

Full Length Research Paper

Floristic diversity and regeneration of wild edible fruit species in the Reserve of Moutourwa and its surroundings (Far-North Cameroon)

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In order to assess the diversity, regeneration and structure of wild edible fruit trees, a study was carried out in the Laf-Madjam forest reserve and its surroundings. A semi-structured interview with local residents and a floristic inventory of woody plants (8 transects of 1000 m × 20 m each) were carried out. 24 species were cited as being used by the local residents. A total of 2134 individuals subdivided into 69 species, 43 genera and 27 families were counted, including 448 edible fruit individuals divided into 25 species, 19 genera and 14 families. The latter with important IVIs are: *Balanites aegyptiaca*, *Sclerocarya birrea*, *Ziziphus mauritiana* and *Hexalobus monopetalus*. Diversity is medium in edible fruit trees (HSI=3.10 bits, E= 0.67). Fruit trees with individuals of diameter ≥ 21 cm are in the majority. Inverted "L" and bell-shaped gaits are observed. The regeneration rate of fruit trees is higher in *Annona senegalensis*, *H. monopetalus*, and *B. aegyptiaca*. The involvement of local people in the management of the reserve's fruit trees is important for sustainable management.

Key words: Edible fruits, Moutourwa, sustainable management, structure, phytodiversity.

INTRODUCTION

The Central Africa forests are sources of income for the countries of the sub-region in both the formal and informal sectors (Eba'a et al., 2011). In most countries of the Congo Basin, the exploitation of forest resources remains the main provider of private wage employment, particularly in remote rural areas. Most scientific work

recognises many benefits of forests, which are classified under the theme of ecosystem services (M.E.A, 2005; Arrif et al., 2011). These services include reducing air pollutants (Nowak et al., 2006), reducing heat islands (Akbari et al., 2001), enhancing precipitation and CO₂ absorption, regulating local climate and mitigating global

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climate change (Laporte and Cordeau, 2007). They also improve the environmental quality of localities on which people's health depends (Jim and Chen, 2008).

In addition, more than half of the world's population lives in urban areas and uses forest resources to meet their needs (Véron, 2007). These high anthropogenic activities are very accentuated and the direct consequence is the marked deterioration of these resources on green spaces. The phenomenon is more noticeable in developing countries, where the sensitivity of city dwellers to the presence of vegetation becomes weaker as the city becomes more densely built (Rusterholz, 2003). This environmentally damaging situation is also observed in Cameroon (Wolff, 2005). The creation of protected areas in Cameroon is in line with the government's desire to preserve ecosystems in order to maintain biological diversity. The Government of Cameroon's objective in terms of biodiversity conservation is to eventually convert 30% of the national territory into protected areas. These include national parks, nature reserves, and zoos (Tieguhong and Betti, 2008). In Cameroon, the total area of protected areas covers more than 17% of the national territory. They are located in both forest and savannah ecosystems. The Far North Region in particular, characterised by a low vegetation cover and very aggressive, has a vast network of protected areas made up of 5 forest reserves and 3 national parks which are also subject to strong anthropic pressure for the exploitation of resources (Wafo, 2008; Fotsing, 2009). The boundaries of the protected areas have greatly regressed and are poorly managed, and the lack of involvement of local populations in management is noticeable (Barbault, 2007). The reserves in the Far North Region, such as those in the Moutourwa locality, have been the scene of abusive exploitation of resources for decades. The latter, despite its status, is threatened by human activity, further accentuated by the unsustainable exploitation of plant species in general and edible fruit trees in particular.

The dry zones of sub-Saharan Africa are characterized by a long dry season and a short rainy season each year. In addition, the Far North Region of Cameroon is characterized by a population explosion and aridity of the soil. This situation is partly responsible for the scarcity of foodstuffs. The populations living in the vicinity of the Laf-Madjam reserve enter this reserve to collect non-timber forest products (NTFPs) such as edible fruits. This exploitation is anarchic and does not allow for the sustainability of these fruit trees and it is important to evaluate them. The real problem here is the unsustainable use of fruit species in the Laf-Madjam Forest Reserve. Several studies have been conducted in and around the reserve, such as those by Fotsing et al. (2003) and Todou et al. (2016). These authors focused their studies on the state of the reserve and riparian areas and on the floristic diversity in this area. Little is known about the floristic diversity of harvested edible fruit trees in this

reserve. This study contributed to the development of edible fruit trees for their effective conservation and sustainable use in the Moutourwa district. Thus, it was a question of inventorying the edible and non-edible fruit trees of the reserve and its surroundings, but also of determining the diversity of fruit species exploited by the local population in the reserve and its surroundings.

