0.001e
Importance valeur index (IVI)	300±71.45^{a}	300±71.45^{a}	300±71.45^{a}	300±71.45^{a}	300±71.45^{a}	300±71.45^{a}

The assigned values of the same letter are not statistically different (*p> 0.05, Duncan's test*).

In terms of density, the most represented species in the undergrowth of *Khaya senegalensis* stands are *Combretum adenogonium* (80 ± 6.98 individuals/ha) in Sanguéré-Paul village; *Acacia senegal* (49 ± 0.43 individuals/ha) in Bamé village; *Terminalia laxiflora* (98±5.09 individuals/ha) in Sanguéré-Ngal village; *Guiera senegalensis* (44 ±1.98 individuals/ha) in Bockli village; *Acacia nilotica* (88 ± 3.32 individuals/ha) in Djalingo village; *Entada africana* (82 ± 2.65 individuals/ha) in Mayo-Djarendji village (Table 5).

In terms of basal area, the most represented species in the undergrowth of *Khaya senegalensis* stands are *Ficus glomusa* (15.67 ± 1.02 m²/ha) in Sanguéré-Paul village; *Tamarindus indica* (9.19 ± 1.11m²/ha) in Bamé village; *Faidherbia albida* (6.27 ± 0.87 m²/ha) in Sanguéré-Ngal village; *Vitellaria paradoxa* (8.21 ± 0.05 m²/ha) in Bockli village; *Sclerocaria birrea* (9.39 ± 0.04 m²/ha) in Djalingo village; *Boswellia papyrifera* (7.34 ± 0.23 m²/ha) in Mayo-Djarendji village (Table5).

Table 5: Density and basal area of the most represented species in the undergrowth of *Khaya senegalensis* stands at each site.

Villages	Species	D	BA
Sanguéré -Paul	*Anacardium occidentale*	14±0.98	10.76±0.12
	Combretum adenogonium	80±6.98	4.09±0.72
	Jatropha curcas	14±0.54	2.09±0.03
	Balanites aegyptiaca	19±0.79	2.44±0.02
	Ficus glomusa	10±0.01	15.67±1.02
Bamé	*Hexallobus monopetalus*	13±1.13	7.33±0.17
	Tamarindus indica	39±0.23	9.19±1.11
	Acacia senegal	49±0.43	3.05±0.09
	Diospyros mespiliformis	32±0.65	5.43±0.32
Sanguéré -Ngal	*Ximenia amaricana*	27±1.33	5.22±0.21
	Faidherbia albida	24±1.02	6.27±0.87
	Terminalia laxiflora	98±5.09	4.12±0.01
	Terminalia schimperiana	75±3.06	5.01±0.04
	Piliostigma thonningii	48±1.54	1.09±0.00
Bockli	*Guiera senegalensis*	44±1.98	7.14±0.02
	Prosopis africana	32±0.88	4.59±0.07
	Vitellaria paradoxa	13±0.02	8.21±0.05
	Burkea africana	11±0.23	5.12±0.01
	Vitexdoniana	33±1.65	1.91±0.00
Djalingo	*Gardenia aqualla*	47±1.87	5.02±0.021
	Acacia nilotica	88±3.32	3.01±0.00
	Sclerocaria birrea	42±2.87	9.39±0.04
	Strychnos spinosa	25±1.76	6.07±0.54
Mayo-Djarendji	*Acacia polyacantha*	78±1.43	3.09±0.02
	Detarium microcarpum	44±0.76	3.41±0.01
	Entada africana	82±2.65	4.93±0.12
	Boswellia papyrifera	13±1.09	7.34±0.23
	Commiphora pedunculata	41±3.54	5.67±0.04

D: Density individuals/ha), BA: Basal area m²/ha).

3.1.3. Floristic similarity

The indices of similarity are generally very high and do not reflect a significant difference between the different stands of *khaya senegalensis* studied. However, these three plots sampled are more floristically similar, since they have floristic affinities greater than or equal to 60%, thus forming the same plant community (Table 6).

