Biophysical and structural vegetation characterization of *Moringa* agroecosystems in Sub-Saharan Africa: A Case from Far North-Cameroon

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Keywords: Biodiversity, Cameroon, *Moringa* agroecosystems, Structure.

Date of Acceptance 9/11/2021, Publication date 30/11/2021, http://m.elewa.org/Journals/about-japs/

1 ABSTRACT
The aim of this study was to assess the floristic composition and vegetation structure of *Moringa* agro-ecosystems in the Far North of Cameroon. The data were collected in 25 m x 25 m quadrat method was undertaken to measure floristic diversity through the use of species richness, Shannon index, Pielou equitability, Simpson index and importance value index. The vegetation structure is determined by density, basal area and regeneration rate. The inventory included trees with a dbh ≥ 5 cm on an area of 1 ha per plot. The experimental device installed is a split plot with 16 repetitions. A total of 10524 individuals distributed in 15 families, 22 genera and 29 species were recorded. Ecologically, the most dominant species are *Mangifera indica*; *Azadirachta indica* and *Acacia nilotica*. In addition, the grouping of species into three subdivisions (Diamaré, Mayo-Danay and Mayo-Tsanaga) showed that the Shannon diversity index varies from 0.63 - 0.67 bits, Pielou index varies from 0.63 - 0.67, Density ranges from 855 ± 21.69 – 1604 ± 50 stems/ha, basal area ranges from 26 ± 0.005 -11.83 ± 0.011 m²/ha. The diametric structure of the population reveals the predominance of individuals with a diameter of less than 5 cm (Diamaré) and 5-10 cm (Mayo-Danay and Mayo-Tsanaga) reflecting the abundance of individuals of small diameters. The regeneration rate varied on average from 25.14 % - 64.11 %. These results can be used as a reference in monitoring the vegetation dynamics of agroecosystems subject to recurrent droughts and anthropogenic pressures. This study provides a better understanding of the vegetation in agroecosystems in order to better manage these plant resources.

2 INTRODUCTION
Tropical forests are considered the world's largest reservoir of terrestrial biodiversity, both in terms of species and ecosystems (Issoufou *et al.*, 2019). However, forest areas decreased by 7 million hectares per year between 2000 and 2010 (FAO, 2016). This is caused by the high dependence of populations on natural resources (Jiagho *et al.*, 2016) in perpetual population growth combined with climate change (Diouf *et al.*, 2002). The ecosystems of the Sudano-Sahelian zone in the Far North of Cameroon do not remain on the margins of this strong degradation. This degradation of resources in this area is caused by human factors such as logging, agriculture, livestock, urbanization and bush fires, but also by climatic factors (MINEP, 2006; Ariori et Ozer, 2005). Faced with this observation, farmers have put in place protective

measures such as preservation; the domestication of species in agroecosystems (Kouakou *et al.*, 2017). Numerous scientific research projects in Cameroon have shown the potential of agroforestry in the sustainable management of biodiversity (Manfo *et al.*, 2015; Zapfack *et al.*, 2016; Mapongmetsem *et al.*, 2016; Noiha *et al.*, 2018; Temgoua *et al.*, 2018; Mandountsap *et al.*, 2017; Baye-Niwah *et al.*, 2020). Indeed, ecological interactions between trees/shrubs and crops are beneficial (Burgess *et al.*, 2004) because woody trees have an effect on soil fertility, organic matter production, and the recycling of soil nutrients, thus improving crop yields (Rivest *et al.*, 2007). They also protect the soil from water and wind erosion. In the Sudano-Sahelian zone in Far North in Cameroon, *Moringa oleifera* is cultivated extensively in association with vegetable crops, tubers and cereals (Baye-Niwah, 2015) with a view to diversifying the income from the sale of their outputs in order to also solve social problems (Rabo *et al.*, 2015) and therefore fight against food insecurity, poverty and unemployment.

Despite the richness of the work carried out on biodiversity, rare scientific studies have looked at the biophysical characterization of *Moringa oleifera* agroecosystems in the Far North of Cameroon. In order to contribute to the sustainable management of woody biodiversity, the objective of this study is to evaluate the composition, diversity, structure and regeneration rate of Moringa agroecosystems in the Far North of Cameroon.

3 MATERIALS AND METHODS

3.1 Study site description: The study was carried out in the Far North Region of Cameroon precisely in three subdivisions (Diamaré, Mayo-Danay and Mayo-Tsanaga) (Fig.1). This region is located between 10º and 13º North latitude and 12º and 15º East longitude (Bayé-Niwah and Mapongmetsem, 2014).The average annual temperature is 28°C and rainfall varies from 400 to 1000 mm (Seignobos et Iyebi Mandjeck, 2000).The climate is tropical Sudano-Sahelian (Morin, 2000).Woody and herbaceous vegetation has Sudanian savannahs, dry savannahs and steppes (Fotsing, 2009).Hydrography consists of periodically flooded rivers (Souare *et al.*, 2020). Soils in the Far North region are vertisol, hardy, sandy, rocky and muddy (FAO, 2011).

