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Ecological and Environmental Study of Sacred Forests, Anthropized and Reforested Savannahs in the Canton of Lara

Tchobsala[*], Djibrilla Mana, Mbolo Marie, Haiwa Gilbert, Kodji Paul
University of Maroua, Department of Biological Sciences, Faculty of Sciences, PO 814 Maroua Cameroon

Original Research Article

***Corresponding author**
Tchobsala

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Abstract: Anthropogenic actions pose a threat to plant biodiversity, leading to an imbalance of flora in Cameroon in general, in the locality of Lara in particular. The objective of our study is to make an ecological and environmental characterization of sacred forests, anthropized savannahs and reforested sites in the locality of Lara. The work involved making floristic inventories and ethnobotanical surveys of local populations. The floristic surveys were carried out on 3 plots of 50 x 50 m in each plant formation and in each village. Statgraphic 5.0 plus, Excel and Xlstat pro, Principal Component Analysis (PCA), Biodiversity Index, Frequency and Density Calculations were used for data processing and analysis. These different analyzes have shown that the remarkable consequences of the impact of human activities on plant biodiversity and on the environment are: the loss of NWFP (87.5%), climate change (80%) and the installation of the desert (69.17%). From this study, 13 species were recorded as overexploited in the locality of Lara. These are primarily *Anogeissus leiocarpus (55%)*, *Sclerocarya birrea* (50.83), *Balanites aegyptiaca* (47.5%), *Detarium senegalensis* (45%) and *Boswellia dalziellii* (44.17%). Regarding the surveys, they were carried out with 150 people in three villages (Bipaing, Lera and Going) or 50 people per village. In order to safeguard plant biodiversity, we envisage in our future prospects: □ Expand the study area throughout the Far North region;□ Promote the practice of agroforestry;

Keywords: Anthropization, plant biodiversity, sacred forest, Lara, Cameroon.

INTRODUCTION

For more than half a century, sub-Saharan Africa has been facing an accelerated degradation of its plant biodiversity as a result of human activities and natural phenomena [1]. Human activities and its many consequences on plant biodiversity are a major challenge for developing countries [2, 3]. Living populations in these countries are highly dependent on natural plant resources and often have relatively limited adaptive capacity [2]. In Cameroon, as in many other countries in sub-Saharan Africa, the effects of human activities are more than ever perceptible, especially in the Far North Cameroon region [4].

Today, the majority of the population residing in the Far North region suffer disproportionately because of the semi-arid conditions of this region and also because of their heavy reliance on agriculture, livestock and natural resources. are the causes of threat to biodiversity [5, 6]. Criticisms of human activities highlight the ecological balance, in a context where the natural environment presents conditions that are naturally conducive to human activity [4]. There is still this support for all human activities on the surface of the earth and it is still the same environment that provides all the vital necessities to the farmers [7]. If we are bound to the earth, to the environment as a framework produced in that it ensures our survival, it is important to recognize the interactions that exist between nature and its constituents, among which, man holds a place of choice through the goods and services provided by the natural environment [8]. Indeed, his daily vital needs lead him to intervene in nature, which intervention has many objectives [9]. It seeks to satisfy its needs by exploiting available natural resources, the reason for all its actions on biodiversity [10]. At this level, we speak of firewood and Non-Timber Forest Products (NTFPs) which concern almost all the households of peasants, not only in the Far North region, but beyond, in almost all households in sub-Saharan countries [4].

There are several activities practiced by man on the environment, including hunting, fishing, agriculture or livestock [11]. Each domain holds a special mark in nature, through its practices that have either negative or positive effects. The questions that are raised refer to methods of agricultural practice that use mechanized means, chemicals such as agricultural inputs (insecticides, pesticides, chemical fertilizers). All of these activities put pressure on plant biodiversity [7]. In order to mitigate this degradation of biodiversity, safeguarding actions deserve to be carried out. Work has been done by Doncfack [12] and Ntoupka [13], in the northern area of Cameroon and Wafo [4] on protected area conservation policy in the Far North region.

At the limit of our knowledge, few studies have been carried out on human impacts on the biodiversity vulnerability of the Lara canton area, which is in an alarming state of degradation. The present work aims generally at the ecological and environmental characterization of sacred forests, anthropized savannahs and reforested sites in the locality of Lara.

MATERIALS AND METHODS

Presentation of the study area

The study took place in the Far North region, Mayo-Kani Department, specifically in the district of Kaele (Canton of Lara). This borough extends over an area of approximately 2000 km² [14]. With geographic coordinates 10 ° 02 ', 10 ° 23' north latitude and 14 ° 03 ', 14 ° 42' east longitude [12], the Kaélé plain is limited to the northeast by the locality of Binder (Chad-Cameroon border), to the south-west by the district of Figuil, to the North by the district of Mindif, to the West by the district of Moutourwa and to the East by the district from Guidiguis. Lara, which is the study area, is located to the east (Figure 1).

Socio-economic surveys

The surveys were conducted on the basis of questionnaires previously prepared in survey cards. They were carried out in the different neighborhoods of Going, Bipaing and Lera villages. The interview used is of a semi-structured type comprising closed questions (which are answered yes or no), open (of which one responds deliberately according to one's point of view) and oriented (some answers are offered to the respondent). The main sections of the questionnaires dealt, on the one hand, with the quantitative approaches and beneficiaries of natural resources of plant origin, and on the other hand with the socio-economic influences of natural resources.