Table 6: Floristic similarity.

Villages	A	B	C	D	E
A	-----	-----	----	-----	-----
B	73	----	-----	-----	-----
C	88	86	-----	-----	-----
D	61	66	74	-----	------
E	76	87	62	75	-----
F	69	83	85	92	94

A: Sanguéré –Paul; B: Bamé;C : Sanguéré –Ngal ;D : Bockli ;E : Djalingo ;F : Mayo-Djarendji.

3.1.4. Vegetation structure

The figure 3 shows the diameter class distribution showing that the number of individuals per diameter class decreases with increasing diameter. This distribution has a decreasing exponential shape (L) with a strong slope of equation: $y = 141.11e^{-1.876x}$ and $R^2 = 0.7531$, showing that the studied stands have several individuals of future to ensure the regeneration.

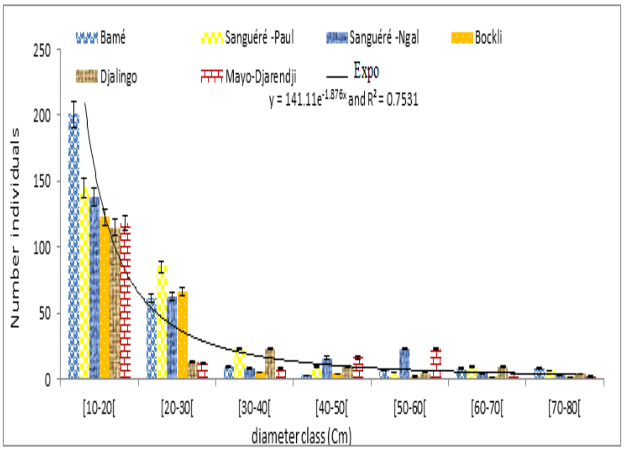

Figure 3: Diameter distribution by individuals in Village.

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Regarding the distribution of circumferences, the analysis shows that there is a highly significant difference ($p < 0.05$). At the village level, the highest circumferences classes are observed in Sanguéré-Ngal village. Its distribution in circumference class has the appearance of a curve in dissymmetrical close with a predominance of the class 70-80 cm in number of stems. This distribution fits better with a polygonal function whose equation is: $y = 0.0355x^4 - 1.2587x^3 + 12.339x^2 - 35.731x + 36$ and $R^2 = 0.8386$ (Fig. 4).

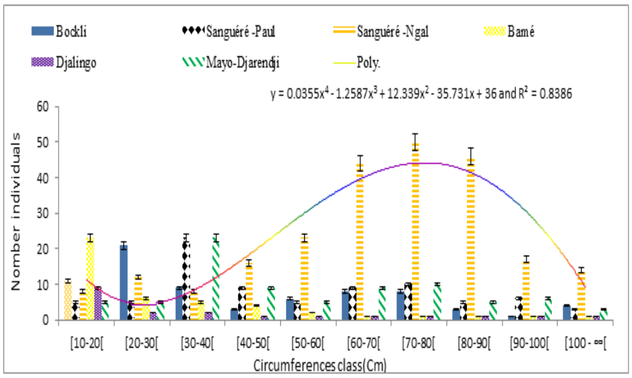

Figure 4: Circumferences distribution by individuals in Village.

For the height classes, the analysis shows that there is a highly significant difference ($p < 0.05$) at the village level, the highest height classes are observed in Sanguéré-Paul village. Indeed, Figure 5 shows the height class distribution has an asymmetrical bell structure centered on the diameter class 24 to 30 cm thus reflecting a predominance of individuals of average heights. This distribution fits better with a polygonal function whose equation: $y = -0.26x^5 + 3.8397x^4 – 18.795x^3 + 31.796x^2 – 5.3189x + 0.3$ and $R^2 = 0.9578$, reflecting a good dynamic population, but with a greater number of stems in Sanguéré-Paul village than in other stands in the villages studied.