MATERIALS AND METHODS

Study site

The district of Moutourwa is located in the division of Mayo Kani, Far North Region. It is located between 10° 09' 36" - 10° 19' 12" North latitude; and between 14° 2' 21" - 14° 17' 7" East longitude (Figure 1). The climate of the Moutourwa council is the Sudano-Sahelian type and is characterized by 2 seasons: a long dry season, from October to May and a rainy season, from June to September. The average annual rainfall is 867 mm and the average annual temperature is 27°C, with a maximum of 38°C from March to April and a minimum of 18°C from December and January (Suchel, 1987). Four types of soils with different characteristics that are threatened by the effects of rain and especially wind erosion. The woody and herbaceous vegetation has elements of Sudano-Sahelian savannahs, dry savannahs and Sahelian steppes (Letouzey, 1968). The flora is characteristic of the thorny steppes, consisting of tree and shrub savannahs with a very irregular herbaceous cover.

Data collection

Ethnobotanical survey

This phase, carried out in September 2020, consisted of administering a questionnaire using the tools of the Accelerated Participatory Research Method (APRM) and a participatory approach described by Sunderland (1998) and Guedjé (2002). These surveys were complemented by direct field observations. They were conducted with local populations and actors involved in the exploitation of resources. The choice of interviewees was random. This interview targeted all categories of people. In total, 4 villages were selected for this survey (Laf, Moulva, Mayel Guinnadji and Bajava) and 117 people were interviewed. The overall survey approach made it possible to gather the following information: the demographic and socio-economic characteristics of the populations of the Laf-Madjam forest reserve, the peasant perception and importance of the forest reserve for the local population, the main human activities practiced in the forest reserve, the most important edible fruit species for the local population, the main NTFPs harvested, the state of the vegetation, the management and development of the vegetation in the area, as well as the priority edible fruit species for the local pharmacopoeia. Data on the use of plant species in all areas were collected.

Floristic inventories

The inventory of plant species was done in 8 transects of size 1000 m × 20 m and consisted of counting all woody individuals present in the different types of plant formations. Following along a line of layons, members of the inventory team scanned the transect to identify, count, measure, and observe individuals of woody species encountered using an inventory form. Each species was identified