In total, 150 people were surveyed, or 40 people per village (Figure 2). Another 30 people were surveyed at the site of exploitation of natural resources, with 10 people per village.

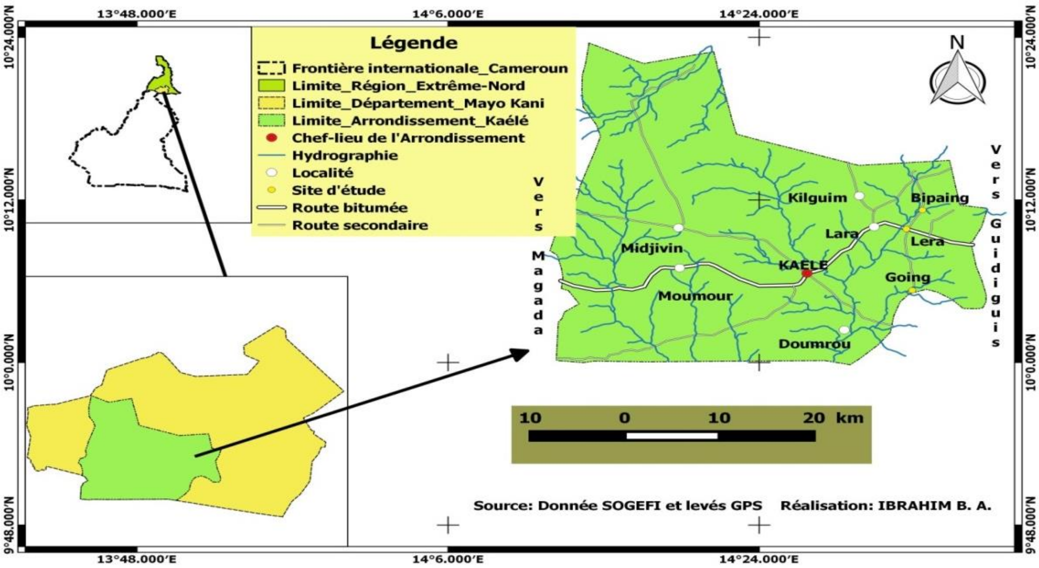


Fig-1: Site Map of Study Sites

Floristic survey

The quadrat method allowed us to carry out the floristic survey. This method has been successfully applied by Tchobsala [15] on perennial savannah vegetation in Adamaoua (Cameroon). It consists in delimiting with a string, a surface of 50x50m inside which, an inventory of the vegetation is made following the layons of 10 meters wide and 50 m long, one after the other. 'Other. The experimental setup is a factorial design with the 3 villages as main treatments, the 3 plant formations as secondary treatments and 3 plots of 50x50m in each plant formation as repetition.

On each plot of 50 x 50 m, all woody plants were inventoried. The dendrometric parameters that have been measured are height, diameter at breast height (DBH) for woody trees with a height ≥1.30m and the diameter at the tussock ; the number of woody feet was also counted and counted in number of live and dead feet.

To identify the indices of anthropization of vegetation (pruning, grazing, burning, cuts, diseases), the method of Ouédraogo *et al.* [16] was used. It consists of observing the tracks and counting the number of feet of sick individuals on the total number of individuals in a plot.

Data Analysis Techniques

Ecological profile

The ecological profile was done using species quantification parameters. The concepts used relate to the evaluation of frequency, abundance and dominance. Frequency is the number of individuals of a species over the total number of individuals of all species at a given site. The absolute frequency of a species represents the total number of surveys where the species occurs. According to Braun-Blanquet [17], the relative frequency is the ratio expressed as a percentage between the number of surveys containing this species and the total number of surveys multiplied by 100. RF (%) = (A) / Bx100 with RF (%) = Relative frequency, A = number of treatments containing the species and B = total number of treatments. This proportion or frequency makes it possible to determine the individuals in accidental species, accessory, fairly frequent, frequent and very frequent (Table 1).

Table-1: Frequency index of [17]

Index	Fréquency	Type of species
I	F< 20	Accidentals 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

Abundance refers to the total number of individuals of the species

The abundance of species can be absolute or relative. Relative abundance is the ratio of absolute abundance to the total number of individuals in the community.

Absolute dominance is the ratio of the total basal area of the species (STTe) to the total basal area of the sample (STTE). DA = STTe / STTE.

Relative dominance or relative recovery is the ratio of the total basal area of the species (STTe) to the total basal area of the community (STTC) multiplied by 100 [18].

RD = STTe / STTC x100

The Value of Ecological Importance Index (ESVI) is the sum of relative density, relative frequency and relative recovery. ESVI (%) = FR + DR + DeR with ESVI : Value of Ecological Importance Index, RF : Relative Frequency, RD: Relative Dominance, RDe: Relative Density. To obtain reliable results, we have also calculated the density by species.

Density

The density is given by the formula : D = N / S with N = number of the species of the study medium and S = area occupied by the species. Associate with this, we calculated the basal area of each species.

Basal area

It is given by the formula: Gi = π DH2 / 4 where Gi is the basal surface of species i, DH is the diameter of the species' puff.