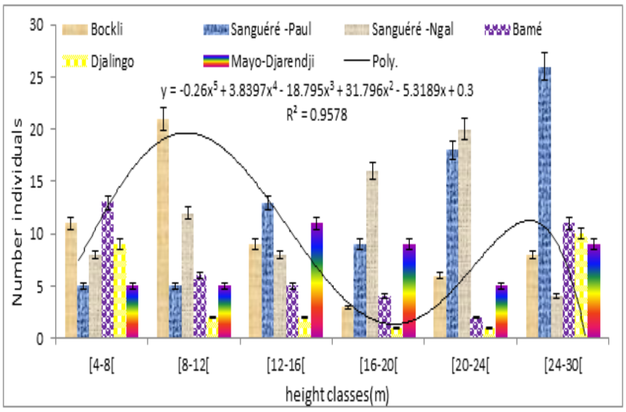

Figure 5: Height distribution by Individuals in Villages.

3.1.5. Annual cropping associated with the undergrowth of different *Khaya senegalensis* stands

For the annual undergrowth associations of *Khaya senegalensis* stands studied in the six villages, seven species are the most cultivated. In all localities, Mil is grown in 24 ± 0.01% of plots in which there are annual crop associations. Cowpea (13 ± 0.04%), groundnuts (12 ±%) are ranked third after maize, which is present in 21.5 ± 0.02% of plots in which there are annual crop associations. For cotton, sesame and *Hibiscus* sp are also cultivated but in small quantities with respectively 9.5 ± 0.012%, 10 ± 0.026 %, 10 ± 0.026% of plots in which there are annual crop combinations (Fig. 6).

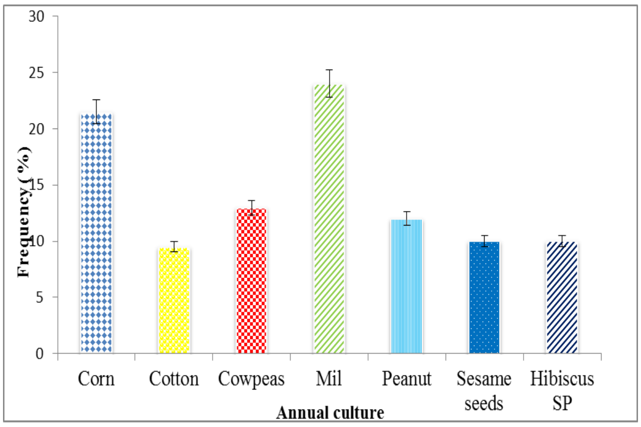

Figure 6: Proportion of annual crops associated in *Khaya senegalensis* stand studied.

Figures 7 and 8 shows the evolution of species richness, the Shannon index and Pielou's equitability according to the anthropization and aridity gradients. We have in the abscissa the groupings and in the ordinate the indices. He observes that the Shannon index is not correlated with the aridity gradient. We also note that the specific wealth does not always follow the Shannon index and Piélou's equitability. On the other hand, anthropization seems to affect species richness, the Shannon index and Piélou's equitability, since there is a slight increase in these three parameters with the accentuation of anthropization. These figures show that the specific diversity varies in a random way between the groups classified according to the two gradients.