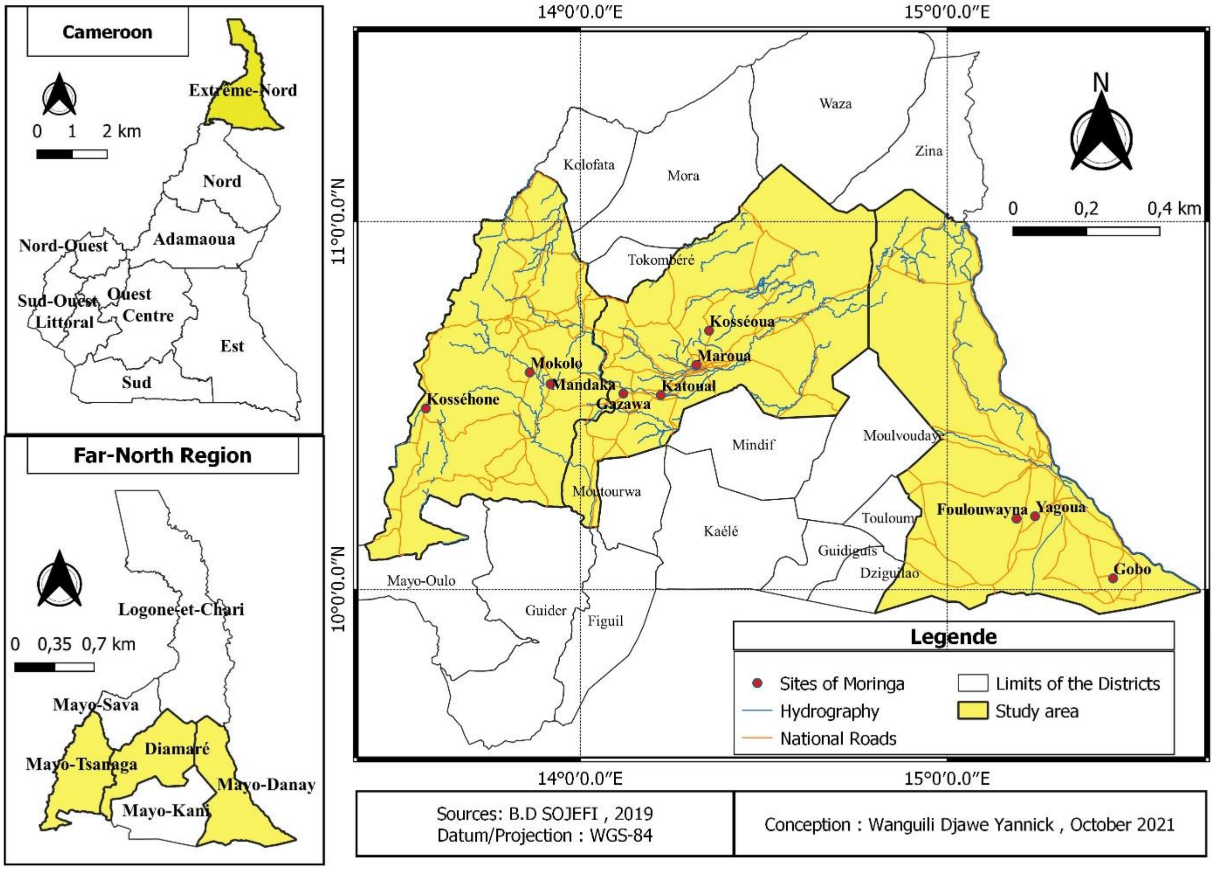


Fig. 1: The geographic location of the study area in the Far North Region of Cameroon.

3.2 Data collection

***3.2.1 Choice of study sites and experimental design**:* The socio-economic importance, availability, age, density and area of Moringa gardens and fields are among other reasons for the choice of the Diamaré, Mayo-Danay and Mayo-Tsanaga subdivisions to make comparative analyses of floristic and structural diversity. Three types of Moringa agroecosystems were selected according to the age groups based on observations made by farmers to examine its dynamics (0-5 years; 6-10 years and over 10 years). The experimental device is a split plot with two factors whose main treatments constitute the study subdivisions (Diamaré, Mayo-Danay and Mayo-Tsanaga) and the secondary treatments are the three types of Moringa agroecosystems selected according to the age groups (0-5 years; 6-10 years and over 10 years) chosen in each subdivisions. Quadrats of 25 m x 25 m are repetitions.