Specific diversity and fairness of Piélou

Specific diversity is analyzed using diversity indices [18, 19]. Indeed, several types of mathematical formulas make it possible to calculate these indices. Among them, those that have been chosen and in common use are:

Shannon's index

The Shannon-Weaver Index is an index used to measure biodiversity. This index is an indicator of species richness. It is given by the formula:

$H' = -\Sigma Pi \ln Pi$

H'= Shannon Biodiversity Index;

i = A species from the middle

p (i) = Proportion of a species i relative to the total number of species (S) in the study medium (or specific diversity of the environment) which is calculated as follows:

p (i) = ni / N where ni is the number of individuals of the species and N is the total number of individuals, all species combined [27].

Simpson Index

The Simpson Index is a formula for calculating the probability that two randomly selected individuals in a given environment are of the same species.

$D = \Sigma$ Ni (Ni-1) / N (N-1)

D: Simpson's index;

Ni: Number of individuals of the given species;

N: Total number of individuals.

The index will vary between 0 and 1. The closer it gets to 0, the higher the chances of getting individuals of different species.

Beside these two indices, one can calculate the equilibrium of Pielou (E) which is the inverse of the Shannon index.

Equitability (EQ) of Piélou

The equitability (EQ) of Piélou [26]: EQ = ISH / LOG2N; it corresponds to the ratio between the observed diversity and the maximum possible diversity of the number of N species.

Statistical analysis of the data

The data was processed and analyzed using the Statgraphics plus 5.0 software, which compared data and dendrometric parameters such as height, DBH, and tassel radius. Species densities were analyzed for variance (ANOVA). Excel is used to calculate averages and plot histograms, Xlstat Pro has been used to do principal component analysis (PCA) and Duncan's test for comparing different averages.

RESULTS

Distribution of species, genera and families of different plant formations

The woody inventory conducted in the study area gave the results shown in Table 3. It summarizes the number of families, the number of species per family, the number of genus and the number of individuals. A total of 1264 woody individuals have been inventoried.

They are distributed in 50 species, 38 genera and 18 families (Table 2). The table shows that sacred forests are rich in phytodiversity in Lera, Bipaing and Going respectively with 160, 150 and 155 individuals ; 20; 24; 30 species, 16; 20 and 14 kinds and with 10; 9 and 10 families respectively. Then comes the reforested sites. It shows that sacred forests are more preserved than other plant formations. This could be explained by the justice of conscience devoted to sacred forests for the exploitation of natural resources in the latté.

Table-2: Floristic composition in species, genera, and families of vegetation

	Lera			Going			Bipaing		
Formation of vegetal	AS	ASa	SF	AS	Asa	SF	AS	Asa	SF
Individuals	154	110	160	142	125	150	148	120	155
Species	24	16	20	22	12	24	21	14	30
Genera	18	14	16	15	10	20	18	10	14
Families	11	10	10	12	6	9	13	7	10

AS: afforested savannah; ASa: anthropized savannah; SF: sacred forest

Ecological characterization of species

The analysis of the floristic richness made it possible to identify 48 species in all the sites studied. Table 3 lists the inventoried species, the most common species and important ecological importance. *Anogeissus leiocarpus* (18.08%) has the highest value of ecological importance. Indeed, this species is the most dominant and the most common species encountered in the different vegetation formations of the Sudano-Sahelian zone. The second species characteristic of the Sahelian environment is *Balanites aegyptiaca* with an ecological importance of 16.62%. Then comes *Piliostigma thonningii* with 16.52% of ESVI.

Table-3: Frequency, density, dominance, Ecologically Significant Value Index and number of individuals of the species

Species	Ni	DeR	RF	DR	ESVI	Species	Ni	DeR	RF	RD	ESVI
Acacia ataxacantha	24	1,9	3,37	3,03	8,3	*Ficus thonningii*	22	1,74	1,12	5,23	8,1
Acacia nilotica	40	2,85	3,37	0,49	6,71	*Ficus sspsycomorus*	14	1,11	1,69	6,58	9,37
Acacia seyal	45	3,56	4,49	1,96	10,02	*Grewia barteri*	19	1,5	2,25	0,12	3,87
Acacia tortilis	46	3,64	3,37	0,25	7,26	*Guiera senegalensis*	45	3,56	3,37	0,16	7,09
Acacia albida	24	1,9	3,37	0,49	5,76	*Haematostaphis barteri*	13	1,03	0,56	0,59	2,18
Acacia senegal	53	4,19	2,25	3,18	9,62	*Hexalobus monpetalus*	18	1,42	2,25	0,48	4,15
Andira inermis	18	1,42	1,69	6,35	9,46	*Khaya senegalensis*	17	1,34	1,69	12,74	15,78
Anogeissus leiocarpus	93	6,57	4,49	7,02	18,08	*Maerua angolensis*	13	1,03	1,69	0,01	2,72
Azadirachta indica	36	2,85	3,37	2,56	8,78	*Phyllanthu muellerianus*	1	0,08	0,56	0,24	0,88
Balanites aegyptiaca	13 5	10,6 8	4,49	1,45	16,62	*Piliostigma thonningii tthonningiithonni ngii*	124	9,81	4,49	2,21	16,52
Boswellia dalzielii	11	0,87	0,56	1,44	2,87	*Prosopis africana*	24	1,9	1,69	7,13	10,71
Cadaba farinosa	17	1,34	2,25	0,21	3,8	*Sarcocephalus latifolius*	10	0,79	0,56	3,47	4,83
Capparis fascicularis	29	2,29	3,37	0,28	5,95	*Sclerocarya birrea*	25	1,98	2,25	5,5	9,73
Combretum aculeatum	27	2,14	2,25	0,09	4,47	*senna singuiena*	6	0,47	1,12	0,07	1,66
Combretum sadenogoni um	37	2,93	3,93	0,92	7,78	*Senna arereh*	2	0,16	0,56	0,91	1,63
Combretum glutinosum	36	2,85	3,37	0,38	6,6	*Steganotaenia araliacea*	9	0,71	0,56	0,51	1,79

