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Variations of the Functional Leaf Traits in Some Agroforestry Woody Species of the Sudano-guinea Savannahs of Ngaoundere, Adamawa Cameroon: Effects of Plant Taxonomy, Life Forms, Habits and Habitats

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Leaf functional traits have been shown to be useful to understand how and why ecosystems and their components vary among plant species and across environmental heterogeneity. This study investigated how leaf functional traits vary according to plant taxonomic (species, families), habit (deciduous, semi-deciduous and evergreen leaves) and habitat (savannah, forest gallery, and plantation). Leaf traits (length, wide, fresh and dry mass, water content, thickness, area, specific

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leaf area, leaf dry matter content, specific leaf mass, and density) and plant height of the 24 agroforestry plant species were examined across sites heterogeneity and taxonomic characteristics in the Sudano-guinea savannahs of the Ngaoundere, Adamawa Cameroon. The results showed that functional leaf traits varied among plant species according to given trait. The length, fresh and dry mass, and thickness were the highest in *T. macroptera* (28,18 cm, de 13,84 g, 6,08 g et 0,55 mm), and the lowest in *S. longepedunculata* (4,71cm; 0,10 g et 0,04 g et 0,13 mm). The wide and area were the highest in *U. togoensis* (18,21 cm; 311,18 cm^2) and the lowest in *S. longepedunculata* (1,00 cm, 5,03 cm^2). The plant height was the highest in *S. g. guineense* (11,50 m) and the lowest in *H. acida* (1,80 m). Water content was the highest in *P. febrifugum* (85,20 %,.) and the lowest in *U. togoensis* (0,20 %). The specific leaf area was the highest in *H. madagascariensis* (249,00 cm^{-2}.g,) and the lowest in *T. macroptera* (de 44,00 cm^{-2}.g). Lastly the leaf dry matter content, specific leaf mass and density were the highest in *H. madagascariensis* (0,85 $g.g^{-1}$, 0,02 mg^{-1}. cm^2 and 0,09 g. mm^{-3}) and the lowest respectively in *P. febrifugum*, (0,29 g. g^{-1} , de 0,001 mg^{-1}. cm^2) and *V. paradoxa* (0,02 g. mm^{-3}). Leaf functional traits were influenced by plant families, life forms, habits, and habitats. These functional leaf traits were correlated among them.

Keywords: Functional traits; taxonomy; life form; habit; habitat; Ngaoundere; Adamawa; Cameroon.

1. INTRODUCTION

Faced with the major challenges posed by current environmental changes (global warming, changes in land use), it is important to describe living beings in terms of functional traits in order to predict changes in the distribution of biodiversity and the functioning of ecosystems. Indeed, functional traits, particularly in plants, make it possible both to study the response of species to environmental gradients and their changes, and to predict the effect of these same species on ecosystem functioning (e.g. biomass production or litter decomposition in plant communities, etc.). [1]

Functional traits, which are all morphological, physiological or phenological characteristics measured at the individual level and having an impact on fitness [2], make it possible to apprehend the expression of an individual's different functions [3]. Functional traits may present intra- and interspecific variations according to environmental conditions and over time [2]. They are therefore characteristics of plants correlated to their functions but easier to measure than the function itself. The use of traits then makes it possible to answer questions such as those concerning (i) the relationships between biotic and abiotic factors in the environment and the functioning of organisms, (ii) the rules governing the assembly of species in communities, (iii) the prediction of ecosystem functioning based on that of organisms and (iv) the controls which the latter exercise over the services provided by ecosystems to human societies [3].

Many functional traits can be measured on an individual; those of interest are defined by [3] as (i) related to a plant function, (ii) relatively easy to observe and quick to quantify, (iii) measurable according to standardised protocols that can be used over a wide range of species and growing conditions, and (iv) allow the establishment of hierarchies between species that are maintained between contrasting environments, without the values of these traits being constant. Thus, the identification and use of traits defined according to these criteria makes it possible to compare the functioning of plants established in different environments [4].

Among the many approaches to measuring traits, the leaf (foliar traits) was the focus of this study. It is necessary to distinguish between "soft" and "hard" traits. We have among others: specific leaf area (SLA); leaf fresh mass (MF); leaf dry mass (MS); leaf density (DE); height (H), etc.

In the Sudano-Guinean savannahs of Adamawa, where the local population derives most of its livelihood from livestock, agriculture and agroforestry products, the situation is proving worrying for the population and the environment. Currently, the rapid increase in these anthropogenic activities and climate change have increased the rate of disappearance of the reserves of cultivable land and affected the functioning of these agroforests such as the decrease in their productivity, the increase in herbivory, the erosion of their biodiversity, etc. To understand and predict the effect of environmental change and anthropogenic pressure on the functioning of the agroforests in the savannahs of Ngaoundere, in the Adamawa, in order to contribute to the selection of plant species to be domesticated and the sustainable management of these agroforests, the so-called functional traits approach can be used. The use of these functional traits requires their prior determination. This type of approach has been gaining ground in Europe over the last 20 years, with very satisfactory results that can be applied in many fields such as ecology, agronomy, etc. The use of these functional traits requires prior determination. Unfortunately, it has been very little used in African savannahs [5] and never in those part of the country.

A better understanding of these processes would make it possible to understand the functional relationships between these species in these environments, and to improve conservation strategies and environmental restoration programmes. It is in this context that our study is situated, the objective being to determine the functional traits of the species characteristic of the agroforests of the Ngaoundere savannahs. specifically, we wish to evaluate the interspecific, inter-family, inter-growth form, inter-leaf type and inter-habitat variations of 24 species of the Sudano-Guinean savannahs of Ngaoundere, but especially in the locality of Dang.

2. MATERIALS AND METHODS

2.1 Study Site

The study site located in Adamawa region (6-8N, 12-15E, altitude 1200 m asl). This geographical situation gives at this region a humid climate according to Suchel, with one dry season (November - March) and one rainy season (April - October). The rainy season extends from July to September, registering maximum amounts in August. The dry season stretches from November to March. The mean annual rainfall is about 1500 mm, with a variation coefficient of 9.8. The mean annual temperature is approximately 22°C and the mean relative humidity about 69%. The seasonally arid situation of Adamawa region is due to the influence of the Harmattan (dry wind) which recalls the harsh climatic conditions of the Sudano-sahelian regions, while its rainfall and its thermal amplitude recall the humid subequatorial regions. The ferralitic soils are the dominant type, with rich clay (40-60%), low organic matter (less than 1%), low soil exchange capacity from 15 to 20 meq/100g and the pH about 4.7 to 5.6. Hydromorphic soils are found in the marshy depressions. The vegetation of Ngaoundere savannahs is constituted of meadows, shrubby and woody savannahs, with predominance of *Daniellia oliveri* and *Lophira lanceolata* Degraded fallow lands and savannahs occasionally used as grazing land and composed of *Acacia hockii* and *Afzelia Africana*. The vegetation aspects are maintained by zoo-anthropic factors such as wildfires and grazing.

The experimental site is located at the University of Ngaoundere (7°26' North, 13°31' East and altitude 1114 m) situated at the village Dang, about 15 km from North of Ngaoundere city. Plots were chosen under three habitats that is savannah up land, plantation and forest gallery.

2.2 Species Selection

In this study, leaves of twenty-four socio-economic and contrasting plant species of the Sudano-guinea savannahs of Ngaoundere were used. The experiment involved sixteen deciduous broad-leaved including two trees (*Ficus sycomorus* and *Terminalia glaucescens*) and fourteen shrubs (*Croton macrostachyus*, *Ficus sur*, *Ficus thonningii*, *Hymenocardia acida*, *Lophira lanceolate, Piliostigma thonningii, Psorospermum febrifugum, Securidaca longepedunculata*, *Syzigium guineense* var. *macrocarpum*, *Terminalia macroptera, Vitex doniana, Vitellaria paradox, Vitex madiensis and Ximenia america)*, five evergreen board-leaved including three trees (*Mangifera indica*, *Syzigium guineense* var. *guineense* and *Uapaca togoensis*) and two shrub (*Allophyllus africanus and Harungana madagascariensis*), three semi-deciduous including one tree (*Persea americana*) and two shrubs (*Annona senegalensis* and *Ficus vogelii*). The biological characteristics of these species are found in Table 1. The distribution area of *Syzigium guineense* var. *guineense, Uapaca togoensis and Allophyllus africanus* is forest gallery, while others species is savannahs land, fallows or degraded forests, except *Mangifera indica* in plantation. The twenty-four plant species play a great socio-economic role in the area. They are a source of income, food, firewood, medicinal products and soil fertility indicators for the farmers of this region (Mapongmetsem [6], Ibrahima et al., [7], Tchobsala [8]). Their leaves are mostly simple, except those of *Allophylus africanus*, *Vitex doniana,* and *Vitex madiensis*. Which are composed leaves species.