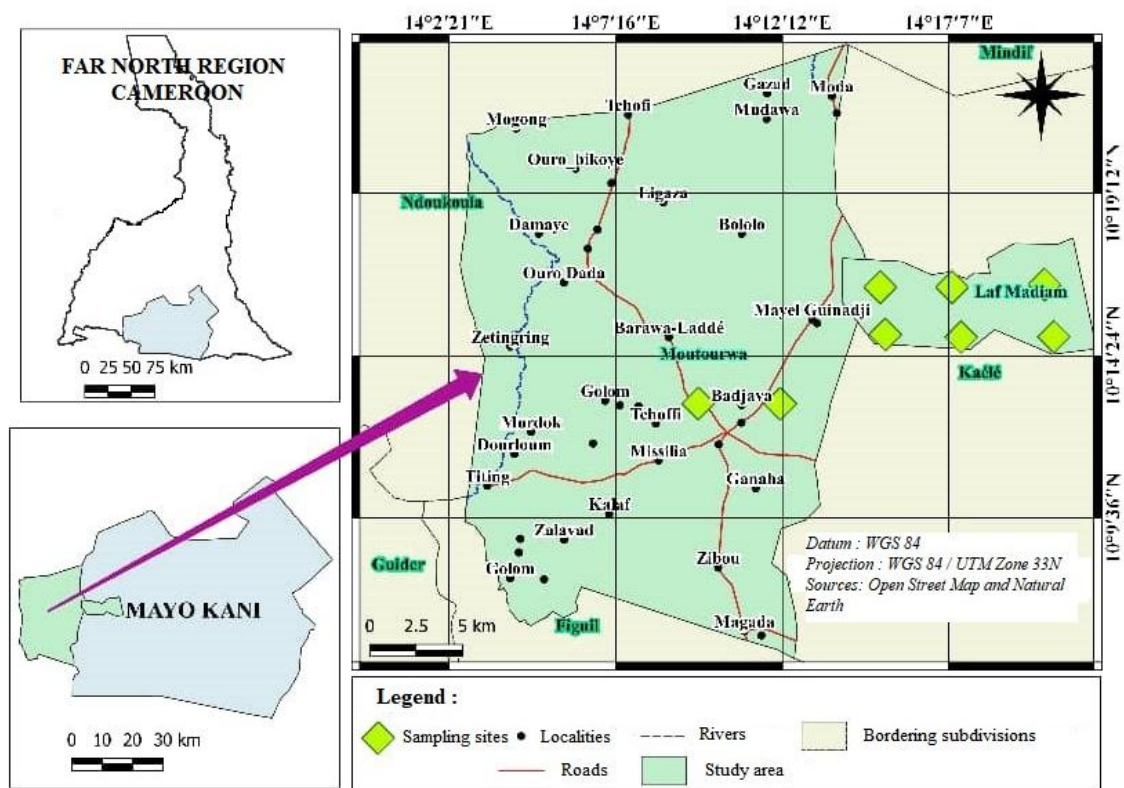


Figure 1. Localization of the study site.
Source: Author

by its scientific and/or local name. For unidentified species, samples were taken and then pressed to make the herbarium. Subsequently, these species could be identified with the help of appropriate documents such as the flora of Arbonnier (2009), but also by the botanists of the Faculty of Science. In addition to counting, dendrometric measurements (trunk circumference at 1.30 m from the ground and height) were taken for edible fruit trees.

Data processing and analysis

The species composition of the different plant formations was described using the following parameters and formulas: (i) the relative frequency (RFR) (Braun-Blanquet, 1932): $RF = (A_i/B) \times 100$, where A_i = number of plots containing the species i and B = total number of plots sampled; (ii) relative dominance (RDo) (Dona et al., 2016): $RDo = \pi D_i^2/4$, RD = relative dominance; D_i = diameter at breast height of the species i ; $\pi = 3.14$; (iii) relative density (RDe) (Ngom et al., 2013): $RDe = P_i \times 100$, where $P_i = n_i/N$, n_i is the number of individuals belonged to taxon i and N is total number of individuals of all sampled plots; (iv) relative diversity (RD_i): $RD_i = \text{number of species of one family} \times 100 / \text{total number of species}$; (v) density (stems/ha) (Ngom et al., 2013): $D = n_i/A$ where n_i is the number of individuals belonging to species i and A is the area in hectares; (vi) basal area (BA) (Devineau, 1984): $BA = (\sum \pi D_i^2)/4$, where D is diameter at breast height and S in m^2/ha ; (vii) importance value index (Cottam et Curtis, 1956): $IVI = \text{relative abundance} + \text{relative frequency} + \text{relative dominance}$; (viii) regeneration rate (Koulibaly, 2008; Konan, 2009): $Tr = (n/N) \times 100$; n is the total number of juvenile individuals with a diameter less

than or equal to 10 cm and N is the total number of individuals in the vegetation unit; (ix) species rarity index (Kokou et al., 2005): $RI = (1 - (n_i/N)) \times 100$ with n_i : the number of records in which species i occurs and N the total number of records. The Fisher test was used to compare some of the different means.

Specific diversity of the site was described using the following indices: Shannon and Weaver index (Frontier and Pichod-Viale, 1995): $H' = -\sum n_i/N \times \log_2 n_i/N$ With n_i is the proportion of a species i to the total number of species (N). Pielou evenness index (Dajoz, 1982): $E = H'/\log_2 N$ or H'/H_{max} , with H' the Shannon diversity and N the species richness. Sorensen's coefficient of similarity (Dajoz, 1985; Krebs, 1999): $Ks = (2c/a+b) \times 100$, where a is the number of species in a list belonging to site A; b is the number of species in a list belonging to site B; and c is the number of species common to the two sites (A and B).

RESULTS

Medicinal plants reported and diseases treated

The ethnobotanical surveys among the local populations showed that 24 species divided into 23 genera and 17 families were cited as being used by the local people (Table 1). The most represented families were Anacardiaceae (3 species), Annonaceae, Arecaceae, Bombacaceae, Moraceae and Rubiaceae (2 species each). Some organs cited by these populations are

Table 1. Edible fruit species and products consumed during the ethnobotanical surveys.

