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Research paper

Floristic diversity, plant structure and physico-chemical properties of soils of Masgaya forest massif in Sudano-sahelian zone of Cameroon

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ABSTRACT The study examined the diversity of woody vegetation and the characterization of physico-chemical properties of the soils of Masgaya forest massif in the Sudano-sahelian zone of Cameroon. The floristic inventory design consisted of four collection units (CU) established in the forest massif. In each CU, twelve plots of 10,000 m^2 each were installed and woody individuals were inventoried. Specimens of soils were collected at 0-25 cm depth at the four corners and the center of each CU. Statistical analyses were performed with XLSTAT Software. A total of 6,465 stems were recorded, representing 64 species grouped in 46 genera and 29 families. The Shannon diversity index (H') varied from 3.00 to 3.20 bits, and Pielou evenness index (EQ) from 0.41 to 0.51. The density varied from 138.08±37.10 to 265.75±70.06 stems/ha and the basal area from 275.88±120.39 to 544.62±240.1 m^2/ha. Results of physico-chemical properties of the soils showed a predominance of sandy fractions over clay fractions, and high values of organic matter and total nitrogen. The analysis of the different parameters revealed a trend for vegetation to deteriorate under anthropogenic actions. The outcomes of this study can be used to develop forest management strategies to ensure sustainable development in this ecoregion.

KEYWORDS: Cameroon, soils, vegetation.

Introduction

In the terrestrial globe, the balance of the ecosystem is ensured by vegetation which is considered as the main biotic element in the nature (Larwanou et al. 2006). Soils are the memory of the parent rock which conditions drainage, withdrawal, waterlogging, fertility and mineralization (Pomel 2008). They also maintain a reciprocal action with the vegetation because it provides them with organic matter. Soil nitrogen and phosphorus content are important components of organic matter produced by plant photosynthesis (Fu et al. 2019). The mineralization of organic matter of soils constitutes a potential source of nitrogen and phosphorus, improves seed germination, and initializes the development and the potentiality of roots to absorb the nutrients (Feller et al. 2003). Thanks to the protection provided by the soil against erosion and solar alteration, the vegetation maintains its fertility and water retention. However, after the major modifications that the plant stands of the planet have undergone over geological time, they are nowadays experiencing a regression in their surface area (Rindfuss et al. 2008) due to natural phenomena and especially to anthropogenic activities. These activities have definite impacts on soil constitution by leading to the loss of organic matter, the availability of nitrates and some physical modifications such as density, structure and porosity (Arouna et al. 2011). Given the fragmentation of forest landscapes resulting from these different activities leading to a degradation of plant biodiversity (Bamba et al. 2010, Sanou et al. 2019, Zampaligre et al. 2019a, Zida et al. 2020), particular attention is committed to the conservation of these ecosystems by the scientific community and decision-makers. In intertropical Africa, millions of people are dependent on savannah ecosystems for their daily needs (Dieng et al. 2016). In the sahelian environment in particular, livestock products, food and wild plants constitute the primary sources of survival and financial incomes for local populations. The impact of human activities is very strongly determining in the dynamics of phytodiversity through local practices on natural resources (Lykke 1998). It imposes a transformation of ecosystems which increases at the rate of population growth. The structure of tree species diversity in the ecosystems varies greatly from place to place due to variations of nature of soils and intensity of disturbances. In Cameroon, the pressure on biodiversity in general and plant resources in particular appears increasingly strong. These natural resources are exploited to meet the needs of populations for food, wood energy, wood for services, and for pastures.

The Far North region located in the Sudano-sahelian zone of Cameroon records an annual demographic growth rate of 3%. This demographic growth pushes the populations to exert ever-increasing pressure on the functioning of natural forests (Mapongmetsem and Laissou 2011) due to intensification of anthropogenic activities, especially in the distribution zone of pastoralists and farmers. The area of arable lands per inhabitant has decreased considerably, and the major facts are extensive agriculture and the search for new fertile lands. These factors cause a serious threat to ecosystem resources and lead to the depletion of the plant species (Bakoulou et al. 2020). In dry regions, soil carbon content is low, due to anthropogenic and natural factors (Tsozue et al. 2021), and the loss of soil organic carbon

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or soil organic matter results in a loss of soil quality. The Masgaya forest massif belonging to this part of the Sudano-sahelian zone does not escape the threats of anthropogenic actions of the populations. The plant cover of this massif is in depletion due to these pressures. According to Melom et al. (2015), knowledge of the phytodiversity of a given area is an essential tool to support sustainable management policies. Also, many plants are not well-adapted to extremely acidic or alkaline soils, resulting in lower floristic diversity because of poor nutrient availability (Palpurina et al. 2017). It is within this framework that the present study was carried out, which aimed at characterizing the woody vegetation and soils of the Masgaya forest massif with a view to contribute to the sustainable management of plant resources in the Sudano-sahelian zone of Cameroon. The survey was conducted specifically to:

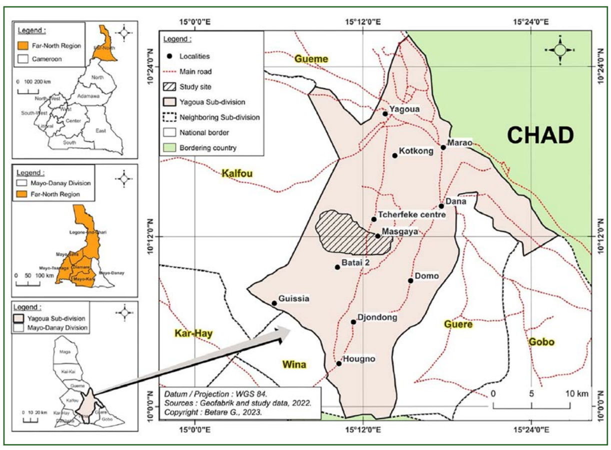
(i) assess the floristic diversity and plant structure of Masgaya forest massif;
(ii) determine the soil physico-chemical properties of Masgaya forest massif.

Materials and methods

Study site

The study was carried out in the Masgaya forest massif in the Sudano-sahelian zone of Cameroon. It covers an area of 1,600 ha and is situated between 10°0'0'' to 10°24'0''N of latitude and 15°0'0'' to 15°24'0''E of longitude and with an altitude of 300 m (Fig. 1). The annual average of rainfall is 800 mm with a short rainy season (June-August) and a long dry season (September-May), and the temperature fluctuates between 20°C and 30°C (Suchel 1987). Clayey soils or vertisols, ferrugineous soils or sesquioxide soils, halomorphic soils and hydromorphic soils are the most represented soils in the area (Sieffermann and Vallerie 1963). The vegetation is made up of *Terminalia avicennioides* Guill. & Perr., *Guiera senegalensis* J.F. Gmel., *Detarium microcarpum* Guill. & Perr., *Faidherbia albida* (Delile) A.Chev., *Strychnos spinosa* Lam., *Prosopis Africana* (Guill. & Perr.) Taub., *Parkia biglobosa* (Jacq.) R. Br. ex G. Don, *Balanites aegyptiaca* (L.) Del., *Ziziphus mauritiana* Lam., *Aristida hordacea* Kunth, *Hypparhenia rufa* (Nees) Stapf, *Sporobolus pyramidalis* P. Beauv., *Cymbopogon giganteus* Spreng., *Echinochloa stagnina* (Retz.) P. Beauv. (Sieffermann and Vallerie 1963, Letouzey 1985, Bakoulou et al. 2021). The relief is a plain, offering a panoramic view of a landscape of steppes and savannahs.

Figure 1 - Map of location of the study site.



Methods

Data collection

Assessment of the floristic diversity and plant structure of Masgaya forest massif

Experimental design

The inventory method is based on plots developed by (Picard et al. 2010). The entire forest massif was divided into four (04) collection units (CU) (Souare et al. 2020a, b) constituting the treatments. In each collection unit, twelve (12) plots of 10,000 m^2 each (40 m * 250 m) which constituted the replications were established, making a total area of 48 ha. The space between two plots were 200 m. In each plot, all woody individuals with a diameter at breast height (dbh) ≥ 5 cm at 1.30 m above the ground were inventoried (Jiagho et al. 2016) and identified by their scientific and local names. For individuals that plug in before 1.30 m in height, their diameters were measured at 10 cm above the ground (Jiagho et al. 2016, Souare et al. 2020a). The height of individuals was estimated using a graduated pole and the diameter a measuring tape. Identification of the species was done with the help of "Flora of West tropical Africa" (Tailfer 1990), the different volumes of "Flora of Cameroon" (Letouzey 1985), and by using APG IV classification system.

Determination of the soil physico-chemical properties of Masgaya forest massif

The soil sampling method used in this study was inspired from Baiyabe II (2020). Soil specimens were taken at a depth of 0 - 25 cm from the ground. During sampling, five samples of soil were taken using picks and machetes at the four corners of each collection unit and one at the center. The mixture of these five samples (P1, P2, P3, P4 and P5) constitutes a sample for a collection unit.

Data processing and analysis

Diversity indices

Diversity tree species were assessed with Shannon-Weaver diversity index (H') (Magurran 2004) and Pielou's Evenness index (EQ).

H' = - ΣNi/N $\log_2$Ni/N, where H' = Shannon-Weaver diversity index, Ni = number of individuals of a given species i, N = total number of individuals, $\log_2$ = logarithm in basis 2.

EQ = H'/$\log_2$N, this index varies from 0 to 1.

Importance value index

To describe the ecological importance of species and families within each collection unit as well as for the whole flora, the species importance value index (IVI) and the family importance value (FIV) (Mori et al. 1983), were also calculated:

IVI = relative density + relative frequency + relative dominance

Relative dominance = (basal area of a species/basal area of all the species) x 100

Relative density = (Number of individuals of a species (N*i*)/total number of individuals of all species (N)) × 100

Relative frequency = (Frequency of a species/sum of all frequencies) × 100

Basal area (BA) = $\sum_{i}^{s}(\pi D^2/_4)$, where D: diameter at breast height (cm); π: 3.141593; BA: basal area (Souare et al. 2020b).