3.2.2 Sampling methods: The quadrat method was used to assess floristic diversity in Moringa garden and field surfaces. Sampling was carried out in the 25m x 25 m (625 m²) plots using the method developed by Hall and Swaine, 1976. This method has been successfully used by several authors such as (Hall and Swaine, 1981; Kokou,1998; Zapfack *et al.*, 2002; Adjonou *et al.*, 2009; Adjonou *et al.*, 2010; Noiha *et al.*, 2015, 2018; Adjonou *et al.*, 2016; Mandounstap *et al.*, 2017; Awé *et al.*, 2019). A total of 288 plots have been installed. Sampling bands were established using compass, decameter, GPS and twine. At the ends of each strip, the stakes were marked equidistant 5 m from the base. At each distance of 5 m, all woody areas were systematically counted, identified and measured. The circumferences of woody trees were measured at 1.30 m above the ground for large trees and 30 cm above the ground for shrubs and for ramified

individuals below 30 cm from the ground. Thus each branched branch is considered an individual. Individuals with a circumference of less than 15.7 cm (or diameter <5 cm) are classified as potential regeneration (Mbayngone *et al.*, 2017). For unidentified species, herbarium samples were made to authenticate the scientific names of other botanists at the University of Maroua and using an appropriate literature manual (Arbonnier, 2000). The circumference values were then converted to diameter (DBH) according to the formula:
$C = \pi D$, with C = circumference, D = diameter, and $\pi = 3.14$.

3.2.3 Characterization of flora and vegetation: The analysis of the plant diversity focused on:

Specifics richness (N): $N = 2^H$; 2 is the basis of the logarithm used to calculate the Shannon-Wiener's index (H) (Mbaiyetom *et al.*, 2021).

Shannon-Wiener's Index (H) : $H = -\Sigma (ni/Ni) * \log_2 (ni/Ni)$ (Frontier & Pichod-viale, 1992) with ni = number of species i, Ni = effective of all species; H is expressed in bit.

Piélou index (E) : $E = H/\log_2 N$ (Piélou, 1996)

Density (D): $D = N/ S$ (Noiha *et al.*, 2017b)
D: density (in trees / ha), N: number of trees present on the surface considered and S: surface area (ha).

Basal area (Ba): $Ba = di^2(Pi/4)$ (di = diameter, Pi = 3.14) (Noiha *et al.*, 2017b)

Relative frequency (RFi) was determined by using the formula: $RFi = AFi / TF \times 100$
Where AFi=Absolute frequency of species and TF = Total Frequency (Sum of AFi).

Relative density (RDi) was determined by using the formula: $RDi = ADi / AD \times 100$
Where ADi = Absolute density of species and AD = Absolute density.

Relative Dominance or Cover (RCi) was determined by using the formula: $RCi = BAi / TBA \times 100$.
Where BAi = Basal area of species and TBA = Total basal area.

Species Importance Value (SIV) of a species was calculated by adding the Relative frequency (RFi), Relative density (RDi) and Relative dominance (RCi) (Curtis *et al.*, 1950).

Distribution by diameter class was adopted to assess the dynamics and evolutionary trends of these stands (Mbayngone *et al.*, 2008). It was distributed as histograms constructed from the observed densities of diameter classes of amplitude equal to 5 cm. The observed densities are calculated by diameter classes and arranged as follows: Class 1 or class of juvenile individuals = <5 cm; Class 2: 5-<10 cm; Class 3: 10-<15 cm; Class 4: 15-<20 cm; Class 5: 20- <25 cm; Class 6: 25-30 cm; Class 7: 30-35 cm; Class 8: 40-45cm.
The regeneration rate (Poupon, 1970). TR (%) = (Number of individuals with diameters ≤ 5cm / Number of individuals with diameters > 5cm) × 100

3.3 Data Analysis: The Excel spreadsheet was used to present the results in the form of histograms, curves and tables. The Analysis of Variance (ANOVA) was carried out using Xlstat 2020 version 5.0, to compare the means of the different parameters studied. In the event of a significant difference between these different parameters calculated for each age group, Turkey's multiple comparison tests was used to compare the means of each parameter at the 5% significance threshold.

4 RESULTS

4.1 Specific riches and diversity: In the three subdivisions, the specific composition of Moringa agroforestry systems varies according to the number of individuals and species (Table 1). The total woody flora identified in these three subdivisions contained 10524 individuals in 15 families, 22 genera and 29 species. The agroecosystems of the Diamaré subdivision are richer in phytodiversity. It is followed by Mayo-Danay and Mayo-Tsanaga subdivisions (Table 1).

Table 1: Comparative studies of the floristic composition according to subdivisions and by site.

Subdivisions	Ages	Families	Genera	Species	Ni
Diamaré	**0-5 years**	9	12	11	1604

	6-10 years	8	8	8	1216
	+ 10 years	10	11	12	907
	Total	14	16	21	3727
Mayo-Danay	0-5 years	8	9	9	1440
	6-10 years	7	6	7	1067
	+ 10 years	7	8	8	1007
	Total	10	14	15	3512
Mayo-Tsanaga	0-5 years	8	9	10	1356
	6-10 years	6	7	10	1074
	+ 10 years	3	3	3	855
	Total	10	10	13	3285
Overall total		**15**	**22**	**29**	**10524**

Ni : Number of individuals.