Table 1. Composition of twenty-four plant species used in this study

Plant species	Cod	Families	Cod	Habitat
Broad-leaved deciduous trees				
Ficus sycomorus CC. Berg	FY	Moraceae	MOR	Savannah
Terminalia glaucescens Planch. Ex Benth.	TG	Combretaceae	COM	Savannah
Broad-leaved deciduous shrubs				
Croton macrostachyuis Hochst. ex Del.	CM	Euphorbiaceae	EUP	Savannah
Ficus sur Forssk	FS	Moraceae	MOR	Savannah
Ficus thonningii Blume	FT	Moraceae	MOR	Savannah
Hymenocardia acida Tul.	HA	Hymenocardiaceae	HYM	Savannah
Lophira lanceolata Van Tigh. Ex Keay	LL	Ochnaceae	OCH	Savannah
Piliostigma thonningii (Schumach.) Milne-Redh	PT	Caesalpiniaceae	CAE	Savannah
Psorospermum febrifugum Spach	PF	Clusiaceae	CLU	Savannah
Securidaca longepedunculata Fres.	SL	Polygalaceae	POL	Savannah
Syzigium guineense var. *macrocarpum*	SM	Myrtaceae	MYR	Savannah
Terminalia macroptera Guill. & Perr.	TM	Combretaceae	COM	Savannah
Vitex doniana Sweet	VD	Verbenaceae	VER	Savannah
Vitellaria paradoxa Gaertn. f.	VP	Sapotaceae	SAO	Savannah
Vitex madiensis Oliv.	VM	Verbenaceae	VER	Savannah
Ximenia Americana L.	XA	Olacaceae	OLA	Savannah
Broad-leaved evergreen trees				
Mangifera indica L.	MI	Anacardiaceae	ANA	Plantation
Syzygium guineense var. *guineense* (Willd.) DC.	SG	Myrtaceae	MYR	Forest Gallery
Uapaca togoensis Pax	UT	Euphorbiaceae	EUP	Forest Gallery
Broad-leaved evergreen shrubs				
Allophylus africanus P. Beauv	AA	*Sapindaceae*	SAP	Forest Gallery
Harungana madagascariensis Lam. ex Poir.	HM	Clusiaceae	CLU	Savannah
Broad-leaved semi-deciduous trees				
Persea americana	PA	Loraceae	LOR	Plantation
Broad-leaved semi-deciduous shrubs				
Annona senegalensis Pers.	AS	Annonaceae	ANN	Savannah
Ficus vogelii (Miq.) Miq.	FV	Moraceae	MOR	Savannah
Psorospermum febrifugum Spach	PF	Clusiaceae	CLU	Savannah

2.3 Methodology

To estimate leaf traits, seven individuals of each of the 24 species were randomly selected from three habitats (Savannah, forest gallery and plantation or cultivation area) in February 2018, following a transect 50 meters width by 500 meters length. The leaf collection method recommended by Cornelissen et al. [9] was adopted. It consisted in collecting a leaf sample 2-3 hours after sunrise or 3- 4 hours before sunset, putting them in plastic bags to go and make multiple measurements of soft or easy to measure traits in the laboratory. From each individual, twenty healthy, unaltered and mature leaves were taken at random from the four cardinal points (North, South, East and West) and from the middle of the canopy, in the morning before sunrise to maintain turgidity. The experimental device is a completely randomized block with four replicates. The treatment is represented by the species or habitats and the number of individuals in the replicates. The experimental unit consists of twenty leaves. The leaf samples, packed in black bags, were transported to the laboratory in a hermetically sealed container. Prior to weighing, the total surface area of the leaves was determined using the digital imaging method (image j) described by Bitjoka et al. [10]. To determine the wet mass, the samples transported to the laboratory were weighed using a Sartorius electronic balance type ISO 9001, LC 2015, and then put in an oven for 48 hours at 60°C to determine the dry mass of the samples. The thickness of the sheets was determined using an electronic calliper. The height of the individuals was measured using a graduated pole. The specific leaf area, density, specific leaf mass and leaf dry matter content were calculated using the following formulae

$$WC (\%) = ((MH-MS)/MS)*100;$$

$$SLA (cm^{-2}.g) = S/MS;$$

$$DE (g.mm^{-3}) = MS/(S*E);$$

SLM (mg .cm^{-2}) = MS/S

LDMC (g.g^{-1}) = MS/MH

Where WC is water content (%), SLA, specific leaf area (cm^2.g-^{1}), DE, density (g.mm-^{3}), SLM, specific leaf mass (g.cm-^{2}), MH, fresh mass (g), MS, dry mass (g), S; leaf area (cm^2), E, leaf thickness (mm) and LDMC (g.g-^{1}), leaf dry matter content.

We have these families: Sapotaceae, Olacaceae, Sapindaceae, Annonaceae, Euphorbiaceae, Moraceae, Hymenocardiaceae, Clusiaceae, Ochnaceae, Anacardiaceae, Loraceae, Caesalpiniaceae, Myrtaceae, Polygalaceae, Combretaceae and Verbenaceae. We have also two life forms: trees and shrubs. Habits are characterized by deciduous, semi-deciduous and evergreens leaves. the habitat is constituted of the savannahs, forest gallery and the plantation zone.

2.4 Statistical Analysis

Using one-way ANOVA (plant species, habitat or growth forms), following by Scheffe's mean comparison test at 5% (if ANOVA was significant) compared leaf traits among plant species and among plant growth forms. ANOVA was also used to test the effects of habitats and families on leaf traits. Pearson's correlation coefficients were calculated between leaf traits. Simple regression model was also used to determine relationships between these parameters. These tests were conducted through software package Statgraphic version 4.0.

3. RESULTS

3.1 Inter-specific Variations in Functional Traits

The 12 leaf functional traits determined in the Dang site vary significantly between species (Table 2). Simple traits such as length, width, wet and dry mass, thickness, leaf area and height of individuals vary from 4.71 to 28.18 cm, 1.00 to 18.21 cm, 0.10 to 13.84 g, 0.04 to 6.08 g, 0.13 to 0.55 mm, 5.03 to 311.18 cm^2 and 1.80 to 11.50 m respectively. Length (LO), both wet (MH) and dry (MS) weights and thickness (E) are highest for *T. macroptera* and lowest for *S. longepedunculata*. Width (LA) and leaf area (S) are highest for *U. togoensis* and lowest for S. longepedunculata. The height (H) of individuals is highest in *S. g. guineense* and lowest in *H. acida*.

With regard to ratios such as water content (WC), leaf area (S), leaf dry mass content (LDMC), specific leaf area (SLA) and density (DE) vary significantly and respectively from 0.20 to 85.20%, from 44.00 to 249.00 cm^{-2}.g, from 0.29 to 0.85 g.g^{-1}, from 0.001 to 0.02 mg-1.cm^2 and from 0.02 to 0.09 g.mm^{-3}. Water content (WC) is highest in *P. febrifugum* and lowest in *U. togoensis*. Specific leaf area (SLA) is highest in *H. madagascariensis* and lowest in *T. macroptera*. Finally, leaf dry matter content (LDMC), Leaf specific leaf mass (SLM) and density (DE) are lowest in *H. madagascariensis* and highest in *P. febrifugum* and *V. paradoxa*, respectively.