Families	Species	Local names	Parts used
Anacardiaceae	<i>Lannea acida</i>	lebew (guiziga)	Pulp, seed
	<i>Haematostaphis barteri</i>	trousse (guiziga)	Leaves, pulp, seed
	<i>Sclerocarya birrea</i>	eedi (foufouldé)	Pulp, seed
Annonaceae	<i>Annona senegalensis</i>	gonokoy (guiziga)	Pulp
	<i>Hexalobus monopetalus</i>	tubulubum (guiziga)	Pulp
Arecaceae	<i>Borassus aethiopicum</i>	doubbi (foufouldé)	Pulp, root of young trees
	<i>Hyphaene thebaïca</i>	gellehi (foufouldé)	Pulp, seed
Balanitaceae	<i>Balanites aegyptiaca</i>	tanni (foufouldé)	Pulp, seed, leaves
Bombacaceae	<i>Bombax costatum</i>	djohi (foufouldé)	Immature fruits
	<i>Adansonia digitata</i>	bokki (foufouldé)	Pulp, seed, leaves
Caesalpiniaceae	<i>Tamarindus indica</i>	djabbi (foufouldé)	Pulp, seed
Ebenaceae	<i>Diospyros mespiliformis</i>	huwung (guiziga)	Pulp
Loganiaceae	<i>Strycnos spinosa</i>	narbatanahi (foufouldé)	Pulp, seed
Mimosaceae	<i>Parkia biglobosa</i>	narehi (foufouldé)	Pulp
Moraceae	<i>Ficus platiphylla</i>	doundéhi (foufouldé)	Whole fruits
	<i>Ficus sycomorus</i>	ibbi gorki (foufouldé)	Whole fruits
Olacaceae	<i>Ximenia americana</i>	tchabboulli (foufouldé)	Pulp
Rhamnaceae	<i>Ziziphus mauritiana</i>	djabi (foufouldé)	Pulp
Rubiaceae	<i>Feretia apodanthera</i>	bouhebehi (foufouldé)	Pulp
	<i>Sarcocephalus latifolius</i>	bakurehi (foufouldé)	Pulp
Sapotaceae	<i>Vitellaria paradoxa</i>	sougoum (guiziga)	Pulp, seed
Sterculiaceae	<i>Sterculia setigera</i>	bobori (foufouldé)	Seed
Tiliaceae	<i>Grewia flavescens</i>	kolehi (foufouldé)	Pulp, seed
Verbenaceae	<i>Vitex doniana</i>	galbihi (foufouldé)	Pulp

Source: Author

consumed directly while others are first processed before use. These include whole fruits, roots, leaves, seeds and pulp. The results showed that the pulp is the part of the fruit tree most used by the local people.

Edible plants used in traditional pharmacopoeia

For medicinal purposes, the local population uses several fruit trees. The organs used and the method of preparation vary according to the species and the diseases. The most used species in the traditional pharmacopoeia was *Balanites aegyptiaca* (85.47%), followed by *Annona senegalensis* (76.92%), *Ximenia americana* (73.50%) and *Tamarindus indica* (72.64%) (Table 2). The most frequent diseases in the study area

encountered were: typhoid, diarrhoea and jaundice (1.12% each). The most used method of preparation was decoction (4.48%), followed by infusion and maceration (1.12% each). As for the organs, bark (4.34%) and leaves (1.55%) were the most used in the recipes (Table 2).

Floristic composition of woody plants

A total of 2134 individuals were inventoried in the Laf-Madjam forest reserve and its surroundings with a total density of 133.37 individuals/ha (Table 3). These individuals are subdivided into 69 species divided into 43 genera and 27 families. The Combretaceae family has the highest number of species (10 species), followed by the Mimosaceae (8 species) and the Anacardiaceae with

Table 2. Edible fruit organs used in traditional pharmacopoeia.