For sarmenting species, the average circumference was calculated by the following formula:

$$Cm=\sqrt{\sum_{t=1}^{n}(Ci)^2}$$ (Todou et al. 2017).

Where Cm is the average circumference of stems; C*i* is the circumference of a stem.

FIV = family relative diversity + relative density + relative dominance.

All the statistical analyses and principal component analysis (PCA) were performed with XLSTAT software 2019. The Vegan package developed by Oksanen et al. (2010) was used to calculate diversity indices and analysis of variance (ANOVA) was used to compare the means of physic-chemical properties of soils in different collection units.

Results

Floristic diversity of woody species in Masgaya forest massif

A total number of 6,465 stems of dbh ≥ 5 cm were recorded within the four collection units (CU) (Tab. 1), representing sixty-four (64) species grouped in fourty-six (46) genera and nineteen (19) families. The number of species per collection unit varied from forty-five (45) to fifty-six (56). That number was higher in CU_1 (n = 56) located in the western part of the massif forest, and lower in CU_4 (n = 45) in its eastern part. The Shannon-Weaver diversity index (H') values varied from 3 to 3.3 bits, and Pielou's evenness index (EQ) from 0.41 to 0.51. For the whole collection units, they were 3.25 bits and 0.47 respectively. Mean diversity measures differed significantly between the collection units (One-Way ANOVA, p = 0.02).

Structural parameters: basal area and density

The basal area varied from 275.88±120.39 m^2/ha to 544.62±240.1 m^2/ha (Tab. 2). The higher value was found in CU_1 (544.62±240 m^2/ha) and the lower value in CU_2 (275.88±120.39 m^2/ha). The value was moderate in CU_3 and CU_4 (380.64±72.71 m^2/ha; 383.98±77.07 m^2/ha respectively). Mean basal areas differed significantly between collection units (ANOVA, p = 0.005). The density varied from 138.08±37.10 stems/ha to 265.75±70.06 stems/ha (Tab. 2). The lower values were found in CU_2 and CU_3 (179.58±55 stems/ha; 192.08±40 stems/ha respectively). The value was moderate in CU_4 (138.08±37 stems/ha), and the higher in CU_1 (265.75±70 stems/ha). Mean density measures differed significantly between collection units (ANOVA, p = 0.005).

Species importance value index (IVI) and Family importance value index (FIV)

The output of species importance value index (IVI) analysis showed that *Balanites aegyptiaca* (29.50); *Combretum glutinosum* (21.10); *Combretum molle* (18.31); *Prosopis africana* (17.20) and *Combretum collinum* (17.10) were the five most important species (Tab. 3). These species represented 34.63% of the total importance value index, while the majority of the species (82.81%) had IVI of less than 10. The families containing these species with higher IVI were *Combretaceae* (9 species) and *Fabaceae*

Table 1 - Floristic composition and diversity of woody species in Masgaya forest massif.

Collection units (CU)	Species	Genera	Families	Number of stems (n)	H' (bits)	EQ
CU_1	56	43	19	2,524	3.30	0.41
CU_2	47	38	16	1,341	3.02	0.44
CU_3	48	39	18	1,480	3.20	0.51
CU_4	45	36	16	1,120	3.00	0.45
Total	64	46	19	6,465	3.25	0.47

CU: collection unit; H': Shannon-Weaver diversity index; EQ: Pielou's evenness index.

Table 2 - Basal area and density in the collection units.

Structural parameters	Collection units			
	CU_1	CU_2	CU_3	CU_4
Basal area (m^2/ha)	544.2±240.1^a	275.88±120.39^b	380.64±72,71^b	383.98±77.07^b
Density (stems/ha)	265.75±70.06^a	179.58±55.16b^c	192.08±40,62^b	138.08±37.10^c

CU: collection unit; values shown are means ± SD; within lines, means followed by different letters are significantly different (p < 0.05).

Table 3 - Importance value index (IVI) of the five most important species (in bold) of each collection unit, and global IVI for all four collection units.