3.2 Variations between Families of the Functional Traits

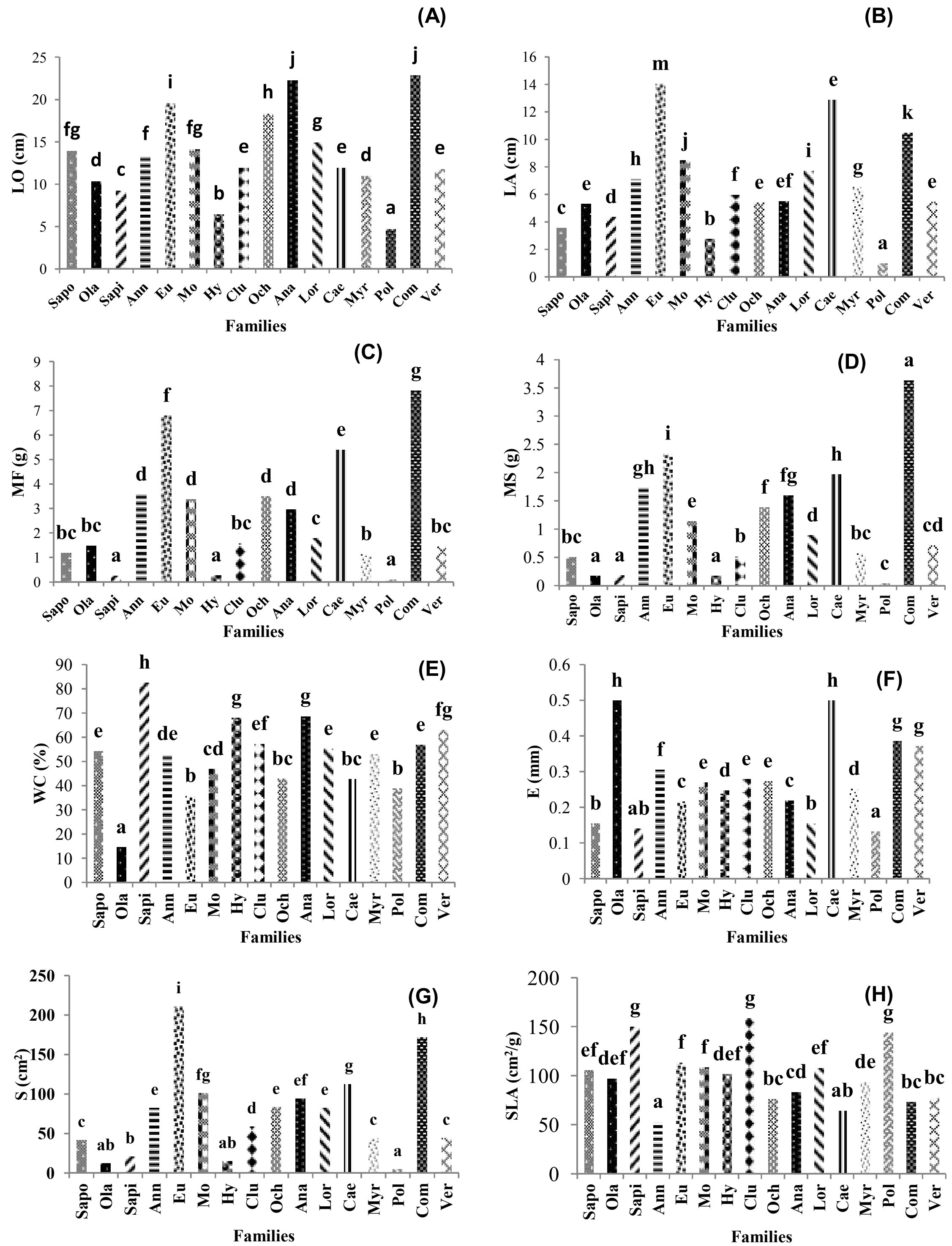
The 12 traits studied vary significantly between families (Fig. 1). The values of these traits range from 4.71 to 22.84 cm, 1.00 to 7.81 cm, 0.1 to 7.81 g, 0.03 to 3.63 g, 0.13 to 0.49 mm, 5.03 to 211.35 cm^2 and 1.08 to 10.64 m respectively for the length, width, both wet and dry mass, thickness, leaf area and height of the individuals. These single trait values are the lowest in the family Polygalaceae, except for the height which is the lowest in Hymenocardiacea.

The highest values are observed in Anacardiaceae for length, in Euphorbiaceae for width and leaf area, in Combretaceae for the two wet and dry masses, in Caesalpiniaceae and Olacaceae for leaf thickness, and finally in Loraceae for height.

As regards the traits resulting from the ratios, they also vary between families according to a given trait, from 14.40 to 82.60%, from 52.98 to 158.62 g.cm^{-2}, from 0.14 to 0.82 g.g^{-1}, 0.001 to 0.02 cm^2.g^{-1} and finally from 0.03 to 0.09 g.mm^{-3}, respectively for the water content, specific leaf area, leaf dry matter content, specific leaf mass and density. These values are the highest in Sapindaceae for water content and leaf dry matter content (LDMC), in Clusiaceae, sapindaceae and polygalaceae for specific leaf area, in Annonaceae for specific leaf mass (SLM), in Annacardiaceae for density. They are lowest in Olacaceae for water content (WC), leaf dry matter content and density, in Annonaceae for Specific leaf Area and in Polygalaceae for specific leaf mass.