4.2 Abundance of species and families of Moringa agroecosystems in according to subdivisions: The result of Table 2 shows that *Moringa oleifera* represent 87.06 % to 89.29 % of the total number of species present in the agroecosystems studied (Table 2). The most represented woody species companions are *Azadirachta indica* (3.65%) in the Diamaré subdivisions; *Acacia nilotica* (4.04%), in the Mayo-Danay subdivisions and *Azadirachta indica* (4.29%) in the Mayo-Tsanaga subdivisions.

Table 2: Specific contribution of species according to the subdivisions studied.

Subdivisions / Species	Diamaré	Mayo-Danay	Mayo-Tsanaga
Acacia nilotica (L.) Willd. ex Del.	0.17	4.04	0.94
Acacia senegal (L.) Willd.	0.10		0.24
Acacia seyal Del.	0.14		0.27
Acacia sieberiana DC.	0.59		0.21
Alchornea cordifolia (Schumach. &Thonn.) Müll. Arg	0.13		
Anacardium occidentale L.		0.06	
Azadirachta indica A. Juss.	3.65	0.85	4.29
Balanites aegyptiaca (L.) Del.	0.08	0.085	
Bixa orellana L.			0.12
Borassus aethiopum Mart.	0.24	0.54	
Calotropis procera (Ait.) Ait. f.	1.25	0.83	
Carica papaya L.	1.02	1.45	1.59
Citrus aurantifolia (Christm.) Swingle		0.14	
Citrus limon (L.) Burm. f.	0.027	0.34	
Citrus medica L.	0.46		
Citrus sinensis (L.) Osbeck	0.19		
Commiphora kerstinjii Engl.			0.030
Delonix regia (Boj.) Raf.		0,68	
Detarium microcarpum Guill. &Perr.	0.54		
Faidherbia albida (Del.) Chev.	0.10		0.15
Guiera senegalensis J.F. Gmel.	2.04		
Mangifera indica L.	0.48	2.48	1.07
Manihot esculenta Crantz.	1.18		
Moringa oleifera Lam.	87.06	88.13	89.29
Parkia biglobosa (Jacq.) R. Br. ex G. Don		0.085	
Phoenix dactylifera L.		0.06	

Piliostigma reticulatum (DC.) Hochst.	0.08		
Senna siamea (Lam.) Irwin & Barneby			0.15
Ziziphus mauritiana Lam.	0.48	0.23	1.65
Overall total	100	100	100

*In bold represents species with a high representativeness by subdivisions studied.

At the Family level, the companion families most represented in the agroecosystems of the three subdivisions studied are among others (Table 3): Meliaceae (3.65%) in Diamaré subdivisions, Mimosaceae (4.125%) in Mayo-Danay subdivisions and Meliaceae (4.29%).

Table 3: Specific contribution of families according to the subdivisions studied.

Subdivisions / **Famillies**	**Diamaré**	**Mayo-Danay**	**Mayo-Tsanaga**
Anacardiaceae	0.48	**2.54**	**1.07**
Arecaceae	0.24	0.6	
Asclepiadaceae	**1.25**	**0.83**	
Balanitaceae	0.08	0.085	
Bixaceae			0.12
Burseraceae			0.030
Caesalpiniaceae	0.62	0.68	
Caricaceae	1.02	**1.45**	**1.59**
Combretaceae	**2.04**		
Euphorbiaceae	**1.31**		
Meliaceae	**3.65**	**0.85**	**4.29**
Mimosaceae	**1.10**	**4.125**	**1.81**
Moringaceae	**87.06**	**88.13**	**89.29**
Rhamnaceae	0.48	0.23	**1.65**
Rutaceae	0.677	0.48	
overall general	**100**	**100**	**100**

*In bold represents families with a high representativeness by subdivisions studied.

4.3 Diversity Index and Pielou's index:

The ISH values vary from 2.95 - 3.20 bits in the Diamaré subdivisions, from 3 bits to 3.15 bits in the Mayo-Danay subdivisions and from 2.93-3.13 bits in the Mayo-Tsanaga subdivisions (Table 4). Pielou's index does not vary significantly with mean values between 0.63 and 0.65 (F=0.000; p=1.00>0.005).

Table 4: Diversity indices by subdivisions and age group of Moringa agroecosystems.