Table-4: Frequency, density, dominance, Ecologically Significant Value Index and number of individuals of the species (continuation and end)

Species	Ni	DeR	RF	RD	ESVI	Species	Ni	DeR	FR	DR	IVIE
Combretum nigricans	11	0,87	0,56	2,14	3,57	*Sterculia setigera*	1	0,08	0,56	0,11	0,75
Commiphora africana	10	0,79	1,12	0,09	2	*Tamarindus indica*	12	0,95	1,12	3,73	5,81
Detarium senegalensis	36	2,85	1,69	6,54	11,08	*Terminalia glaucescens*	12	1,82	2,81	1,01	5,64
Dichrostachys cinerea	13	1,03	2,25	0,35	3,63	*Vitex doniana*	12	0,32	0,56	0,12	1
Diospyros mespiliformis	39	3,09	2,81	6,13	12,03	*Ximenia americana*	12	1,34	2,25	2,54	6,13
Feretia apodanthera	49	3,8	4,49	0,43	8,72	*Ziziphus mauritiana*	24	2,45	3,37	0,74	6,56
						Total	1264	100	100	100	300

NI = Number of individuals, RF = Relative frequency, RDe = Relative density, RD = Relative dominance, ESVI: Ecological importance value index

Ecological characterization of species according to botanical families

The inventoried species are distributed among 18 families (Table 5). Mimosaceae are the most numerous in family tem with a value of ecological importance of 62.01%. They are followed by Combretaceae and Combretaceae (53.23%) and Césalpiniaceae (46.154%) These three families dominate the entire Sahelian zone of Cameroon.

Table-5: Frequencies, Density, Dominance, Importance Value of Curtis and Number of Individuals and Family Genres

Families	Ng	FR	RDe	RDe	ESVI
Annacardiaceae	1	1,97	2,24	5,50	9,72
Annonaceae	2	2.45	2.80	1.06	6.32
Appiaceae	1	0.71	0.56	0.51	1.78
Balanitaceae	1	10.68	4.49	1.44	16.62
Burseraceae	2	1.66	1.68	1.52	4.87
Caesalpiniaceae	5	15.66	10.67	19.81	46.154
Capparaceae	3	4.76	7.30	0.49	12.46
Combretaceae	4	20.72	20.78	11.71	53.23
Ebenaceae	2	6.01	4.49	11.78	22.28
Euphorbiaceae	1	0.07	0.56	0.24	0.88
Meliaceae	2	4.09	5.05	15.30	24.55
Mimosaceae	3	20.96	24.15	16.88	62.01
Olacaceae	1	1.24	2.24	2.53	6.13
Rhamnaceae	1	2.35	3.37	0.73	6.55
Rubiaceae	2	4.58	5.05	3.90	13.54
Sterculiaceae	1	0.07	0.56	0.11	0.75
Tiliaceae	1	1.60	2.24	0.11	3.86
Verbenaceae	1	0.31	0.56	0.11	0.99
Total	34	100	100	100	300

Ng = Number of genus, RF = Relative frequency, RDe = Relative density, RD = Relative dominance, ESVI = Ecological Value Importance Index

Ecological distribution of plant species in the sites

Calculated frequencies show the horizontal distribution of species in plant formations. The histogram of the frequencies of woody species recorded in the study sites (Figure 2) shows that of the 48 species, 20.46% of the flora have a frequency index equal to I. Some of them are rare. This is the case of the species, *Andira inermis, Ficus sycomorus, Haematostaphis barteri, Lannea microcarpa, Ptercarpus erinaceus, Steganotaenia araliacea, Prosopis africana, Detarium sp, Sterculia setigera, Vitellaria paradoxa, Vitex doniana.* 27.08% of species have a frequency index equal to II.

The species therefore the frequency index is III accounts for 22.73% of the flora of the study sites. 20.46% of the flora has a frequency index equal to IV, represented by *Acacia tortilis, Azadirachta indica, Anogeisus leiocarpus, Combretum adenogonium, Balanites aegyptiaca.*

Very frequent species with a frequency index equal to V are 7 or 14.58% of the inventoried flora. Among them *Acacia seyal, Combretum aculeatum, Combretum glutinosum* each have a percentage of 100%, so appear in at least one time in the surveys.

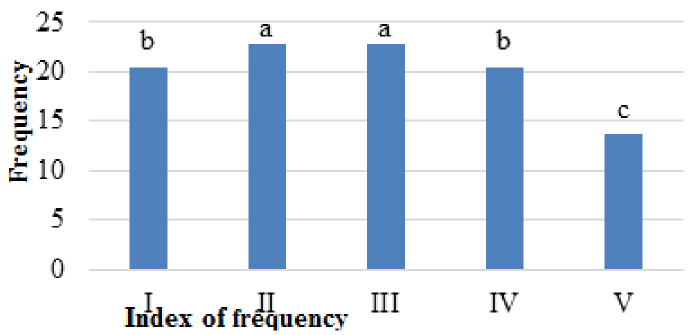


Fig-2: Frequency index

Histograms with the same letters have no significant difference at the 5% threshold.