Table 2. Morphologicals traits of the 24 species

	LO (cm)	LA (cm)	MF (g)	MS (g)	WC (%)	E (mm)	S (cm^2)	SLA (cm^2/g)	LDMC ($g.g^{-1}$)	SLM (g/ cm^2)	DE (g. mm^{-3})	H (m)
AA	9,24±2,00ml	4,35±1,25 l	0,26±0,15 lm	0,18±0,10 k	82,60±55,30 a	0,14±0,03 f	21,01±9,50 km	149,83±115,79 b	0,82±0,55 a	0,01±0,01 ijk	0,07±0,04 de	2,25±0,30 lmn
AS	13,43±1,98 g	7,12±1,46gh	3,57±1,40 e	1,73±0,61 e	53,08±21,49d	0,30±0,03 f	82,72±24,74 gh	52,98±23,40 kl	0,53±0,21 de	0,02±0,01 b	0,07±0,03 de	2,40±0,57 klm
CM	12,65±2,96 h	9,85±2,42 d	3,37±0,92 e	0,93±0,27 h	30,18±13,19 fg	0,22±0,03 f	111,52±73,44 cd	131,59±103,98 c	0,30±0,13 ijk	0,01±0,01 hij	0,05±0,03 ghi	6,64±1,56 gh
FS	12,40±2,26 hi	9,86±2,17 d	1,33±0,99 ijk	0,70±0,36 i	66,51±44,33 b	0,14±0,04 f	76,33±31,79 gh	130,62±73,41 c	0,66±0,44 b	0,01±0,01 hijk	0,08±0,06 cd	5,57±0,68 hi
FY	10,64±2,59 klj	8,07±1,52 e	1,62±0,73 hij	0,69±0,37 i	49,81±30,35 de	0,26±0,03 f	48,86±16,89 hi	85,31±49,47 fghi	0,49±0,30 defg	0,01±0,01 cde	0,06±0,03 fg	8,45±2,10 e
FT	10,60±3,00 klj	4,95±1,49 k	1,71±0,97 hi	0,48±0,26 j	38,09±31,29 ef	0,33±0,05 f	43,95±27,10 hijk	112,86±87,92 d	0,38±0,31 ghiijk	0,01±0,01 def	0,04±0,02 i	6,90±1,17 g
FV	22,90±4,94 c	10,95±1,79 c	8,85±2,56 c	2,68±0,93 c	0,33±0,03 g h	0,34±0,03 c c	235,65±94,02 b b	105,19±84,58 de d	0,32±0,16 hijk	0,01±0,01 fgh	0,04±0,02 l l	7,50±0,85 f f
HA	6,42±1,29 mn	2,75±0,46 n	0,27±0,08 lm	0,17±0,07 kl	68,12±33,85 b b	0,24±0,04 f f	15,31±4,99 m k	101,70±50,42 def	0,68±0,34 b b	0,01±0,01 ghi	0,05±0,03 ghi	1,80±0,16 o n
HM	14,71±2,93 f	7,50±1,71 fg	2,33±1,47 g	0,49±0,33 j	29,27±24,12 f g	0,31±0,05 f	86,83±33,36 fg	249,63±164,13 a	0,29±0,24 j k	0,00±0,00 kl	0,02±0,01 k	2,63±0,52 kl
LL	18,35±3,33 d	5,40±0,94 j	3,49±1,02 e	1,38±0,55 f	42,80±22,36ef	0,27±0,03 f	83,61±28,40 gh	76,47±70,15 hij	0,42±0,22 efgh	0,01±0,01 c	0,06±0,04 ef	2,60±0,39 kl
MI	22,28±5,52 c	5,49±1,39 j	2,97±1,48 f	1,59±0,83 e	0,21±0,02 gh	0,21±0,02 f	94,26±43,73 ef	83,30±78,31 fghij	0,68±0,49 b	0,02±0,01 b	0,09±0,07 b	9,00±1,44 d
PA	14,93±3,61 f	7,70±1,77 ef	1,78±0,60 h	0,88±0,32 h	55,28±28,60 cd	0,15±0,03 f	82,48±30,04 gh	107,80±60,61 de	0,55±0,29 cde	0,01±0,00 ghij	0,08±0,05 c	10,64±1,95 b
PF	9,14±1,81 ml	4,42±1,10 l	0,84±0,60 kl	0,55±0,30 j	85,20±62,32 a	0,24±0,04 f	31,04±14,98 jl	67,61±39,07 ijk	0,85±0,62 a	0,02±0,01 b	0,08±0,06 c	2,34±0,43 klm
PT	11,91±1,77 hi	12,86±2,46 b	5,40±1,85 d	1,96±0,62 d	42,76±25,18 ef	0,49±0,14 f	112,70±44,99 c	64,29±36,70 jk	0,42±0,25 efgh	0,02±0,01 b	0,05±0,03 hi	3,24±0,61 jk
SG	11,24±1,78 ijk	6,08±1,29 i	1,39±0,37 hijk	0,71±0,22 i	54,56±20,90 d	0,27±0,03 f	50,22±13,01 hi	79,68±73,91 ghij	0,54±0,21 cde	0,01±0,01 efg	0,05±0,02 ghi	11,50±1,80 a
SM	10,67±1,71 jkl	7,00±1,22 h	0,90±0,32 kl	0,42±0,17 j	0,23±0,05 gh	0,23±0,05 d	39,21±10,73 ijkl	107,44±60,23 de	0,52±0,26 def	0,01±0,00 ghij	0,05±0,03 l	5,00±1,63 ij
SL	4,71±0,65 on	1,00±0,20 o	0,10±0,03 ml	0,04±0,01 kl	38,84±16,94 gh	0,13±0,02 f	5,03±1,42 n l	143,79±64,59 bc	0,39±0,17 ghij	0,01±0,00 jkl	0,07±0,03 l	1,96±0,17 mno
TG	17,50±2,50 e	7,99±1,23 e	2,14±0,70 g	1,18±0,41 g	64,20±47,34 b	0,21±0,02 f	102,46±30,60 de	101,87±60,53 def	0,64±0,47 bc	0,01±0,00 fghi	0,05±0,03 fgh	8,78±1,42 d
TM	28,18±3,86 a	12,96±2,34 b	13,48±4,05 a	6,08±1,59 a	0,55±0,06 gh	0,55±0,06 b	242,07±76,98 b	44,59±26,35 l	0,49±0,32 defg	0,02±0,01 a	0,05±0,03 l	6,57±3,11 gh
UT	26,46±3,78 b	18,21±3,47 a	10,20±3,77 b	3,74±1,40 bb	0,20±0,03 g h	0,21±0,03 a a	311,18±88,52 a a	95,09±45,21 efg defgh	0,41±0,21 fghi	0,01±0,00 fghi	0,06±0,03 l	9,42±1,05 c
VD	11,14±3,02 jk	5,31±1,31 jk	1,48±1,08 hijk	0,69±0,29 i	0,28±0,05 gh	0,28±0,05 e	47,96±20,41 hij	81,04±47,55 ghij	0,61±0,40 bcd	0,01±0,00 cde cde	0,06±0,03 l l	5,78±1,69 i h
VM	12,42±3,80 hi	5,59±1,66 j	1,41±0,68 hijk	0,73±0,40 i	0,46±0,08 gh	0,46±0,07 d	40,84±20,18 hijk	74,05±56,67 hij	0,64±0,46 bc	0,02±0,01 b	0,05±0,04 l	2,30±0,69 klm
VP	13,92±3,28 g	3,57±0,99 m	1,18±0,58 jkl	0,50±0,22 j	54,26±42,95 d	0,15±0,03 f	41,94±16,71 ijkl	105,40±81,72 defg	0,54±0,43 cde	0,01±0,00 cde	0,09±0,05 a	6,85±0,96 gh
XA	10,35±1,97 lk	5,31±1,31 jk	1,48±1,08 hijk	0,17±0,10 i	14,54±9,93 bc	0,49±0,14 f	12,54±4,13 hijk	97,20±83,65 hij	0,15±0,10 bcd	0,01±0,00 cd	0,03±0,01 j	2,30±0,53 klm
F	548,46 ***	702,53 ***	672,34 ***	711,91 ***	136,69 ***	927,31 ***	477,30 ***	44,91 ***	25,50 ***	37,87 ***	109,93 ***	800,01 ***


(A)
LO (cm)
(B)
LA (cm)
(C)
MF (g)
(D)
MS (g)
(E)
WC (%)
(F)
E (mm)
(G)
S (cm²)
(H)
SLA (cm²/g)
Sapo Ola Sapi Ann Eu Mo Hy Clu Och Ana Lor Cae Myr Pol Com Ver
Families

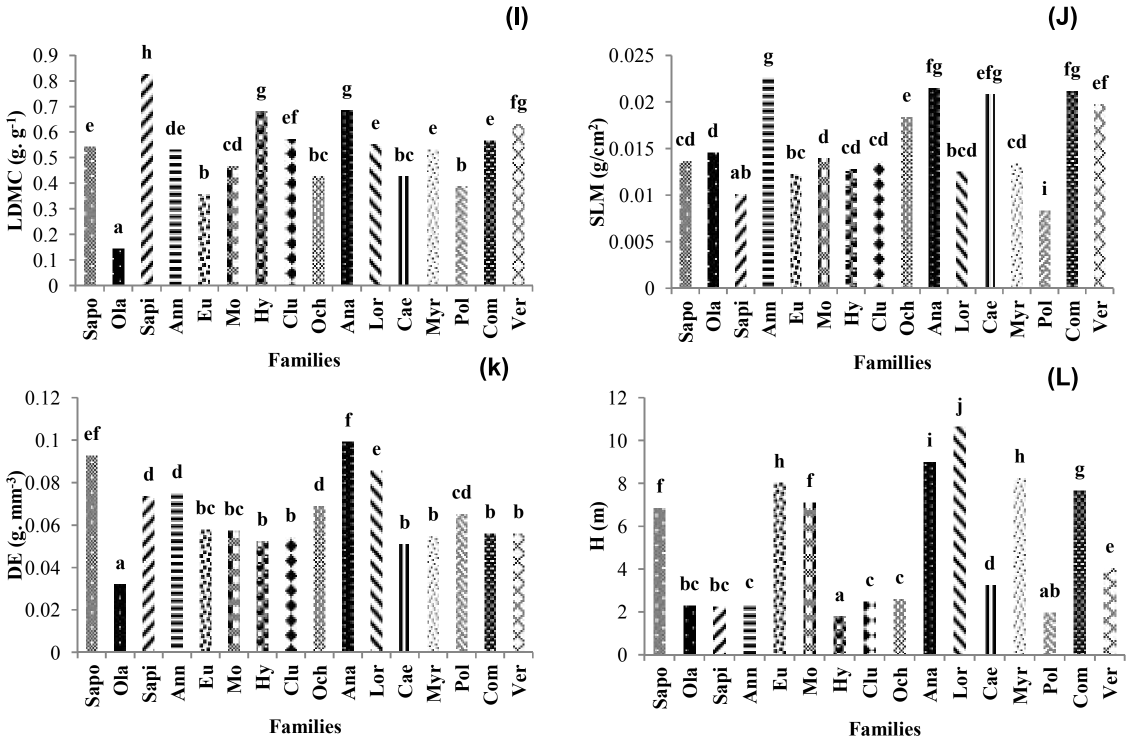


Fig. 1. Variations in functional traits according to families

Sapo= Sapotaceae ; Ola= Olacaceae; Sapi= Sapindaceae; Ann= Annonaceae ; Eu= Euphorbiaceae ; Mo= Moraceae ; Hy= Hymenocardiaceae ; Clu= Clusiaceae ; Och= Ochnaceae ; Ana= Anacardiaceae ; Lor= Loraceae ; Cae= Caesalpiniaceae ; Myr= Myrtaceae; Pol= Polygalaceae; Com= Combretaceae; Ver= Verbenaceae

3.3 Inter-life Forms Variations of Leaf Features

All leaf traits studied vary significantly between life forms, i.e. between trees and shrubs (Table 3). These traits are significantly higher in trees (17.17 cm, 8.92 cm, 3.35 g, 1.47 g, 1.47 g, 55.64%; 114.91 cm^2 , 0.55 g.g$^-$, cm^2 . g^{-1}, 0.001 cm^2.g^{-1}, 0.07 g.mm^{-3} and 9.63 m) than in shrubs (12.95 cm, 6.71 cm, 2.86 g, 1.10g, 50.35 g, 50.35%, 73.90 cm^2, 50.00 g.g^{-1}, 0.01 cm^2. g^{-1}, 0.05 g.mm^{-3} and 4.14 m) except for the thickness and specific leaf area which are lower in trees (0.22 mm and 92.17 cm^2.g^{-1}) than in shrubs (0.29 mm and 105.35 cm^2.g^{-1}) and the specific leaf mass does not differ significantly between trees (0.01 cm^2.g^{-1}) and shrubs (0.01 cm^2.g^{-1}).