Family	Scientific names	Local names	Exploited organ	Mode of preparation	Treated diseases	% of respondents
Anacardiaceae	<i>Haematostaphis barteri</i>	trouss (guiziga)	Bark	Decoction	Anaemia	53.84
			Bark	Decoction	Rheumatism	
	<i>Sclerocarya birrea</i>	eedi (foufouldé)	Bark	Decoction	Dysentery	67
			Bark	Decoction	Tooth ache	
Annonaceae	<i>Hexalobus monopetalus</i>		Leaves	Infusion	Hypertension	58.11
			Leaves	Decoction	Yellow fever	
			Roots	Maceration	Typhoid	
Balanitaceae	<i>Annona senegalensis</i>	gonokoy (Guiziga)	Bark	Decoction	Diarrhea	76.92
			Bark	Powder	Wounds	
			Seeds	Maceration	Yellow fever	
Balanitaceae	<i>Balanites aegyptiaca</i>	tagwar (Guiziga)	Roots, bark	Decoction	Diarrhea	85.47
			Seeds	Maceration	Typhoid	
			Leaves	Expression	Eye pain	
			Leaves	Expression	Eye pain	
Bombaceae	<i>Adansonia digitata</i>	bokki (foufouldé)	Leaves	Powder	Diarrhea	59.82
Caesalpinaceae	<i>Tamarindus indica</i>	djabbi (foufouldé)	Flowers	Infusion	Yellow fever	72.64
			Fruits	Infusion	Fever	
			Fruits	Decoction	Typhoid	
Ebenaceae	<i>Diospyros mespiliformis</i>	nelbi (foufouldé)	Flowers	Decoction	Rubeola	69.23
			Leaves	Infusion	Stomach ache	
Mimosaceae	<i>Parkia biglobosa</i>	narehi (foufouldé)	Leaves	Infusion	Eve pain	58.97
Moraceae	<i>Ficus platiphylla</i>	doundéhi (foufouldé)	Bark	Decoction	Dysentery	58.97
Olacaceae	<i>Ximenia americana</i>	toumbour (guiziga)	Bark	Decoction	Diarrhea	56.41
Rhamnaceae	<i>Ziziphus mauritiana</i>	hilvid (guiziga)	Roots	Decoction	Yellow fever	73.50
Rubiaceae	<i>Sarcocephalus latifolius</i>	bakurehi (foufouldé)	Bark	Decoction	Malaria	58.97
			Bark	Decoction	Malaria	
Sapotaceae	<i>Vitellaria paradoxa</i>	sougoum (guiziga)	Bark	Maceration	Typhoid	66.66
Verbenaceae	<i>Vitex doniana</i>	zougoui (guiziga)	Bark	Decoction	Malaria	66.66
			Seeds	Oil extraction	Rheumatism	58.11
			Bark	Decoction	Itchiness	63.24

Source: Author

Table 3. Comparison of the taxonomic richness of the different plant formations.

Taxonomic groups	Shrubby savannah	Woody savannah	Gallery forest	Hills	Total
Species number	35	34	38	45	69
Genera number	25	24	24	31	43
Families number	16	17	17	21	27
Individuals number	369	642	603	372	2134
Density	92.25	160.50	150.75	93	133.37

Source: Author

Table 4. Comparison of the taxonomic richness of fruit trees in different plant formations.

Taxonomic groups	Shrubby savannah	Woody savannah	Gallery forest	Hills	Total
Species number	6	7	12	16	24
Genera numbers	6	7	12	12	18
Families number	5	6	10	9	14
Individuals number	67	113	115	154	449

Source: Author

Table 5. Diversity indices of different plant formations in the study area.

Plant formations	Diversity indices		
	Maximum diversity	Shannon-weaver index	Pielou evenness
Woody savannah	5.09	3.66	0.72
Shrubby savannah	5.13	3.80	0.74
Forestry gallery	5.25	4.00	0.76
Hills	5.49	4.22	0.77
Study area	6.11	4.53	0.74

Source: Author

7 species.

Taxonomic richness of edible fruit trees

A total of 449 individuals of edible fruit trees were recorded and divided into 24 species, 18 genera and 14 families (Table 4). The richest plant formation was hillside with 16 species followed by gallery forest with 12 species.

Species diversity

The Shannon-Weaver diversity index value was 4.53 bits for the study area and varied from 3.66 bits for the woody savannah to 1.22 for the hills (Table 5). The Pielou's evenness index was 0.74 for the study site and varied from 0.78 for woody savannah to 0.77 for the hills.

For edible fruit trees, the Shannon diversity index calculated in all formations was 3.10 bits. This value varied from 1.10 in the shrubby savannah to 2.03 bits in

the hills (Table 6). The Pielou evenness index was 0.67 in the study area. This value varied from 0.43 for the shrubby savannah to 0.50 for the hills and the tree savannah.

Sorensen's coefficient of similarity for all woody plants was $\geq 50\%$ for all plant formations (Table 7) while for fruit trees only (Table 8), these values were $\leq 50\%$ all plant formations.

Rarity index and species importance value index

The calculation of the rarity index of the species encountered in the different formations of Moutourwa and its surroundings shows that 2 species have a rarity index higher than 80%, *Diospyros mespiliformis* and *Gardenia ternifolia* rarity index of 87.5%. Among the species, *Sclerocarya birrea* was found in all 8 transects and had a rarity index of zero (RI = 0). The high abundance of certain species could be considered as a response of the rural society which considers them as a priority species

Table 6. Diversity indices of edible fruit trees in different plant formations of the study site.