Shannon Diversity Indices and Piélou Fairness

The Shannon diversity index is higher in the sacred forests of the three villages : Lera (3,293), Going (3,13) and Bipaing (3,196) as shown in Table 7. The same is true for the Pielou equitability which is higher in the sacred forests: 0.359, 0.377 and 0.366 respectively for Going, Lera and Bipaing whereas it is lower in the anthropized savannas: Going (0.299), Lera (0.259) and Bipaing (0.283). This means that plant biodiversity is less dense in anthropized savannas compared to sacred forests and reforested sites: Going (ISH = 2.963 and EQ = 0.34), Lera (ISH = 3.17 and EQ = 0.363) and Bipaing (ISH = 3.052 and EQ = 0.349).

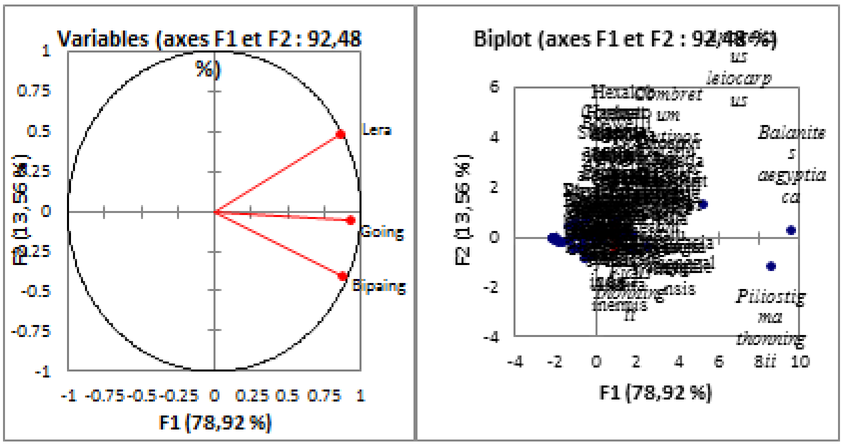
Table-6: Shannon index (ISH), its inverse (D) and equitability of Piélou (EQ)

Villages	Formation of vegetal	ISH	EQ	D
GOING	RS	2.963	0.34	4.451
	AS	2.609	0.299	5.056
	SF	3.13	0.359	4.213
LERA	RS	3.17	0.363	4.104
	AS	2.264	0.259	5.745
	SF	3.293	0.377	3.950
BIPAING	RS	3.052	0.349	4.270
	AS	2.475	0.283	5.267
	SF	3.196	0.366	4.077

RS = Reforested site; AS = Anthropised Savannah; SF = Sacred forest, ISH = Shannon index, EQ = Piélou equitability

Analysis of variables in principal component according to the density

The principal component variable (PCA) analysis shows that the three (03) villages are positively correlated with each other and the different species are also positively correlated with each other (Figure 3a). Species such as Anogeissus leiocarpus, Balanites aegyptiaca, Piliostigma thonningii and Combretum spp. are the most represented (Figure 3b). The species dispersed in this figure are very dense which we have more chance to meet them in all the study sites. The other species that are less represented form clouds around the two (axes f1 and f2: 92.48%). The species represented as point clouds are less dense and can not be found anywhere in the study sites. Ecologically, these species are accidental in the different sites.



A- Correlation between villages B-Dispersion of species

Fig-3: Woody species dispersion

State of vegetation according to the villages

Figure 5 shows the state of dead and living species in the plant formations of the three villages. The living feet present a very high number in each village: 285,289 and 287 respectively for Going, Lera and Bipaing. Dead individuals are a minority but the numbers are worrying in each village: Going (44), Lera (49) and Bipaing (46).

Nomber of individuals

Living exit living exit living exit

Fig- 4: vegetation status

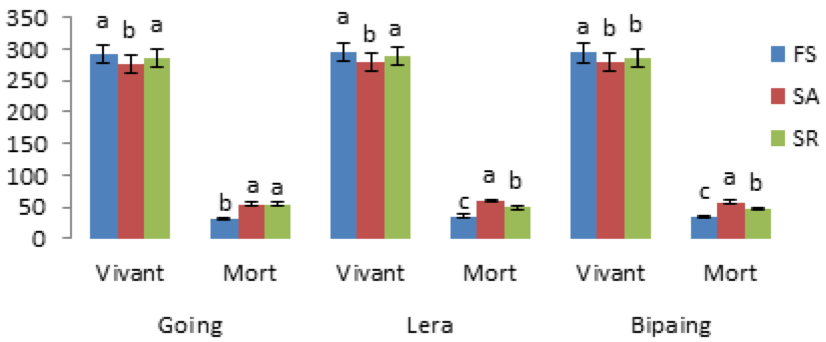
Histograms with the same letters have no significant difference at the 5% threshold.