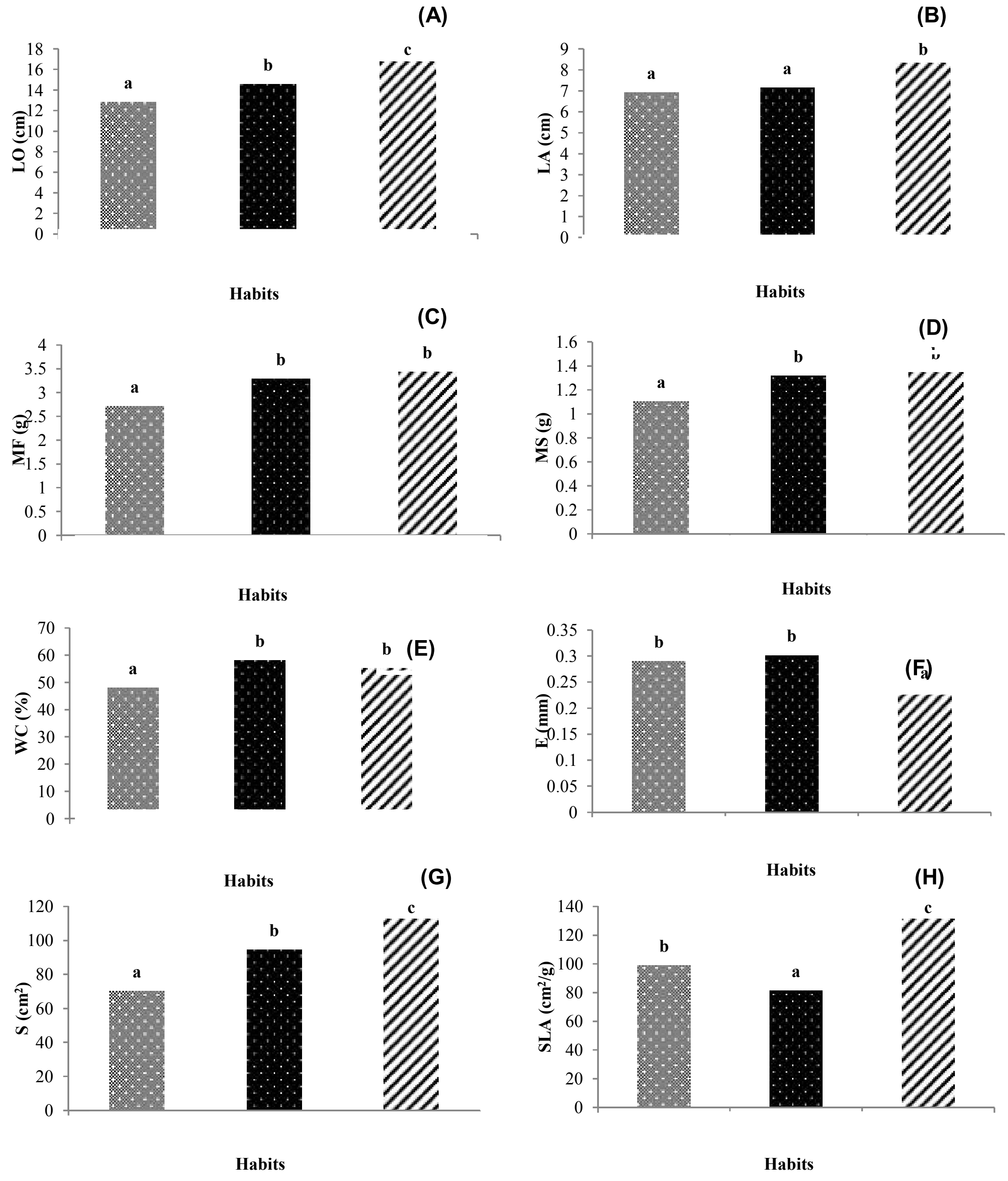
Table 3. Functional traits between life forms (trees and shrubs)

	Trees	Shrubs	F
Length (cm)	17,17±6,69^b	12,95±6,07^a	320,82***
Width (cm)	8,92±4,68^b	6,71±3,64^a	126,96***
Fresh mass (g)	3,35±2,15^b	2,86±1,196^a	86,25***
Dry mass (g)S	1,47±1,28^b	1,10±0,45^a	114,58***
Water content (%)	55,64±35,86^b	50,35±38,88^a	20,11***
Thickness (mm)	0,22±0,04^a	0,29±0,14^b	64,49***
Leaf area (cm^2)	114,91±100,60^b	73,90±67,12^a	158,3***
Specific leaf area (g.cm^{-2})	92,17±63,13^a	105,35±90,46^b	16,98***
Leaf dry mass content (g.g^{-1})	0,55±0,35^b	0,50±0,38^a	20,17***
Specific leaf mass (cm^2.g^{-1})	0,01±0,00^a	0,01±0,01^a	14,33ns
Density (g.mm^{-3})	0,07±0,04^b	0,05±0,04^a	36,12***
Height (m)	9,63±1,98^b	4,14±2,34^a	1442,80***

****P < 0.001; ns : non- significant*

3.4 Variations of the Functional Traits between Leaves Habits

As in the case of growth forms, the leaf features studied and the height of the individuals vary significantly (P< 0.001) between leaves habits, from 12.82 to 16.78 cm, 6.92 to 8.32 cm, 2.71 to 3.42 g, 1.10 to 1.34 g, 48.08 to 58.14%, 0.23 to 0.30 mm, 70.25 to 112.70 cm^2 , 81.53 to 131.50 cm^2. g^{-1}, 0.48 to 0.58 $g.g^{-1}$, 0.13 to 0.18 $g.cm^{-2}$, 0.05 to 0.06 $g.mm^{-3}$, and 5.03 to 6.96 m. These values are highest in evergreens for all leaf traits except for thickness, leaf dry matter content (LDMC), specific leaf mass (SLM) and density which are highest in semi-deciduous trees. And the lowest values were observed in deciduous trees for all traits except specific leaf area and height which are lowest in semi-deciduous trees.