Species	Global	IVI			
	IVI	CU_1	CU_2	CU_3	CU_4
Acacia ataxacantha DC.	1.70	3.64	0.80	2.76	0.79
Acacia gerrardii Benth.	1.19	1.01	1.73		
Acacia seyal Del.	1.30	2.00	1.00		0.78
Acacia sieberiana DC.	2.10	0.86			4.14
Amblygonocarpus andongensis (Oliv.) Exell et Torre	1.20	1.84		0.55	
Annona senegalensis Pers.	0.50	0.35	0.41	0.85	
Anogeissus leiocarpa (DC.) Guill. & Perr.	14.20	17.67	14.13	11.73	11.82
Balanites aegyptiaca (L.) Del.	**29.50**	**26.56**	**21.57**	**35.52**	**40.26**
Bombax costatum Pellegr. & Vuillet	4.09	1.83	5.95	3.50	5.08
Boscia senegalensis (Pers.) Lam. ex Poir.	0.40	0.70	0.40		
Bridelia ferruginea Benth.	0.70		0.99		
Bridelia scleroneura Müll. Arg.	0.91		1.37	0.95	0.49
Cadaba farinosa Forssk.	1.50	2.49	1.46	1.63	0.99
Capparis facicularis Dc.	0.20	0.35			
Capparis sepiaria L.	4.50	3.83	2.23	5.54	4.78
Combretum aculeatum Vent.	1.50	1.24	1.19	1.81	
Combretum collinum Fres.	**17.10**	**13.26**	**22.81**	**13.65**	**24.82**
Combretum fragrans Steud. ex A. Rich.	3.50	1.70	1.76	1.26	8.38
Combretum glutinosum Perr. ex DC.	**21.10**	**24.62**	**28.10**	**22.22**	**22.95**
Combretum micranthum G. Don.	2.50	3.30			
Combretum molle R. Br. ex G. Don	**18.31**	**11.27**	**26.64**	**22.94**	**28.47**
Commiphora pedunculata (Kotschy & Peyr.) Engl.	3.40	2.49	5.96	2.75	2.28
Crossopteryx febrifuga (Afzel. ex G. Don) Benth.	4.50	2.28	3.47	11.25	0.53
Daniellia oliveri (Rolfe) Hutchinson & Dalziel	0.70	0.84			
Detarium microcarpum Guill. & Perr.	7.32	9.58	12.20	11.42	1.02
Dichrostachys cinerea (L.) Wight & Arn.	1.16	1.52	0.81		
Entada africana Guill. & Perr.	2.03	2.70	3.46	3.93	1.25
Feretia apodanthera Del.	4.50	6.19	5.57	8.89	0.50
Ficus platyphylla Del.	1.75				2.74
Ficus thonningii Blume	1.90	1.08			2.43
Ficus vogelii (Miq.) Miq.	1.70	1.24		2.06	
Flueggea virosa (Roxb. ex Willd.) Voigt	1.40	2.69		0.39	0.99
Gardenia erebuscens Stapf & Hutch.	0.60			0.96	0.60
Gardenia ternifolia Schum.. & Thonn.	0.70	0.71	0.41	0.81	
Guiera senegalensis J.F. Gmel.	14.50	24.63	13.99	12.45	12.08
Hexalobus monopetalus (A. Rich.) Engl. & Diels	10.40	24.07	10.67	12.02	3.58
Hymenocardia acida Tul.	3.20	3.58	4.43	4.93	3.57
Lannea fruticosa (Hochst ex A. Rich.) Engl.	3.50	2.38		6.67	2.82
Lannea microcarpa Engl. & K. Krause	5.70	7.11	7.14	2.79	
Lonchocarpus laxiflorus Guill. & Perr.	4.70	4.44	2.22		5.22
Maerua angolensis DC.	3.21	1.88	2.25	4.60	2.11
Maytenus senegalensis (Lam.) Exell	0.25	0.35		0.39	
Pachystela brevipes (Baker) Adolf Engl.	1.40	0.86	1.79		
Parkia biglobosa (Jacq.) R. Br. ex G. Don	0.50			0.40	1.16
Piliostigma reticulatum (DC.) Hochst	4.20	5.04	3.35	2.88	6.50
Piliostigma thonningii (Schum.) Milne-Redhead	0.70			0.85	
Prosopis africana (Guill. & Perr.) Taub.	**17.20**	**26.11**	**19.78**	**14.90**	**14.15**
Pterocarpus erinaceus Poir.	0.80	0.50	1.19	1.82	0.50
Sclerocarya birrea (A. Rich.) Hochst	10.10	5.10	10.54	7.57	13.79
Securidaca longipedunculata Fres.	4.02	2.47	4.26	5.44	4.12
Senna singueana (Del.) Lock	1.45	1.23	1.22	2.00	1.50
Sterculia setigera Del.	16.02	15.69	11.75	14.51	24.85
Stereospermum kunthianum Cham.	0.60	0.80	0.79		
Strychnos innocua Del.	0.30		0.41		0.50
Strychnos spinosa Lam.	6.90	4.51	7.83	5.31	9.51
Swartzia madagascariensis Desv.	1.40		1.54		
Tamarindus indica L.	1.30	1.31	0.78	0.42	2.48
Terminalia avicennioides Guill. & Perr.	10.52	4.40	13.28	17.81	6.44
Vitellaria paradaxa Gaertn. f.	1.30	1.71		0.42	1.64
Vitex simplicifolia Oliv.	7.22	1.22	11.93	6.95	4.80
Ximenia americana L.	1.70	3.22		2.06	
Ziziphus abyssinica Hochst. ex A. Rich.	2.25	2.15	1.27	1.86	6.22
Ziziphus mauritiana Lam.	2.90	1.58		2.38	4.41
Ziziphus mucronata Willd.	2.59	3.80	3.19	1.22	1.98

(18 species).

The family importance value index (FIV) was 51.14 for the *Fabaceae* family and 108.50 for the *Combretaceae* family (Tab. 4). They represented 53.39% of the total family importance value index. The majority of the families (63.15%) had FIV less than 10. The *Zygophyllaceae* family represented by a species, *Balanites aegyptiaca*, was one of the three most important family (26.58). The least important families with FIV<1 were: *Bignoniaceae* (0.27) and *Celastraceae* (0.12) which accounted for 0.26% of the total FIV (298.97).