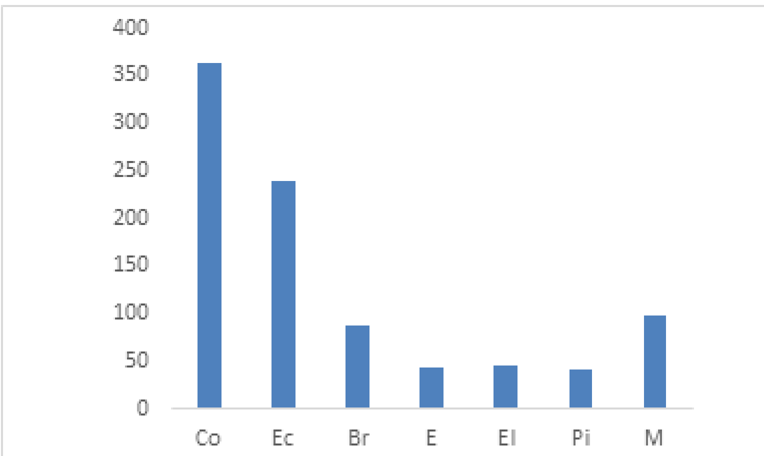
Index of vulnerability of species in different plant formations

Cutting and skinning are the most common on the vegetation in study area 364 and 239 respectively (table 9). These traces are more represented in the anthropized savannas. The woodcutting (364) could be explained by the need for firewood and skinning (239) has its origin in the importance given to traditional medicine.

In the locality of study. This result justifies the strong anthropic pressure in these villages and in these plant formations.

Table 9: anthropisatio index





Co = Sections ; Ec = skinning; Br = Brulure; E = Emondage; El = pruning; Pi = Trampling; M = Illness, T = Totals

Overexploitation of biodiversity by the local population

The cutting of wood for the energy source, the intensification of agriculture, the traditional pharmacopoeia, the construction of traditional houses and the marketing of wood are responsible for the loss of species in plant formations. The overexploited species are threatened with extinction in the district of Kaélé and its surroundings.

Although peasants have a good command of over-exploited species, the frequency of overexploited species varies according to the villages and species exploited (Table 7). The average frequency of species ranges from 3.33% in Combretum adenogonium to 64.17% in Anogeissus leiocarpus. This overexploitation is due to the fact that these species are very much in demand by the population in this area of study. This observed variability is very significant between species. While between villages there is not a significant difference.

Table-7: Over-exploited species

Species	Going	Lera	Bipaing	average/Ecartyp
Anogeissus leiocarpus	65	67,5	60	64,17±3,81^{a}
Balanites aegyptiaca	67,5	60	60	62,50±4,33^{a}
Sclerocarya birrea	67,5	60	55	60,83±6,29^{a}
Acacia albida	50	45	37,5	44,17±6,29^{b}
Khaya senegalensis	40	47,5	30	39,17±8,77^{bc}
Andira inermis	35	40	27,5	34,17±6,29^{cd}
Boswellia dalzielii	37,5	30	25	30,83±6,29^{de}
Steganotaenia araliacea	32,5	25	20	25,83±6,29^{ef}
Annona senegalensis	25	30	20	25,00±5^{ef}
Parkia biglobosa	22,5	27,5	20	23,33±3,81^{ef}
Combretum nigricans	22,5	20	25	22,50±2,5^{f}

Table-8 : Over-exploited species (follow-up and end)

Species	Going	Lera	Bipaing	Average/Ecartype
Grewia barteri	25	17,5	22,5	21,67±3,81^{fg}
Detarium senegalensis	27,5	20	15	20,83±6,29^{fg}
Prosopis africana	17,5	10	15	14,17±3,81^{gh}
Diospyros mespiliformis	15	5	12,5	10,83±5,2^{hi}
Piliostigma thonningii	12,5	7,5	10	10,00±2,5^{hi}
Stereospermum kunthianum	10	5	12,5	9,17±3,81^{hi}
Sterculia setigera	7,5	5	5	5,83±1,44^{i}
Sarcocephalus latifolius	5	2,5	5	4,17±1,44^{i}
Average/Ecartyp	26,54±18,63^{a}	23,56±19,21^{a}	21,54±15,81^{ab}	23,88±17,88$^{f}_{a}$

Figures with the same letters do not differ significantly at the 5% level

Threatened woody species according to local populations

Table 9 presents the most endangered plant species in the study area. This table shows that *Anogeissus leiocarpus* (55 ± 10%), *Sclerocarya birrea* (50.83 ± 9.46%), *Balanites aegyptiaca* (47.50 ± 6.61%) and *Detariuum senegalensis* (45 ± 13.91%) are respectively the most endangered ligneous.

Table-9: Most threatened plant species by village (%)

Species	Going	Lera	Bipaing	Averagee/Ecartyp
Anogeissus leiocarpus	65	45	55	55,00±10^{a}
Balanites aegyptiaca	40	52,5	50	47,50±6,61^{a}
Boswellia dalzielii	47,5	50	35	44,17±8,03^{ab}
Detarium senegalensis	30	57,5	47,5	45,00±13,91^{ab}
Piliostigma thonningii	55	37,5	37,5	43,33±10,1^{ab}
Prosopis africana	37,5	25	22,5	28,33±8,03^{b}
Sclerocarya birrea	57,5	55	40	50,83±9,46^{a}
Average/Ecartyp	47,50±12,41^{a}	46,07±11,44^{a}	41,07±10,88^{b}	44,88±11,57$^{a}_{a}$

Figures with the same letters do not show a significant difference at the 0.05 level.

Consequences of human activities on the environment

According to our results from surveys of local populations, the decline in non-timber forest products (87.5 ± 6.61%), the increase in temperature (80 ± 5%), the degradation of ecosystems (69, 17 ± 5.20%) and the decrease in agricultural yields (45 ± 10%) are respectively the most cited consequences of the vulnerability of plant biodiversity to the environment (Table 10).