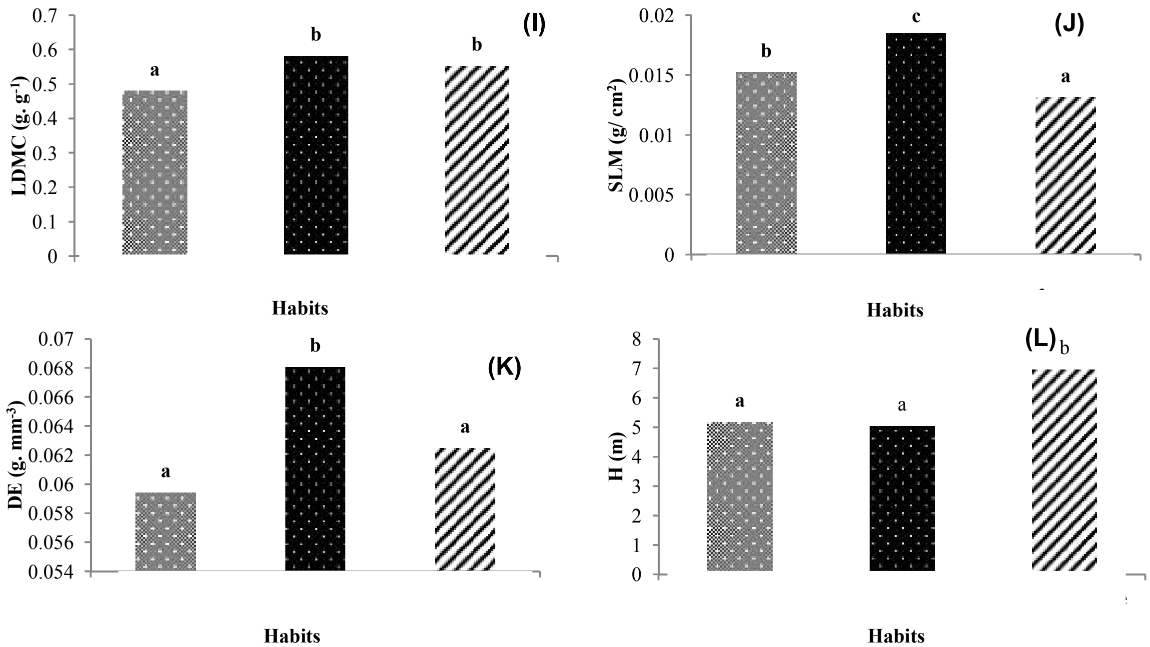


Fig. 2. Variations of the functional traits between habits

D= Gallery ; S-d= semi-decidous Savannah; E= evergreen

3.5 Variations of the Functional Traits According to Habitat

All functional leaf features and individual heights vary significantly (P<0.001) between habitats, from 13.27 to 18.60 cm, from 6.60 to 9.54 cm, from 2.38 to 3.95 g, from 1.13 to 1.54 g, from 49.36 to 61.97%, from 0.18 to 0.30 mm, from 76.87 to 127.47 cm^2 , from 95.55 to 108.20 $cm^2.g^{-1}$, from 0.49 to 0.61 $g.g^{-1}$, from 0.00 to 0.017 $g.cm^{-2}$, from 0.05 to 0.09 $g.mm^{-3}$, and 4.71 to 9.82 m. Only the thickness has the highest value in the savannah (0.30 mm) and the lowest in the plantation area (0.18 mm). For the other traits, their values are highest in forest gallery species, except for leaf length, specific leaf mass (SLM), density and height of individuals which are highest among species in the plantation area. The lowest values were observed in savannah species, with the exception of fresh mass, specific leaf area (SLA), which are the lowest among species in the plantation area. On the whole, the functional foliar traits are the weakest in savannah species.

3.6 Correlations among Leaf Functional Traits

Significant correlations were found for all plant traits (Table 4). Leaf length was positively correlated with leaf wide (r=0.697; $P < 0.05$), fresh mass (r=0.856 $P < 0.001$), dry mass (0.857 $P < 0.001$) and leaf area (r=0.886; $P < 0.001$) and negatively correlated with water content (r=-0.512; $P < 0.05$). Leaf wide was positively correlated with fresh mass (r=0.803; P < 0.001), dry mass (r=0.745; P < 0.001), leaf area (0.880; P < 0.001). Fresh mass was positively correlated with dry mass (r=0.970; P < 0.001), leaf area (r=0.935; P < 0.001) and negatively with water content (r=0.878; P < 0.001). Leaf thickness was negatively correlated with leaf density (r=-600; P < 0.01). Specific leaf area was negatively correlated with specific leaf mass (r=-0.773; P < 0.001) and lastly leaf dry matter content was positively correlated with leaf density (r=625; P < 0.01).

The first three components of the PCA explained 44.68%, 20.65% and 15.31% of leaf trait variation (Table 5). The first component was highly and negatively correlated to water content (WC), and highly and positively correlated to simple functional leaf traits as length (LO), wide (LA), fresh mass (MF), dry mass (MS), thickness (E), and area (S), and more weakly to tree height (HO), whereas the second component was highly and positively correlated to leaf dry matter content (LDMC), specific leaf mass (SLM), and density (DE), and negatively correlated to specific leaf area (SS) (Fig. 4a). The first components (F1) clustered the simple

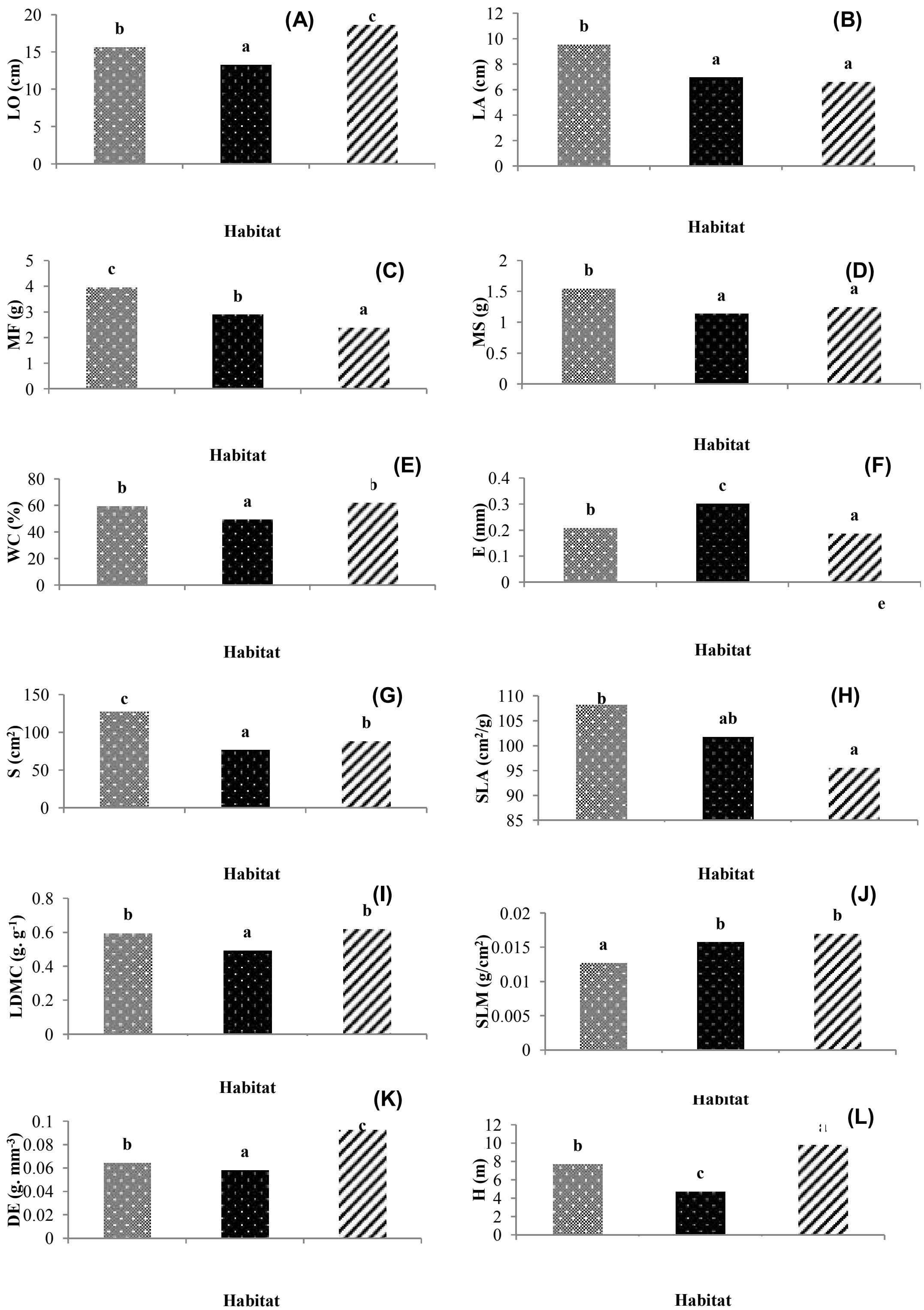


Fig. 3. Variations of the functional traits according to habitat
G= Forest gallery ; S= Savannah; P= Plantation

Table 4. Pair-wise relationships amongst 12 functional traits of 24 Ngaoundere savannah species. Values indicate Pearson's coefficient. Significant correlations at *P* < 0.001 are indicated in bold, in bold and italics *P* < 0.05