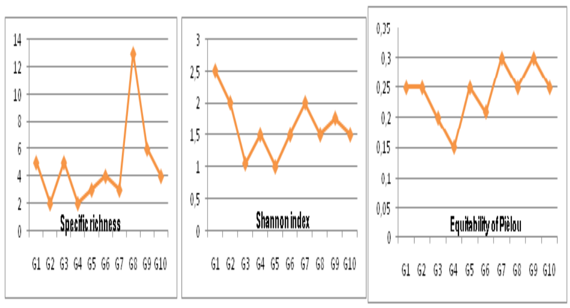

Figure 7: Phytodiversity according to the anthropization gradient

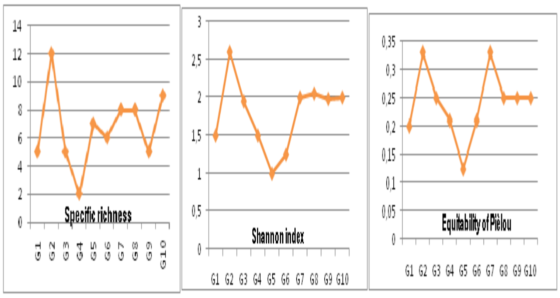

Figure 8: Phytodiversity according to the aridity gradient.

3.2. DISCUSSION

The floristic inventory identified a total of 6743 individuals (dbh ≥10 cm) distributed in 24 families, 33 genera and 54 species. This shows that the undergrowth of *Khaya senegalensis* stands is very diverse with a predominance are Combretaceae, Caesalpiniaceae, Fabaceae, Anacardiaceae, Rubiaceae, Loganiaceae because the species in these families provide important social and economic services for the local population (Thiombiano *et al*., 2006, Avakoudjo *et al*., 2013, Savadogo *et al*., 2016). These are species whose products are used either in food or feed, as firewood or in construction. The dominance of these families could be explained by the fact that most species of these families are better suited to climatic conditions and human activities in Sudano-Sahelian zone.

The high species richness of *Khaya senegalensis* stands observed in Bamé village is explained by environmental conditions that would favor the regeneration of the most predominant species in the undergrowth of *Khaya senegalensis* stands as *Acacia sieberiana; Tamarindus indica, Faidherbia albida; Guiera senegalensis; Acacia nilotica; Acacia polyacantha*. In all the stands studied, thorny species are dominant because they are more adapted to water stress. This corroborates those of Laminou *et al*. (2009) in the Sahelian zone of Burkina-Faso.

A *Khaya senegalensis* stand has the highest value in Bamé village (5.87 ± 0.12 bits). This can be explained by the ecological conditions that would be favorable for the regeneration of the species present in the sites studied and also by the well-controlled anthropogenic actions cited by Noiha *et al*. (2018). This result is close to those Dongmo (2002) in the Young fallows, fallow averages, Old fallow, secondary forests, Cocoa forest zone of Cameroon with respectively 5.37 bits; 5.31 bits; 5.76 bits; 5.89 bits; 5.79 bits.

The pielou's equitability is maximum in Bamé village stands (0.80 ± 0.01). This high value reflects a good recovery of the floristic diversity of the undergrowth, probably because of the favorable conditions of the environment. Indeed, the Shannon indices and Pielou equitability vary significantly. The Simpson index of *Khaya senegalensis* stands is very high in Bamé village (0.098 ± 0.001), this site has a heterogeneous distribution of their flora and the probability that two individuals is taken at random belonging to the same species is strong in this site.

The highest average densities in the stands were recorded in Bamé village (194 ± 3.12 individuals/ha) which would represent an appreciable regeneration within the stands. In fact, the importance of regeneration in the stands studied is that it favors the protection of the land by preventing rainwater from having a beating effect thanks to foliage and root systems (Malagnoux *et al*., 2007). This result is in the range 103 to 267 individuals/ha obtained by Ali *et al*. (2014) in the sacred forests of south-eastern Benin. The most common species in the undergrowth of *Khaya senegalensis* stands are *Combretum adenogonium; Acacia senegal; Terminalia laxiflora; Guiera senegalensis; Acacia nilotica; Entada africana.*

The higher basal area observed in Bamé village (25.87 ± 0.06 m²/ha) is indicative of large tree specimens. Among the undergrowth species of *Khaya senegalensis* stands, some have a high shade rate, such as *Ficus glomusa; Tamarindus indica; Faidherbia albida; Vitellaria paradoxa; Sclerocaria birrea; Boswellia papyrifera.* This may explain the high proportion of species that can provide shade in any season (Leblanc &Malaisse, 1978).