Table-10: Consequences of Plant Species Vulnerability (%)

Consequencies	Lera	Bipaing	Going	Average/Ecartyp
Decrease in NWFPs	85	82.5	95	87,5±6,61^{a}
Temperature increase	75	80	85	80,00±5^{ab}
Installation of the desert	67.5	75	65	69,17±5,20^{b}
Farm yield fuck	35	55	45	45,00±10^{c}
Drop in rainfall	25	37.5	30	30,83±6,29^{d}
Loss of biodiversity	20	35	15	23,33±10,40^{d}
Average/Ecartyp	51,25±25,48^{a}	60,83±23,3^{b}	55,83±25,13^{a}	55,97±24,63$^{e}_{a}$

Affected values of the same letter do not differ significantly at the 5% threshold

In general, the degradation begins with an alteration of the vegetation. Then, the vegetation cover clears up, the production of biomass decreases.

Fig-5: Degradation of the soil

Woody decline by years in the three study villages

Due to an irrational exploitation of the woody cover, a good part of the population begins to perceive the disappearance of the ligneous vegetation cover. This finding is reflected in the natural resource removal distance that has evolved significantly in recent decades compared to the Far-North region in general (Table 11). It goes from 1986 to 2016 from 1.5Km to 15Km, 0.5Km to 13Km and 1Km to 16Km respectively for Lera, Bipaing and Going. This growing trend in natural resource removal distances confirms the high exploitation of plant-based resources.

Table-11: Evolution of removal distances of natural resources in the study area

Years	Lera	Bipaing	Going
1986	1.5Km	0.5Km	1Km
1996	5Km	3Km	4Km
2006	10Km	8Km	10Km
2016	15Km	13Km	16Km

DISCUSSION

This study made it possible to determine the anthropogenic impact on the vulnerability of plant biodiversity in the Sudano-Sahelian zone of Cameroon. The results obtained in this study are similar to those of Ntoupka[20] in the Laf Forest Reserve in Cameroon, located in the same agro-ecological zone (53 woody species inventoried). They are however far from those of Sandjong *et al.* [20] in the Mozogo-Gokoro National Park which identified 62 woody species and Dimobé *et al.* [21] in the Oti-Mandouri Reserve in northern Togo (116 species). The differences observed in the Mozogo-Gokoro National Park (yet located in the same agro-ecological zone) are due to the disparity of the texture of the soil in the two sites. Indeed, the soils of Mozogo - Gokoro have a sandy-loamy texture very favorable to vegetable production. On the other hand, the number of species in the Oti-Mandouri Reserve is twice as high as in Lara. This can be explained by the fact that the Oti-Mandouri Reserve is located in an area less subject to degradation factors than the locality of Lara. The most common species are *: Balanites aegyptiaca* with 135 individuals and the relative frequency of 4.49% followed by *Piliostigma thonningii* with 124 individuals inventoried with a relative frequency of 4.49% followed by *Anogeissus leiocarpus* with 93 feet. These results are similar to those obtained by Evaliste *et al.* [22] in the Waza National Park. The majority of genres are mono specific. Only four of them are represented by at least two species. Acacia is the most diverse genus with 6 species that are *Acacia albida, Acacia ataxacantha, Acacia nilotica, Acaci senegal, Acacia seyal* and *Acacia tortillis,* among others. It is followed by the combretum and senna genera, which each have 4 and 2 species respectively. These results show that species of the genera Acacia, Combretum and Senna are more suitable in the locality of Lara. These results are contrary to those of Tchobsala *et al*. [11].

Of the 48 species, 20.46% of the flora have a frequency index equal to I. Some of them are rare. This is the case of the species, *Andira inermis, Ficus sycomorus, Haematostaphis barteri, Lannea microcarpa, Ptercarpus erinaceus, Steganotaenia araliacea, Prosopis africana, Detarium sp., Sterculia setigera, Vitellaria paradoxa, Vitex doniana*. 27.08% of species have a frequency index equal to II.

The species therefore the frequency index is III accounts for 22.73% of the flora of the study sites. 20.46% of the flora has a frequency index equal to IV, represented by *Acacia tortilis, Azadirachta indica, Anogeisus leiocarpus, Combretum adenogonium, Balanites aegyptiaca.*

Very frequent species with a frequency index equal to V are 7 or 14.58% of the inventoried flora. Of these, *Acacia seyal*, *Combretum aculeatum, Combretum glutinosum* each have a percentage of 100%, so appear in at least one time in the surveys. Tchobsala [11] in his work on the peri-urban savannah of Ngaoundere showed that the vegetation consists of 37.67% of the species with index of frequency I, 28% of species with an index equal to II, 23.18% with index equal to III, 6.63% of species of frequency equal to IV and 3.52% with frequency equal to V. This structure of the flora presents a homogeneity of the medium which would be due to the contribution of the reforestation and the setting in defense of reforested sites.

The Shannon diversity index is higher in the sacred forests of the three villages : Lera (3,293), Going (3,13) and Bipaing (3,196) as shown in Table 7. The same is true for the Pielou equilibrium which is higher in the sacred forests : 0.359, 0.377 and 0.366 respectively of Going, Lera and Bipaing whereas it is lower in the anthropized savannas of Going (0.299), Lera (0.259) and Bipaing (0.283).). This means that plant biodiversity is less dense in anthropized savannas compared to sacred forests and reforested sites : Going (ISH = 2.963 and EQ = 0.34), Lera (ISH = 3.17 and EQ = 0.363) and Bipaing (ISH = 3.052 and EQ = 0.349).The low Shannon diversity and the Piélou equitability indices obtained in the anthropized savannas are due to anthropogenic pressures on these terrestrial ecosystems. This result is different from that of Tchobsala in 2011 which found almost equal values in these different plant formations. The diversity index (Shannon) is high in sacred forests, with a value relatively close to that found by Sandjong *et al.* [20] in the Mozogo-Gokoro National Park and that obtained by Evaliste *et al.* [22] in the Waza National Park. This shows that the disturbances, although visible in this plant formation, did not have a strong influence on the ligneous diversity, and that one is in the presence of relatively old, mature and structured stands. In the anthropized savanna, however, this index of diversity is weak ; which shows the strong disturbance of the environment, with the consequent disappearance of the plant species.