Variables	LO	LA	MF	MS	WC	E	S	SLA	LDMC	SLM	DE
LO	1										
LA	0,697	1									
MF	0,856	0,803	1								
MS	0,857	0,745	0,970	1							
TE	-0,512	-0,363	-0,506	-0,446	1						
E	0,249	0,293	0,477	0,455	-0,463	1					
S	0,886	0,880	0,935	0,878	-0,465	0,236	1				
SLA	-0,227	-0,156	-0,307	-0,413	0,116	-0,371	-0,165	1			
LDMC	-0,163	-0,281	-0,314	-0,147	0,471	-0,386	-0,271	-0,243	1		
SLM	0,183	0,105	0,267	0,391	-0,087	0,406	0,107	-0,773	0,381	1	
DE	-0,012	-0,195	-0,197	-0,067	0,343	-0,600	-0,135	-0,294	0,625	0,375	1
H	0,467	0,397	0,271	0,288	-0,161	-0,223	0,419	-0,156	-0,026	-0,121	0,1680

functional leaf traits as LO, LA, MF, MS, E, and S on the positive side, and leaf water content on the negative side of this axis, whereas the second components (F2) clustered the ratio mass as LDMC, SLM, and DE on the positive side, and the ratio area as SS on the negative side of this axis. Based on these results, species with high simple functional leaf as *T. macroptera* (TM) and *U. togoensis* (UT) were clustered on the positive side and species with high leaf water content as *P. febrifigun* (PF), *A. africanus* and *H. acida* (HA) were clustered on the negative side of the first axis of the ordination plot, whereas species with high specific leaf area (SLA) as *H. madagascariensis* (HM) on the negative side of the second axis (Fig. 1b).

Table 5. PCA components (variance explained) and loadings of leaf traits for a set of 24 species

Axis	LO	LA	MF	MS	WC	E	S	SLA	LDMC	SLM	DE	H
F1 (44,68%)	0,89	0,84	0,97	0,94	-0,62	0,53	0,93	-0,36	-0,35	0,29	-0,24	0,38
F2 (20,65%)	0,11	-0,05	0,02	0,19	0,298	-0,20	-0,01	-0,69	0,77	0,74	0,81	0,15
F3 (15,31%)	0,27	-0,23	-0,02	0,004	-0,19	0,77	-0,29	-0,41	-0,11	0,54	-0,35	-0,64
F4 (6,33%)	0,02	-0,19	-0,18	-0,17	-0,45	0,03	-0,17	-0,30	-0,21	0,01	0,04	0,54

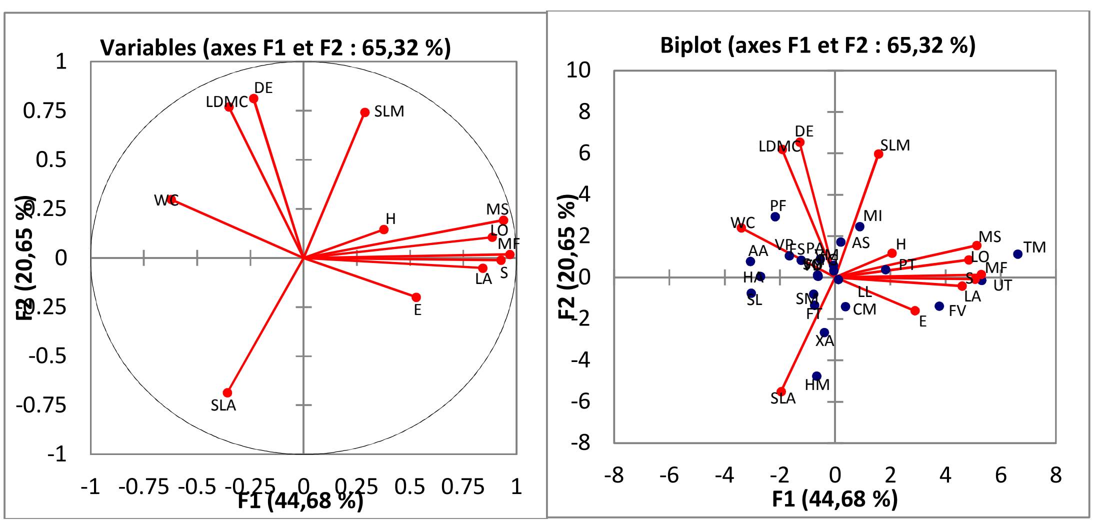


Fig. 4. Principal component analysis biplot of functional trait data for 24 species. Different symbols indicate grouping by different functional classifications: a.) relationships and b) Scores of leaf functional traits on the first and second axis

4. DISCUSSION

Weighing in the laboratory gives us details of the weight of the sheets. The structure of the leaves, the middle or a gradient can explain this difference. In relation to the fresh masses, the loss of water content the leaves does not lead to a change in the order of the mass values obtained here. It is true that just because a leaf is large (length, width, leaf area), it does not necessarily have a greater thickness than another small leaf. In this study, we find that a species like *A. africanus*, although having a generally small leaf area, has a large thickness. The explanation would be related to the tissues of these species. A thicker leaf has more photosynthetically active parenchyma.

The leaf area is a very important parameter for the plant. The larger it is, the greater the photosynthesis phenomenon is accentuated and the functioning of the plant is improved. It often varies according to the environment. Souto et al, [11] show in their study carried out on a tropical tree (*Embothrium coccineum*) that smaller and thicker leaves logically with their specific mass in response to increased heat and drought in summer. The explanation would be related to the tissues of these species. Smaller leaves limit transpiration while ensuring good photosynthesis of carbohydrates (Mapongmetsem et al.) [12]. Martin and Segalen [13] explain that the Adamaoua soil becomes less ferralitic as it moves towards the northern limit of the plateau. Nalovic and Pinta (1969-70) [14] on soils in Madagascar concluded that ferralitic soils are relatively richer than tropical ferruginous soils. The fact that length or width are positively correlated with other features such as mass, thickness or leaf area shows how they are related to each other.

The specific leaf area gives information on the capacity to capture the light resource of a plant: the larger the leaf area of the leaf, the greater the quantity of photons captured. In the relationship between them, an increase in specific surface area leads to a decrease in specific mass. Species in dry environments develop small, succulent leaves to limit water evaporation and will on average have a smaller specific leaf area (Larcher) [15]. Variations in specific leaf area, leaf area at the interspecific level are strongly dependent on the water content of the leaves (and therefore the dry matter content) Shipley [16]. They can also be due to differences in chemical composition and/or morphological **(**hairiness, thorns) (Lambers and Poorter) [17], i.e. variations related to an investment in tusks.

This variation in the leaf dry matter content of leaves is also conditioned by SLA. SLA, LDMC, leaf nitrogen content or leaf life vary during the year for a given species but the species ranking is nevertheless maintained within a measurement season (or year) (Garnier et al., [18], Al Haj Khaled et al., [19]). Leaves with high LDMC tend to be relatively tough (see Physical strength of leaves below) and are thus assumed to be more resistant to physical hazards (eg herbivory, wind, hail) than leaves with low LDMC. Some aspects of leaf water relations and flammability (see under Flammability) also depend on LDMC. Species with low LDMC tend to be associated with productive, often highly disturbed environments. In cases where leaf area is difficult to measure (see above), LDMC may give more meaningful results than SLA, although the two traits may not capture exactly the same functions. This trait gives an approximation of leaf tissue density and is correlated with the nutrient conservation strategy within the plant (Garnier et al.,) [20]. It is also related to water content (WC).

A study carried out on a tropical tree (*Embothrium coccineum*) revealed an increase in AML (smaller and thicker leaves) in response to increased heat and drought in summer [11] It increases when density generally increases in this study. Leaf density varies with SLM. However, as Witkowski and Lamont [21], pointed out, it is important to remember that the densest leaves are not always the leaves with the highest specific leaf area (SLA). Leaf density is related to SLA. The denser a leaf is, the smaller its specific leaf area is and vice versa. This is for example the case of *H. madagascariensis* which has a high SLA but a low DE. Low leaf densities could mean that the environment is productive and that we are in the presence of species exploiting the environment.

Woody trees in the tropical zone are generally not large. Height is a soft trait and helps to account for the strategies adopted by the species in the environment. It can account for more than 60% of the variations in the agronomic properties of the ecosystem. It also accounts for response strategies to fertility and use (Ansquer, 2006) [22]. Hallé and Oldeman, [23]; Hallé et al. [24] showed that, independently of species or families, plants can be grouped according to their development strategy.