Subdivisions	**Diamaré**		**Mayo-Danay**		**Mayo-Tsanaga**	
Parcels (Ages)	**ISH**	**EQ**	**ISH**	**EQ**	**ISH**	**EQ**
0-5 years	3.20±0.003^{a}	0.67±0.01^{a}	3.15±0.002^{a}	0.65±0.01^{a}	3.13±0.002^{ab}	0.63±0.01^{a}
6-10 years	3.08±0.005^{a}	0.67±0.01^{a}	3.02±0.002^{a}	0.65±0.01^{a}	3.03±0.001^{ab}	0.63±0.01^{a}
+ 10 years	2.95±0.002^{a}	0.67±0.01^{a}	3.00±0.002^{a}	0.65±0.01^{a}	2.93±0.003^{a}	0.63±0.01^{a}
Total (M±E)	3.07±0.010	0.67±0.03	3.05±0.06	0.65±0.03	3,03±0.006	0.63±0.03
F	4.086	0.000	0.99	0.000	6.910	0.000
P (Value)	0.58	1.000	0.406	1.000	0.007	1.000

*For each column, the assigned mean values of the same letter are not significantly different at the 5% threshold (Tukey test). ISH: Shannon Index; EQ: Piélou's equitability; Total (M±E): Average ± type range total.

4.4 Ecological importance of the most represented species: The Species Importance Value (SIV) (Table 5) is dominated by *Moringa oleifera* in the three subdivisions (212.19 % in Diamaré, 199.22 % in Mayo-Danay and 211.04 % in Mayo Tsanaga). This species is followed by *Mangifera indica* (15.48 %) in the Diamaré subdivision; *Acacia nilotica* (18.84 %) in Mayo-Danay subdivision and *Mangifera indica* (23.165 %) in the Mayo-Tsanaga subdivision.

Table 5: Ecologically important species in Moringa agroecosystems of the three subdivisions (SIV).

Subdivisions	Species	RFi	RDi	RCi	IVI
Diamaré	*Moringa oleifera*	40.41	84.64	87.14	212.19
	Mangifera indica	6.85	8.15	0.48	15.48
	Azadirachta indica	9.28	1.46	3.64	14.38
	Calotropis procera	6.85	0.18	1.23	8.26
	Carica papaya	2.01	3.98	1.019	7.01
Mayo-Danay	*Moringa oleifera*	28.56	82.49	88.17	199.22
	Acacia nilotica	12.27	2.53	4.04	18.84
	Mangifera indica	8.83	1.82	2.47	13.12
	Azadirachta indica	8.83	1.53	0.85	11.21
	Carica papaya	7.12	0,67	1.45	9.24
Mayo-Tsanaga	*Moringa oleifera*	33.28	88.44	89.32	211.04
	Mangifera indica	15.28	6.82	1.065	23.165
	Azadirachta indica	15.28	0.65	4.29	20.22
	Carica papaya	4.31	2.30	1.58	8.19
	Acacia nilotica	6.64	0.013	0.94	7.59

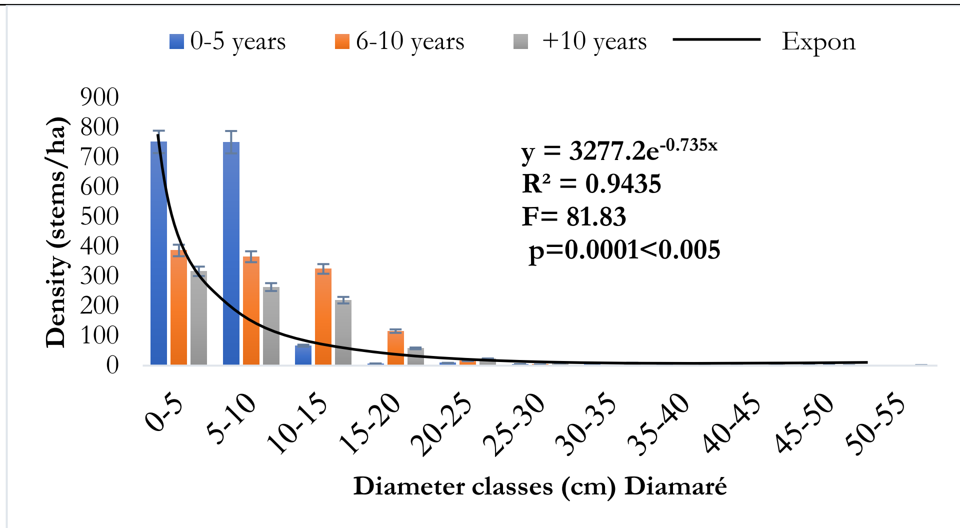
4.5 Density and Basal area: In the three subdivisions, the basal area and density of Moringa agroforestry systems vary according to age and subdivisions (Table 6). The total basal area is higher in the Mayo-Tsanaga subdivisions with 22.56 m²/3ha and the highest density was observed in the Diamaré subdivisions with 3727 individuals/3ha. Plots less than 5 years old have high densities in all subdivisions (1356 - 1604 stems/ha) while the largest basal areas are found in plots of 6 to 10 years (4.89 m²/ha in the Diamaré subdivisions) and more than 10 years (8.61 m²/ha and 11.83m²/ha respectively for Mayo-Danay and Mayo-Tsanaga subdivisions).