The importance value index does not vary and is very high in the sites (IVI = 300 ± 71.45). This could be explained by the strong presence of tall-topped trees in the different stands studied. This finding is consistent with (Ngom*et al*., 2013; Noiha *et al*., 2018b), which asserts that crown trees contribute more to recovery and to a degree of recovery, altering ecological conditions. By reducing the evaporative power of the air, by promoting the water balance of the soil and by improving the fertility.

The floristic similarity in *Khaya senegalensis* stands in the six villages is greater than or equal to 60%, due to the fact that the stands studied in the different villages are located in the same agro-ecological zone. This very high similarity means that there is little floristic difference between of *Khaya senegalensis* stands studied in the six villages of the Benue department.

According to local communities, the annual crops associated with the undergrowth of different in *Khaya senegalensis* stands give interesting yields and generate significant income. This situation is explained by the fact that the forest stands thus formed have a soil cover rate that favors the productivity of annual and sun-loving crops. This mode of management of forest stands allows the diversification of the sources of income over time, which gives the capacity to the local communities to face the challenges of their economic development and

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the protection of their environment. The management of this diversity of groups of plants found in the undergrowth of the different in *Khaya senegalensis* stands studied, allows farmers to feed, treat, warm, beautify their surroundings and care for their environment at the same time (Mapongmetsem *et al*., 2009; 2016).

The analysis of the distribution of individuals by diameter classes reveals an "**L**" distribution with an exponential equation reflecting the predominance of small diameter individuals. This distribution has also been described by several authors in other ecosystems (Fongnzossie *et al*., 2008; Noiha *et al*., 2018). This distribution indicates that these ecosystems have a regular dynamic denoting a constant regeneration over time (Rasatatsihoarana, 2007; Noiha *et al*., 2018a) and characterizes a woody population that interacts with each other (Fongnzossie *et al*., 2008*;* Noiha *et al*., 2018c). The predominance of young plants would strongly influence tree diameter (Noiha*et al*., 2018b).

The height class distribution has an asymmetrical bell structure centered on the diameter class 24 to 30 cm, thus reflecting a predominance of medium height individuals. This situation is observed in an unstable population characterized by an absence or a very small proportion of individuals in one or more classes (Ouédraogo, 2006; Noiha *et al*., 2018). It may be one of the consequences of recurring droughts due to the effects of strong pressure on fodder resources (Cornet *et al*., 2002; Lhoste, 2007 *in* Noiha *et al*., 2018).

This Ascending Hierarchical Classification (CAH) shows 10 groups of species according to the similarity of their diversity with formation of 5 complexes with the following similarities: (G2-G9): 40% (G3-G8): 83%; (G1-G7): 85%; (G4-G10): 90%; (G5-G6): 92% dependent on their potential for diversity in Sudano-Sahelian zone of Cameroon. Diversity potential is the main determinant of the groups, with a clear separation between species with high density values of other species at low densities.

Gradients of anthropization and aridity generally affect woody diversity. These translate how anthropogenic pressures and climatic factors impacted in *Khaya senegalensis* stands and other stands in Sudano-Sahelian zone of Cameroon.

4. CONCLUSION

The present study made it possible to make an evaluation floristic diversity of *Khaya senegalensis* stands in Benue department, Northern region, Cameroon. This diversity is relatively high compared to other agro-ecological zones of Cameroon. Preponderance of woody species such as *Acacia sieberiana; Tamarindus indica: Faidherbia albida; Guiera senegalensis; Acacia nilotica; Acacia polyacantha* testifies to their resistance to sometimes difficult climatic conditions and to anthropic actions. All these data are arguments for the preservation and conservation of *Khaya senegalensis* stands. They also describe elements of biodiversity and provide information on the implementation of management guidelines for the safeguarding of such a plant species with multiple uses.

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