The values of the single traits are lowest in the family Polygalaceae, except for the height which is lowest in Hymenocardiacea, and highest in Anacardiaceae for length, in Euphorbiaceae for width and leaf area, in Combretaceae for both wet and dry masses, in Caesalpiniaceae for leaf thickness, and finally in Loraceae for height. The ratios are the highest in the Sapindaceae for the water content and leaf dry matter content (LDMC), in the Clusiaceae for the specific leaf area, in the Annonaceae for the specific leaf mass (SLM), in the Annacardiaceae for the density. They are lowest in Olacaceae for water content, dry matter content and density, in Annonaceae for specific leaf area and in Polygalaceae for specific leaf mass.

The majority of pruning-related traits are associated with simple traits, despite the fact that traits such as leaf area is a trait of a report. They are all represented by polygalaceae which have small size values. The highest values are observed in families such as Combretaceae, Euphorbiaceae, Caesalpiniaceae and Annonaceae. Combretaceae are a plant family abundant in all Sahelo-Sudanian formations. It has about 20 gender and 475 species worldwide, including 9 gender and about 244 species in tropical Africa (Adjima, 2006) [25]. Density is also related to the size of the leaf since small leaves are often very dense.

The difference between tree and shrub is perceptible when observing the height of the individual, hence the significant difference observed between these two life forms. Thus, the features related to the size of the leaves are most represented by trees, except for some features such as thickness and specific leaf area which are represented by shrubs. The specific leaf mass does not differ significantly between the two life forms probably due to the low number of tree species (7 species) compared to shrubs (18 species); and since it is a ratio, the dry masses and leaf areas of the groups have been closer together. For the majority of the functional traits of this study, trees are the best represented, except for traits such as thickness, specific leaf area and specific leaf mass. All woody species in general, and all trees in particular, go through an ephemeral herbaceous stage, followed by a shrubby stage lasting a number of years (Becker et al.,) [26]. Shrubs could therefore be thought to be a juvenile stage of the tree. Growth forms or biological types are usually related to the type of foliage.

Functional traits are influenced by the leaf habits. This can be seen here when leaf size traits are associated with evergreen species, although traits such as thickness, leaf dry matter content, specific leaf mass and density are higher in semi-deciduous species. This is due to the fact that these species have foliage that is almost completely maintained throughout the year and in specific environments. Deciduous species have small leaf areas, but high densities because they are mostly shrubs that live mainly in the savannah. Semi-deciduous species have high water content but also a high thickness. On the other hand, despite a high water content for evergreen species, they have or contain low thicknesses in this study. This could be related to the tissues of each species.

Leaf size traits are mainly related to gallery forests and plantation areas. These are environments or habitats with predominantly large species called trees. The observation made in these different environments is that the leaves of the trees are also large. One explanation for this phenomenon is that the frequent availability of water and the quality of the soil create favourable conditions for each species to flourish. Cultivated (plantation) plants such as *M. indica* and *P. americana* also receive all the necessary elements for them to flourish in plantation areas, which is why they are classified as trees. Leaf size is generally related to the life form, leaf habit and leaf size is generally related to the life form, leaf habit and habitat of the species.

5. CONCLUSION

At the end of this study, Variations of the functional leaf traits in some agroforestry woody species of the sudano-guinea savannahs of Ngaoundere, Adamawa Cameroon: effects of plant taxonomy, life forms, habits and habitats, it emerges that all the morphological traits are correlated together in the Dang site. Interactions between families, life forms, leaf habits and habitats also reveals significants differences between functional traits of different species. A pioneer in Adamawa, Cameroon, this study brings a new approach to the fight against current climates changes. It therefore needs to be further developed for future studies.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Chalmandrier L. Phylogenetic conservatism of plant functional traits. Internship report. Report. 2010;31.
2. Violle C, Navas M-L, Vile D, Kazakou E, Fortunel C, Hummel I, Garnier E. Let the concept of trait be functional! Oikos. 2007;116:882–892.
3. Garnier E, Navas ML. Functional Diversity of Plants Brussels. ed De Boeck. 2013;64.
4. Loranger J, Prediction of leaf damage causes by invertebrate herbivores in an experimental meadow from plant traits. Thesis Presented to the Department of Biology with a view to obtaining the degree of Master of Science (M.Sc.). 2012;138.
5. Diatta M. Study of the carbon stock potential of agroforestry species and their functional traits in relation to land use systems in Senegal. Doctorate / Ph.D thesis. in forest sciences, Universite de Laval, Quebec Camnada. 2015;161.
6. 6 Mapongmetsem P. M. Phenology and contributions to the soil of biogenic compounds by the litter of wild fruit trees in the high Guinean savannas (Adamaoua, Cameroon). State doctoral thesis, University of Yaoundé I, Cameroon. 2005;168.
7. Ibrahima A, Biyanzi P, Halima M. Changes in organic compounds during leaf litter leaching: laboratory experiment on eight plant species of the Sudano-guinea Savannas of Ngaoundere, Cameroon, iForest. 2007;1:27-33;
8. Tchobsala. Influence of logging on the dynamics of natural vegetation in the peri-urban area of Ngaoundere (Adamawa). University of Yaoundé I, Cameroon, Doctoral Thesis PhD. 2010;204.
9. Cornelissen JHC, Lavorel S, Garnier E, Díaz S, Buchmann N, Gurvich DE, Reich PB, Ter Steege H, Morgan HD, Van der Heijden MGA, Pausas JG, Poorter H. A handbook of protocols for standardized and easy measurement of plant functional traits worldwide. Australian Journal of Botany. 2003;51:335-380.
10. Bitjoka L, Boukar O, Tenin D, Mbofung CMF, Tonye E. Digital camera images processing of hard-to-cook beans. Journal of Engineering and Technology Research. 2010;2(9):177–188
11. Souto C, Andrea C, Peter B. Complex bioclimatic and soil gradients shape leaf trait variation in Embotrium coccineum (Protaceae) among austral forests in Patagonia. in Revista Chilena de Historia Natural. 2009;82(2):209-222.
12. Mapongmetsem PM, Kapchie VN, Tefempam HB. Diversity of local fruit trees and their contribution in sustaining the rural livelihood in the northen Cameroon. Ethiopian Journal of Environmental Studies and Management. 2012;5(1):32-46
13. Martin D, Segalen P. Explanatory note. Soil map of eastern Cameroon at 1 / 1,000,000. Orstom, Yaoundé, Cameroon. 1996;10.
14. Nalovic L, Pinta M. Research on trace elements in tropical soils: study of some soils from Madagascar. Géoderina. 1969-1970;3(2):117-132.
15. Larcher W. Physiological plant ecology. Annals of Botany. 2003;93(5):513.
16. Shipley W. Structured intrerspecific determinants of specific leaf area in 34 species of herbaceous angiosperms. Functional Ecology. 1995;9:312–319.
17. Lambers H, Poorter H. Inherent Variation in Growth Rate Between Higher Plants: A Search for Physiological Causes and Ecological Consequences. Advances in Ecological Research. 1992;23:187-126.
18. Garnier E, Shipley B, Roumet C, Laurent G. A standardized protocol for the determination of specific leaf area and leaf dry matter. Functional Ecology. 2001;15:688–695.
19. Al haj Khaled R, Theau JP, Plantureux S, Cruz P. Variation in leaf characteristics depending on the season and levels of N availability and its consequences for the classification of grassland species. Journal of vegetation Science. 2005;16(4):391-398.
20. Garnier E, Cortez J, Billès G. Plant functional markers capture ecosystem properties during secondary succession. Ecology. 2004;85:2630-2637.
21. Witkowski ETE, Lamont BB. Leaf specific mass confounds leaf density and thickness. Oecologia. 1991;88:486-493.
22. Ansquer P. Agroecological characterization of natural grassland vegetation in response to agricultural practices. Contributions for the construction of diagnostic tools. Doctoral thesis from the National Polytechnic Institute of Toulouse, France. 2006;307.
23. Hallé F, Oldeman RAA. Essay on the architecture and growth dynamics of

tropical trees. Paris: Masson & Cie. 1970;178.
24. Hallé F, Oldeman RAA, Tomlinson PB. Tropical trees and forests: An architectural analysis. Berlin, Heidelberg, New York: Springer-Verlag. 1978; 441.
25. Adjima T, Marco S, Holger K, Sitaguinko. Influence of the climatic gradient on the distribution of Combretaceae species in Burkina Faso (West Africa). Candollea. 2006;61(1):189-213.
26. Becker M, Picard J-F, Timbal J, Germain G. Larousse des trees, shrubs and shrubs of Western Europe. Ed Masson, Educational editorial achievements, France. 1982;36.

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