Table 6: Density and basal area of Moringa agroecosystems according to subdivisions

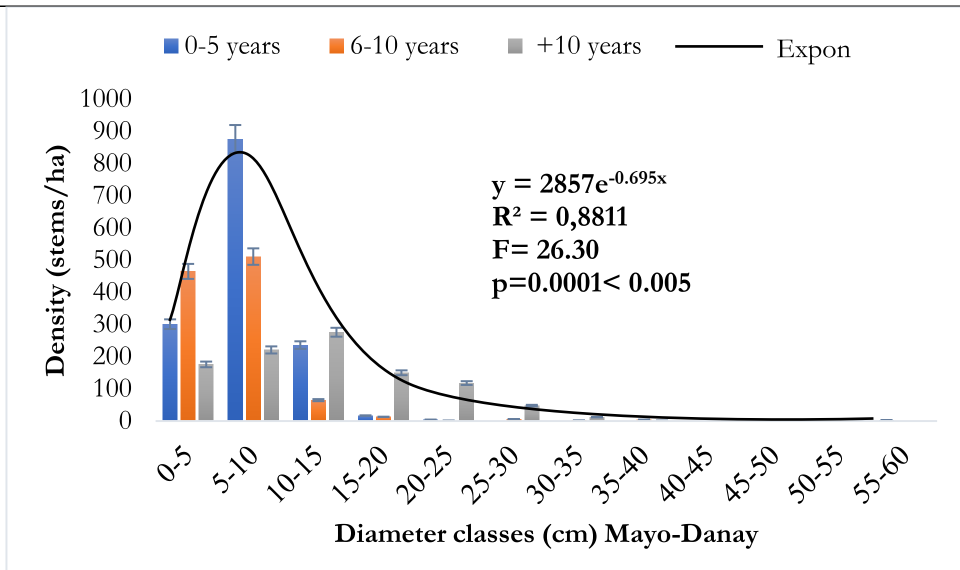
Subdivisions	**Diamaré**		**Mayo-Danay**		**Mayo-Tsanaga**	
Sites	**BA**	**Density**	**BA**	**Density**	**BA**	**Density**
0-5 years	3.38±0.003^{a}	1604±50^{b}	4.30±0.008^{b}	1440±27.32^{c}	3.10±0.006^{a}	1356±43.03^{b}
6-10 years	4.89±0.009^{c}	1216±38.59^{a}	2.26±0.005^{a}	1067±25.73^{b}	7.61±0.007^{b}	1074±25.30^{a}
+ 10 years	4.26±0.006^{b}	907±21.36^{a}	8.61±0.010^{c}	1005±18.96^{a}	11.83±0.01^{b}	855±21.69^{a}
Overall total	**12.53±0.018**	**3727±109.95**	**15.18±0.023**	**3512±72.01**	**22.56±0.023**	**3285±90.02**
R²	0.994	0.539	1.000	1.000	0.511	0.543
F	116.75	8.770	185.47	332.19	7.827	8.904
Pr > F	<0.0001	0.003	<0.0001	<0.0001	0.005	0.003

* For each column, the mean values assigned the same letter are not significantly different at the 5% threshold (Tukey test) by subdivisions and by site. BA: Basal Area.

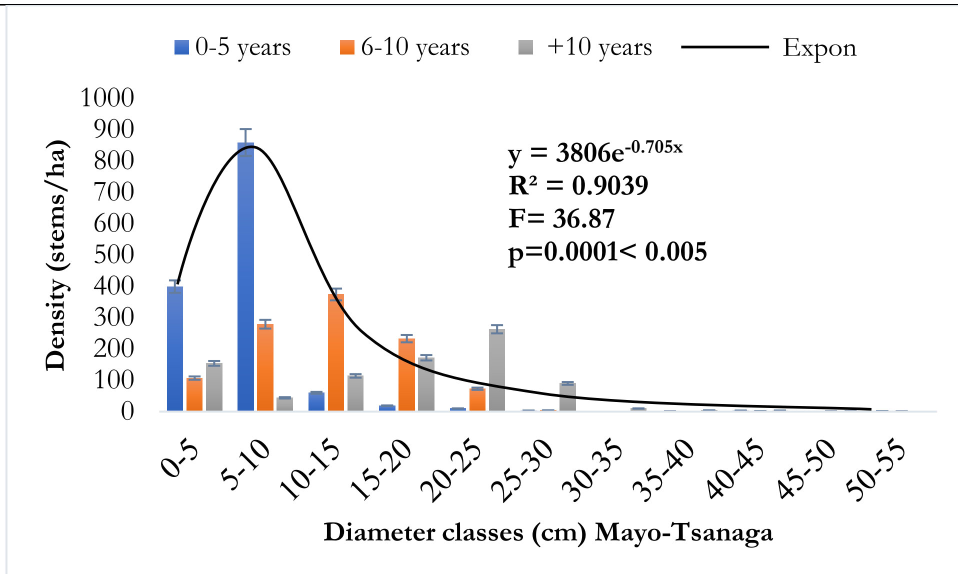
4.6 Diametric structure of woody stands in agroecosystems according to the subdivisions studied.: The distribution of individuals of woody species by diameter class generally has an inverted "J" shape, decreasing exponentially in the Diamaré subdivisions and a decreasing "Bell" shape in Mayo-Danay and Mayo-Tsanaga subdivisions where the young individuals of small diameter (<5cm in Diamaré subdivisions and 5>Dbh≤10 cm in Mayo-Danay subdivisions and Mayo-Tsanaga subdivisions) are in greater proportion in all the subdivisions studied. The analysis of the structure shows a significant difference (0.0001 <0.005) in the three subdivisions. Individuals with a diameter greater than 30 cm are rare as in all subdivisions (Fig.2).