When we evaluate the homogeneity or heterogeneity of the different plant formations in the different study villages by the Jaccard test (Table 7), the floristic difference is strong between the anthropized savannah and the sacred forest of the three villages : Lera (19,35), Going (16,22) and Bipaing (12.50). This could be explained by the strong anthropogenic pressure on the savannah and moreover the sacred forests are generally located at the edge of the watercourse, so that the species found there grow a little faster. In addition, there is a not very significant floristic difference between the reforested savanna and the sacred forest in the villages : Lera (26.83), Going (26.09) and Bipaing (29.73). This could be explained by the little measures taken to reforested sites. These results are in agreement with those of Ntoupka [13] in the Sudano-Sahelian zone which showed that the Hamming distances between the different plant formations are unevenly varied.

Cutting and skinning are the most common on the vegetation in Study Area 364 and 239 respectively (Table 10). These traces are more represented in the anthropized savannas. The woodcutting (364) could be explained by the need for firewood and skinning (239) has its origin in the importance given to traditional medicine in the locality of study. This result justifies the strong anthropic pressure in these villages and in these plant formations. These results are similar to those of Tchobsala *et al*. [15].

Although peasants have a good command of over-exploited species, the frequency of overexploited species varies according to the villages and species exploited (Table 11). The average frequency of species ranges from 3.33% in Combretum adenogonium to 64.17% in Anogeissus leiocarpus. This overexploitation is due to the fact that these species are very much in demand by the population in this area of study. This observed variability is very significant between species. While between villages there is not a significant difference. The analysis of variance shows that there is not a very significant difference between the villages (P>0,05) but between the overexploited species, there is a highly significant difference (0,001<0,05). These results are in agreement with those of Wouldata [23] on the situation of NTFPs of plant origin in the Sahelian zone of Cameroon but are different from that of Tchobsala [11] who found instead the species *Syzygium guineense* spp, Vitellaria paradoxa and Parkia biglobosa, as the most used in food, pharmacopoeia, service and fodder.

According to the results of surveys of local populations, the decline in non-timber forest products (87.5 ± 6.61%), the increase in temperature (80 ± 5%), the degradation of ecosystems (69, 17 ± 5.20%) and the decrease in agricultural yields (45 ± 10%) are respectively the most cited as consequences of the vulnerability of plant biodiversity to the environment. The analysis of variance shows that there is not a very significant difference between the villages (P>0,05) but between the threatened species, there is a highly significant difference (0,001<0,05). These results are similar to those of Serge [24].

Due to an irrational exploitation of the woody cover, a good part of the population begins to perceive the disappearance of the ligneous vegetation cover. This finding is reflected in the natural resource removal distance that has evolved significantly in recent decades compared to the Far-North region in general (Table 11). It goes from 1986 to 2016 from 1.5Km to 15Km, 0.5Km to 13Km and 1Km to 16Km respectively for Lera, Bipaing and Going. This growing trend in natural resource removal distances confirms the high exploitation of plant-based resources. These results corroborate those of Dobie [25] who showed that logging increases with land degradation and decreased productivity.

Threats to these species are believed to be due to anthropogenic pressures for different uses. This result is different from that of Tchobsala [11] who cites Hymenocardia acida as the most endangered species following exploitation. Dead individuals are a minority but the numbers are worrying in each village : Going (44), Lera (49) and Bipaing (46). This result is similar to Ouédraogo *et al*. [20] who showed that the number of dead feet is worrying in Burkina Faso.

CONCLUSION

At the end of this work, we can present the impact of human activities on the vulnerability of plant biodiversity in the Sudano-Sahelian zone of Cameroon. The fundamental question of this research revolved around the determination of the consequences of human activities on plant biodiversity. At the end of our various investigations, several causes of the vulnerability of plant biodiversity were identified, the most important of which are among others : agriculture (94.17%), livestock (85.00%) and strong demand firewood (74.17%). In terms of the environment, we note the degradation and the decline of vegetation cover in tree and shrub savannas (floristic richness and low diversity indices). There is also a decline in non-timber and wood forest products, uneven distribution of vegetation in the study area, heterogeneity of vegetation, and the health status of vegetation threatening the disappearance of plant biodiversity *(Anogeissus leiocarpus, Sclerocarya birrea* and *Balanites aegyptiaca*). The ecological balance is at the center of all questions and questions related to natural resources. At a time when activities are related to the natural physical environment, it is important to ask ourselves the problem of the exploitation of natural resources, and their consequences on this natural environment. Finally, demographic pressure and climatic variations also have a direct or indirect influence on plant biodiversity. Natural resources require sound and rational control over their exploitation and management. They are fragile when they are exploited at an accelerated rate, especially those taken from the natural physical environment, and strong pressure can lead to ecological imbalance.

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