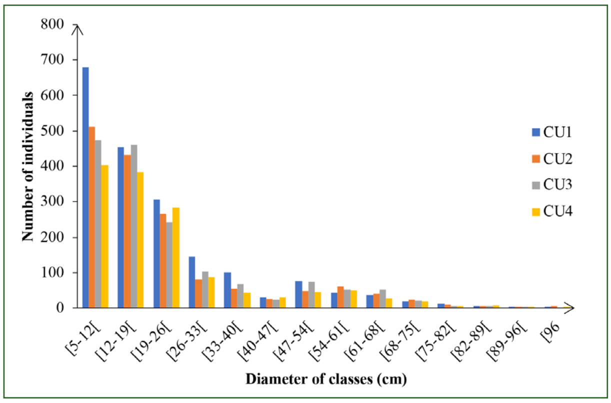
Table 4 - Family importance value index (FIV) of the three most important families (in bold) of each collection unit and global FIV for all collection units.

Families	Global FVI	FVI			
		CU_1	CU_2	CU_3	CU_4
Anacardiaceae	15.27	14.59	17.67	17.02	16.61
Annonaceae	13.20	24.42	11.08	12.87	3.58
Bignoniaceae	0.27	0.80	0.79	-	-
Burseraceae	5.10	12.07	5.96	2.75	2.28
Capparaceae	9.13	9.25	6.34	11.76	7.89
Celastraceae	0.12	0.35		0.39	
Combretaceae	**108.50**	**102.10**	**121.90**	**103.87**	**114.96**
Fabaceae	**51.14**	**53.05**	**50.07**	**41.93**	**39.48**
Loganiaceae	7.88	4.51	8.24	5.31	10.00
Malvaceae	22.18	17.52	17.69	18.01	29.93
Moraceae	4.76	2.32		2.06	5.16
Phyllanthaceae	4.30	6.26	6.79	6.27	5.05
Polygalaceae	4.83	2.47	4.26	5.44	4.12
Rhamnaceae	7.23	7.53	4.45	5.46	12.61
Rubiaceae	10.34	9.18	9.45	21.91	1.63
Sapotaceae	1.80	2.56	1.79	0.42	1.64
Verbenaceae	5.33	1.22	11.93	6.95	4.80
Ximeniaceae	1.01	3.22		2.06	
Zygophyllaceae	**26.58**	**26.56**	**21.57**	**35.52**	**40.26**

Distribution of the stems in diameter classes in the collection units

The distribution of individuals in diameter classes in the four collection units showed fourteen classes (Fig. 2). The evolution of the diameter classes was quite the same in the four collection units. The first three diameter classes [5-12[cm; [12-19[cm and [19-26[cm represented the majority of individuals inventoried. The number of individuals decreased when the diameter increased. The distribution curve is an inverted "J", showing that large diameter stems are very poorly represented compared to young individuals in the study site.

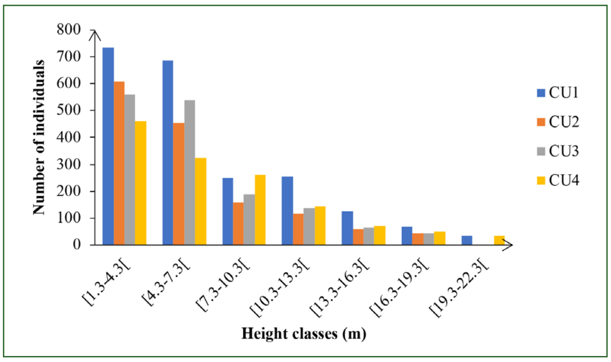
Figure 2 - Distribution of the woody individuals in diameter classes.



Height class distribution of the stems

The number of stems per height class decreases as the height increases (Fig. 3). That distribution showed seven classes and the evolution was the same in the four collection units. The majority of individuals was found in the first four height classes [1.3-4.3[m; [4.3-7.3[m; [7.3-10.3[m and [10.3-13.3[m. There were fewer individuals found with height greater than 12 m. The woody stratum of the study area was therefore shrubby. The low presence of individuals higher than 12 m is justified by the influence of anthropogenic activities consisted of felling systematically the stems with good shape.

Figure 3 - Distribution of individuals in height classes.



Physico-chemical properties of soils of Masgaya forest massif

The physico-chemical analysis of the soils concerned the sand, clay, hydrogen potential (pH), organic matter (OM), total nitrogen (N), carbon (C), C/N, phosphorus (P), magnesium (Mg), calcium (Ca), potassium (K)

Table 5 - Physico-chemical properties of the soils of Masgaya massif forest.