A



B



C

Fig. 2. Diametric distribution of individuals of woody species in the different agroecosystems by subdivisions studied: A: Diamaré; B: Mayo-Danay; C: Mayo-Tsanaga.

4.7 Regeneration rate: In the three subdivisions, the juvenile density and the regeneration rate of agroecosystems in Moringa vary according to age and subdivisions (Table 7). The regeneration rate is high in Diamaré (64.11%) and low in Mayo-Tsanaga (25.14%). The highest regeneration rates are observed in plots of less than 5 years (88.26%) in Diamaré, Mayo-Tsanaga (41.69%) and in plots of 6 to 10 years in Mayo- Danay (77.24%) (Table 7).

Table 7: Comparative studies of the density and rate of regeneration according to the subdivisions and by agroecosystems sites.

Subdivisions	Sites	Regeneration	Adults	R (%)
Diamaré	(0-5 years)	752±19.25c	852±21.80b	88.26
	(6-10years)	387±9.90b	829±21.22b	46.68
	(+10 years)	317±8.10a	590±15.10a	53.72
	Total	**1456**	**2271**	**64.11**
	F et p value	F=81.83 ; p=0.0000	F=31.57 ; p=0.006	
Mayo-Danay	(0-5 years)	301±7.70b	1139±29.15c	26.42
	(6-10 years)	465±11.90c	602±15.41a	77.24
	(+10 years)	176±4.50a	829±21.22b	21.23
	Total	**942**	**2570**	**36.65**
	F et p value	F=31.51 ; p=0,0000	F=108.9 ; p=0,0000	
Mayo-Tsanaga	(0-5 years)	399±10.21c	957±24.49b	41.69
	(6-10 years)	107±2.73a	967±24.75b	11.06
	(+10 years)	154±3.94b	701±17.94a	21.96
	Total	**660**	**2625**	**25.14**
	F et p value	F=36.87 ; p=0.0000	F=34.09 ; p=0.003	

* For each column, affected average values of the same letter are not significantly different at the 5% threshold (Tukey test) by subdivisions and sites. R (%): Regeneration rate or renewal rate expressed as a percentage.

5 DISCUSSION

5.1 Specific riches and diversity: The total woody flora recorded in these three subdivisions contained 10.524 individuals divided into 15 families, 22 genera and 29 species. This result is lower than those of Awé *et al.* (2021) in Cashew Agro-ecosystems in North-Cameroon (38 species) but higher than those of Madountsap *et al.* (2017) in Cocoa Agroforests in the Central region of Cameroon (21 species). Moringa agroecosystems in the Diamaré subdivisions are richer in terms of phytodiversity compared to other subdivisions, due to the fact that, these farmers of this subdivision associate with the endogenous species conserved more exotic species useful in the fields of Moringa and their choices being guided through commercial, food and therapeutic opportunities. Regarding species abundance, the term 'agroecosystem Moringa' agroforestry systems for the fields is justified by the fact that he alone *Moringa oleifera* represent more than 87.06% to 89.29 % of the total number of woody plants saved or introduced into the fields in the three subdivisions studied. Moreover, the abundance of these species (*Acacia nilotica*, *Azadirachta indica*, *Mangifera indica*, *Carica papaya*, *Manihot esculenta*, *Ziziphus mauritiana*), shows the importance that farmers give to species used as hedge or windbreak (*Acacia nilotica*) as firewood or shade (A*zadirachta indica*), as edible tubers (*Manihot esculenta*) and as fruit (*Mangifera indica*, *Carica papaya*, *Ziziphus mauritiana*) providers of large income. These species were also observed by Baye-Niwah *et al.* (2020) in the agricultural systems of the Far North Cameroon.

5.2 Diversity Index and Pielou's equitability: The ISH values of between 2.93 - 3.20 bits in all the subdivisions reflect an average diversity of Moringa agroecosystems. These ISH values obtained are similar to that found by Noiha *et al.* (2017a) in North Cameroon; Dan Guimbo *et al.* (2010) in southwestern Niger; Noumi *et al.* (2018) in the same area of the Far North Cameroon. Pielou index values between 0.63 and 0.67 show a less equitable distribution of individuals within woody stands. This fairness value is caused by the great predominance of the *Moringa oleifera* species (more than 87% representativeness) requested because of its filtering crown and less shade for the growth of vegetable crops to the detriment of other woody species. This fairness value is contrary to those of Noiha *et al.* (2017a) Noumi *et al.* (2018); Ali *et al.* (2017) in Niger who found an equitable distribution of individuals in agroecosystems.

5.3 Species Importance Value (SIV): The high Importance Value Index of *Mangifera indica*, *Azadirachta indica*, *Carica papaya* and *Acacia nilotica* suggests that the environmental conditions are favorable to them and their socioeconomic importance favors their conservation in agroecosystems.

5.4 Density and Basal area: The total basal area is higher in the Mayo-Tsanaga subdivisions (22.56 m²/3ha) compared to other subdivisions while the highest density was observed in the Diamaré subdivisions with 3727 individuals/3ha. This difference in density and basal area between the subdivisions could be linked to ecological characteristics such as the type of soil, topography, rainfall and the mode of management of agricultural land by farmers (level of thinning intensity in the fields). The high density in plots less than 5 years old in all subdivisions (1356 - 1604 stems/ha) could be explained by the reduced distances between tree feet, while the largest basal areas found in the plots from 6 - 10 years (4.89 m²/ha in the Diamaré subdivisions) and over 10 years (8.61 m²/ha and 11.83 m²/ ha respectively for Mayo-Danay and Mayo-Tsanaga subdivisions) could be explained by the existence of large diameter trees. The basal area results are similar to Ngarnougber *et al.* (2017) in Chad; Natta *et al.* (2012) in Benin. The density values are higher than Bayé-Niwah *et al.* (2020) in the Far North Cameroon; Mbaygone *et al.* (2017) in Chad.

5.5 Diametric structure of woody stands in agroecosystems according to the subdivisions studied. The diametral structure showed that the stand regenerates well thanks to the large representation of young individuals (<5cm in Diamaré and 5> Dbh≤10 cm in Mayo-

Danay and Mayo-Tsanaga). This structure is typical of natural formations in which the density of plants is generally high. The "L" structure in Diamaré is comparable to the type of distribution obtained by Noiha *et al.* (2017a) in North Cameroon); Bayabe Il, (2020) in the Far North Cameroon, Wala *et al.* (2005) in Togo. This structure also would demonstrate the selective removal of larger diameter trees by the managers of these gardens and fields, which would justify the rarity of class species greater than 30 cm in Moringa agroecosystems. The shape of the diametric distribution obtained in Mayo-Danay and Mayo-Tsanaga is similar to Ngarnougber *et al.* (2017) in Chad and Froumsia *et al.* (2012) in the Far North Cameroon. Individuals with a diameter of more than 30 cm are rare in all the subdivisions, characteristic of predominantly shrub vegetation.

5.6 Regeneration rate: The regeneration rate is high in Diamaré (64.11 %) reflects the strong concern of farmers to rejuvenate the woody species conserved or introduced in Moringa agroecosystems. The low regeneration rate in Mayo-Tsanaga (25.14 %) reflects maintenance agricultural practices (weeding, use of phytosanitary products) which eliminate woody regeneration individuals in the fields and gardens of Moringa agroecosystems. These results are similar to the work of Bayabe Il, (2020) in the reforested sites of the Ouro-Dabang site (27.74 %), Tcherféké (34.09 %) and Boboyo (19.55 %). However, regeneration in Moringa agroecosystems is a function of the desired species and the desired density.

6 CONCLUSION

This study has enabled to make a species richness evaluation, structure, indexes and regeneration rates of Moringa agroecosystems in the Far North of Cameroon. The results have identified 10524 individuals distributed in 15 families, 22 genera and 29 species with a dominance of *Mangifera indica*; *Azadirachta indica* and *Acacia nilotica*. The presence of important species in agricultural systems on base Moringa (ISH = 3.03 - 3.07 bits) proves that these fields are real biodiversity reserves. The results showed that the species richness index, density, basal area varies with age and according agroecosystems subdivisions. This is due to the different ecological characteristics such as the type of soil, topography, rainfall and the way in which agricultural land is managed by farmers. The diametric structure has shown that farmers tend to regenerate the woody stand. This regeneration of Moringa agroecosystems depends on the species desired to be conserved or introduced and the density desired by the farmers. However, sensitization of farmers to the safeguard of existing scattered local species and the planting of ex-situ seedlings are important for the conservation and survival of certain vulnerable species having a low abundance in the plots.

7 ACKNOWLEDGEMENTS

The authors thank all the agricultural producers who agreed to participate in this study.

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