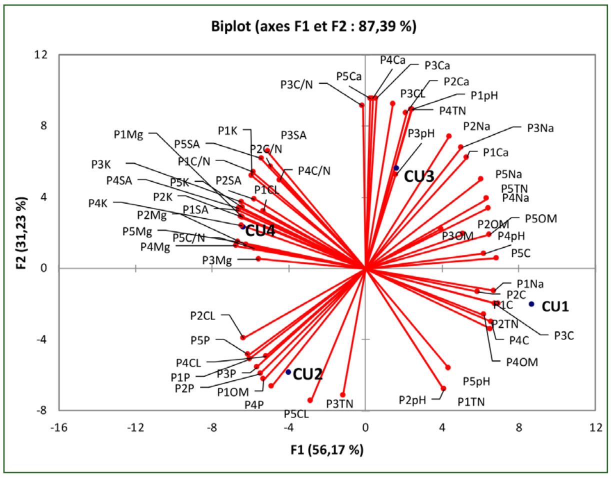
Physico-chemical properties	Collection units (CU)			
	CU_1	CU_2	CU_3	CU_4
Sand (%)	65.68 ± 2.09^{a}	67.02 ± 1.45^{a}	68.99 ± 1.41^{a}	$70,4 \pm 1,61^{a}$
Clay (%)	37.80 ± 1.15^{b}	37.22 ± 2.98^{b}	38.25 ± 1.08^{b}	38.23 ± 1.08^{b}
pH	6.24 ± 0.14^{c}	6.22 ± 0.27^{c}	$6.35 \pm 0,27^{c}$	6.17 ± 0.11^{c}
OM (%)	6.91 ± 1.46^{d}	6.85 ± 1.33^{d}	6.97 ± 0.54^{d}	6.74 ± 1.08^{d}
TN (%)	0.36 ± 0.04^{e}	0.35 ± 0.04^{e}	0.35 ± 0.01^{e}	0.34 ± 0.02^{e}
C (%)	4 ± 0.84^{f}	3.97 ± 0.76^{f}	4.04 ± 0.31^{f}	3.91 ± 0.62^{f}
C/N	10.82 ± 1.16^{g}	11.26 ± 0.90^{g}	11.42 ± 1.08^{g}	11.55 ± 0.82^{g}
P (%)	0.32 ± 0.02^{h}	0.36 ± 0.03^{h}	0.31 ± 0.02^{h}	0.35 ± 0.04^{h}
Mg (meq)	2.86 ± 0.67^{i}	3.43 ± 0.73^{i}	3.35 ± 0.47^{i}	3.35 ± 0.51^{i}
Ca (meq)	12.29 ± 2.00^{j}	11.69 ± 2.00^{j}	13 ± 1.44^{j}	12.73 ± 1.65^{j}
K (meq)	2.78 ± 0.40^{k}	3.16 ± 0.58^{k}	3.19 ± 0.87^{k}	3.55 ± 0.81^{k}
Na (meq)	0.41 ± 0.11^{l}	0.3 ± 0.10^{l}	0.42 ± 0.09^{l}	0.36 ± 0.06^{l}

The numbers followed by the same letters along the lines are not significantly different (p > 0.05).
CU: collection unit; pH: hydrogen potential; OM: organic matter; TN: total nitrogen; C: carbon; N: nitrogen; P: phosphorus; Mg: magnesium; Ca: calcium; K: potassium; Na: sodium.

and sodium (Na) (Tab. 5). The sand content varied from 65.68±2.09 % to 70.40±1,61 %. The high content was observed in CU_4, and the means between the collection units were not significantly different (F=3.1; p = 0.08).

The plots (P1SA, P2SA, P3SA, P4SA, P5SA) were strongly linked to CU_4, shown by biplot (Fig. 4) and negatively correlated to F1 axis. The clay content varied from 37.22±2,98 % to 38.25±1,08 %, with the highest value found in CU_3, and the means between the collections units were not significantly different (F=0.13; p = 0.94). The clay values were negatively correlated to F2 axis, except P3Cl which is positively and significantly correlated to CU_3 and F2 axis (Pearson, r = 0.96). Soil pH was weakly acidic and varied from 6.17±0.11 to 6.35±0.27. The means between the collection units were not significantly different (F = 0.26; p = 0.87), but considering the plots separately, P3pH was highly and positively linked to CU_3. The high value of ration C/N in average was observed in CU_4 (11.55±0,82) and the low value in CU_1 (10.82±1,16). The organic matter values varied in average from 6.74±1.08 % to 6.97±054 % with the highest value in CU_3 and CU_1. The carbon values were high in CU_3 (4.04±0.31 %) and CU_1 (4±0.84 %), and the plot values were strongly linked to CU_1 and CU_3 (Fig. 4).

Figure 4 - Distribution of the physico-chemical properties of the soils within the collection units according to the factorial plan F1-F2.



P1, …, P5: plot 1, …, plot 5; SA : Sand; Cl: Clay; pH: hydrogen potential; OM: organic matter; TN: total nitrogen; C: carbon; C/N: ration carbon and nitrogen; P: phosphorus; Mg: magnesium; Ca: calcium; K: potassium; Na: sodium.

The high value of the phosphorous content was found in CU_2 (0.36±0,03 %) and the low value in CU_3 (0.31±0,02 %). These observations were confirmed by the biplot (Fig. 4). For the exchangeable bases, notably calcium, magnesium, potassium and sodium, the high value of the Ca content was found in CU_3 (13±1.44 meq) and the low value in CU_2 (11.69±2.00 meq). The means between the collection units were not significantly different (p = 0.32). The plots were positively linked to CU_3 and strongly correlated to F2 axis. The Mg content was high in CU_4 (3.35±0.51 meq) and low in CU_1 (2.86±0.67 meq). The plots were strongly linked to CU_4 and were significantly and negatively correlated to F1 axis (Pearson, r = -0.90). The K values were high in CU_4 (3.55±0.81 meq) and low in CU_1 (2.78±0.40 meq) and confirmed by the biplot. The Na content was high in CU_3 (0.42±0.09 meq) and CU_1 (0.41±0.11 meq), and low in CU_2 (0.3±0.10 meq). The plots were in majority linked to CU_3 shown by the biplot.

Discussion

Floristic diversity of Masgaya forest massif

The floristic inventory indicated 64 species distributed in 46 genera and 19 families according to the APG IV classification system. These results were similar to those obtained by Sandjong et al. (2013) who identified 62 woody species in Mozogo-Gokoro National Park, located in the same ecological zone. They were different from the results obtained by Froumsia et al. (2012) who identified 86 species distributed in 42 genera and 25 families in the Kalfou forest reserve. This difference could be explained by the fact that our study was carried out in an opened ecosystem and accessible to local populations who daily carry out anthropogenic activities including land-use change, fire, logging, grazing, fuel wood extraction and collection of non-timber forest products. Forest communities considered rich (Kent and Coker 1992) are characterized by a Shannon diversity value index (H') of about 3.5 bits or higher. The four collection units established within the Masgaya massif forest showed different values of Shannon's index (Tab. 1). These values reflect the anthropogenic disturbances, through the logging for the needs of firewood for domestic charges and for sale, and the natural phenomena such as drought and floods. According to Todou et al. (2016), for any Shannon diversity index lying in the interval (3< H< 4), the diversity is moderate and could be considered as a good regeneration of species in the sahelian ecoregion. This index is lower in CU_4 (H' = 3.00 bits) located in the eastern side of the massif. In fact, this side of the massif is inhabited mainly by the Massas who constitute an ethnic group gifted in the exploitation of natural resources. This index is higher in CU_1 (H=3.30 bits). This high value could be explained by the fact that this flank of the massif is in continuity with the Kalfou forest reserve and that anthropogenic activities could be reduced. Our results corroborate those of Souare et al. (2020a) who obtained the Shannon diversity index (H' = 3.05 bits) in the Laf forest reserve which is in depletion in Cameroon. Similarly, Mbaiyetom et al. (2021) found the Shannon-Weaver diversity index (H' = 3.04 bits) in the wooded park of the Sudanian zone of Chad. This result also confirms that of Froumsia et al. (2019) in Moutourwa in the Sudano-Sahelian zone of Cameroon who indicated with H' = 3.53 bits carried out in a protected area and H' = 3.30 bits in unprotected area. These results could be explained by the fact that our study area was in the same ecological conditions. Indeed, ecological and climatic conditions influence the distribution and plants growth. As for Pielou's evenness (EQ), it varied from 0.41 to 0.51 depending on the collection units. The lowest value is represented in CU_1 and the highest values are found in CU_3. These results confirm those of Bakoulou et al. (2020) in the ecosystems of Mayo-Danay who found the Pielou's evenness index of 0.45 in the village of Bangana and those of Souare et al. (2020a) who obtained the Pielou's evenness of 0.47 in the Laf forest reserve. For Dajoz (1982), ecosystems which are in a state of transition or which are subject to permanent disturbances have a low Pielou's evenness index. The low Pielou's evenness index values could be attributed to anthropogenic disturbances in the massif forest.

The large values of basal area and density (Tab. 2) observed in collection unit 1 can be justified by the presence of large trees and less intense human activities in this collection unit. This could be due to the fact that this collection unit is located a long distance from houses. Our results are low, compared to those of Peltier (2009) in the classified forest of Tientiergou in Niger with 705 stems/ha of density and 2.13 m^2/ha of basal area, and by Paré (2008) in two classified forests in Burkina-Faso with tree densities varying between 531 ± 88 and 796 ± 90 trees/ha and values for basal areas varying between 6.55 ± 1.1 and 15.92 ± 3.4 m^2/ha. The low values of density and basal area in the collection units are due to anthropogenic activities and climatic disorders that exist in this agroecological zone. Indeed, in villages and especially with population explosion, local populations depend on natural resources. They put pressure on non-timber and wood forest products; either for food or as a source of income by selling them in local markets. According to Sounon et al. (2007) and Azaria et al. (2024), demographic growth accompanied by certain modes of exploitation leads to land degradation with the consequence of a disruption of environmental balances, in turn on vegetation. Species such as *Anogeissus leiocarpa*, *Balanites aegyptiaca*, *Combretum glutinosum*, *Guiera senegalensis*, *Hexalobus monopetalus*, *Prosopis africana* and *Sterculia setigera* are the most dominant and mark the physiognomy of the vegetation in our study area. The dominance of these species may also be due to their strong regeneration capacities (Akpo and Grouzi 1996), the advantages they provide to agriculture (Larwanou 2005) and the fact that they are favorable to the pedoclimatic conditions of the area (Ambouta et al. 1998, Karoune 2016). In addition, some of them like *Guiera senegalensis* have the ability to grow in the dry season in fields after harvest (Bationo et al. 2012). This helps to protect the soil against the sun and wind erosion and provides fodder and wood in the dry season. It is a pioneer species, hardy to cut and therefore easily colonizes spaces. Larwanou et al. (2012) affirm that the choice of species spared and protected in the fields is a function of a certain number of criteria such as the capacity of the species to regenerate, its usefulness in terms of uses and provision of services such as protection against wind, wood production, improvement of soil fertility and traditional pharmacopoeia. The species observed in our collection units are those which seem to be resistant to water stress and high temperatures (Savadogo et al. 2016). These species are those that provide important economic and social services to local populations (Thiombiano et al. 2006). The *Combretaceae* and *Fabaceae* families dominate over other families in the different areas of our study site. This result corroborates those of Kemeuze et al. (2015) who stated that in the semi-arid areas of Cameroon, *Combretaceae* are recognized as the most dominant families. Indeed, the drought of the Sahel has allowed the natural selection of the most robust species (Souare et al. 2020a) like those belonging to this family.

Structural distribution of woody individuals

The diameter structures established for the four collection units showed an inverted "J" distribution (Fig. 2). The inverted "J"-shape reflects good regeneration of the environment. The distribution of trees from different sites showed that individuals with a diameter of less than 26 cm are the most abundant. Those with diameters above 75 cm were rare, and it was the same observation in all the different collection units. These results are similar to those of Zampaligre et al. (2019b) in the silvopastoral zone of Dindéresso, Burkina Faso who demonstrated an inverted "J"-shaped curve, those of Savadogo et al. (2007) in the Tiogo forest and those of Froumsia et al. (2012) in the Kalfou Forest Reserve who also demonstrated an "inverted J"-shaped curve. The "upside-down J"-shape reflects a reduction in the number of stems when moving from small to larger diameter classes. Such a diametric distribution of woody individuals indicates a disturbed environment, in full reconstruction (Nusbaumer et al. 2005). This rarity of large diameter species is explained by a disruption of savannah ecosystems due to the overexploitation of woody species by humans. In view of these results, it should be noted that although regeneration is assured, populations are not evolving due to intense human activities which negatively influence the evolution of plant species in the different woody formations.

Physico-chemical properties of the soils

Regarding the physicochemical properties of the soils, the textural analysis revealed, overall, a predominance of sandy soils in the Masgaya forest massif. The predominance of sand content in this area explains great porosity, thus promoting good circulation of water and air and accelerating the action of microorganisms in the decomposition of plant debris. Our results corroborate those obtained by Tossou et al. (2006) in the agricultural valleys of the Abomey-Bohicon conurbation in Benin. The pH obtained in the different collection units is weakly acidic and tends towards neutrality. For Doucet (2006), soils that have a neutral pH have the best chemical characteristics for plant survival. Regarding the carbon-nitrogen ratio, these values found in the different collection units are average. This indicates that the carbon content is proportional to the total quantity of organic matter, so that the C/N ratio is lower as the organic matter is richer in nitrogen. However, if soil microorganisms have their activity slowed down by an excess of carbon in the humus, this is on the contrary accelerated by a high nitrogen level. (Banville 2009) showed that a high C/N ratio represents a low rate of carbon decomposition since decomposer organisms use nitrogen which quickly becomes limiting. A low C/N ratio indicates a high nitrogen concentration and a high degree of decomposition. (Duchaufour 1997) stated that any reduction in the C/N ratio of humus means an increase in biological activity in the soil. Any increase to the contrary in this ratio betrays a decrease in this activity, therefore, a drop in the C/N ratio and rapid decomposition of humus.

Conclusions

Anthropogenic activities in Sudano-sahelian ecoregion threaten biodiversity and ecosystem integrity. The survey aimed at examining the diversity of woody vegetation and the characterization of physicochemical properties of the soils of Masgaya forest massif in Cameroon. A total of 6,465 woody individuals were recorded, representing 64 species grouped in 46 genera and 29 families. The most dominant families in the area were *Combretaceae* and *Fabaceae* families. The different values of diversity index showed that anthropogenic activities have a negative impact on the stability of forest massif. Results of physico-chemical properties of the soils showed a predominance of sandy fractions over clay fractions, and high values of OM and TN. The pH obtained in the different collection units was weakly acidic and tends towards neutrality, reflecting the best chemical characteristics for plant survival. The outcomes of this study can be used to develop forest management strategies to ensure sustainable development in this ecoregion. Since soil degradation is a deterioration of its physico-chemical and biological properties, our future research will focus on the soil biological properties of Masgaya forest massif. Furthermore, the study will be extended to other forest massifs of the sudano-sahelian and sudano-guinean zones of Cameroon.

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