Plant formations	Diversity indices		
	Maximum diversity	Shannon-weaver index	Pielou evenness
Woody savannah	2.81	1.40	0.50
Shrubby savannah	2.58	1.10	0.43
Forestry gallery	3.58	1.68	0.47
Hill	4	2.03	0.50
Study area	4.64	3.10	0.67

Source: Author

Table 7. Coefficient of similarity of woody species in the study area.

Coefficient of similarity	Plant formations			
	Woody savannah	Shrubby savannah	Forestry gallery	Hillside
Woody savannah	-	63.77	72.22	40.51
Shrubby savannah	-	-	65.75	50
Forestry gallery	-	-	-	53.01

Source: Author

Table 8. Coefficient of similarity of edible fruit trees in the study area.

Coefficient of similarity	Plant formations			
	Woody savannah	Shrubby savannah	Forestry gallery	Hillside
Woody savannah	-	46.15	63.16	26.09
Shrubby savannah	-	-	44.44	18.18
Forestry gallery	-	-	-	28.57

Source: Author

(Sigaud and Eyog-Matig, 2001).

The ecological importance of the species here is assessed by the high value of their IVI. The species with high IVI values were: *B. aegyptiaca* (72.56), *S. birrea* (37.54), *Ziziphus mauritiana* (23.36) and *Hexalobus monopetalus* (22.38) (Table 9).

Density and basal area of fruit trees

The highest density value (38.24 stems/ha) and the lowest value (16.77 stems/ha) and the highest basal area (1.95 m²/ha) and the lowest value (0.94 m²/ha) were found, respectively in the hills and shrubby savannah (Table 10). Analysis of variance of absolute density and basal area showed a highly significant difference between formation types ($p=0.05$).

Horizontal structure of edible fruit trees

The distribution of individuals by diameter class in the

study area shows some structural divergences clearly discriminated by the number of stems. In the present study, the structure of edible fruit trees in the savannah shrubland and edible fruit trees in the hillside showed 'inverted L' curves (Figure 2). The structure of edible fruit trees in the forest gallery and in the tree savannah showed a bell-shaped curve.

Vertical structure of edible fruit trees

The vertical structure of the plant population showed "L" curves with high proportion of individuals in the class height [$<-$; 10]- in the different formations (Figure 3). This structure showed high proportion of young plants and low proportion of adult individuals.

Regeneration of species

A total of 141 individuals grouped into 11 species were recorded in the different formation types. In the shrubby

Table 9. Species with high Ecological importance of edible fruit trees.

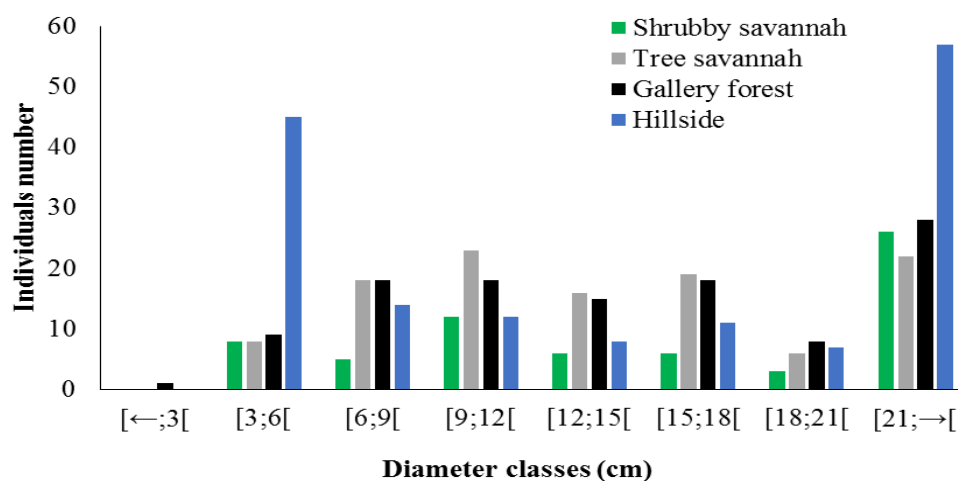
Family	Species	Relative dominance	Relative density	Relative frequency	IVI
Anacardiaceae	<i>Haematostaphis barteri</i>	10.01	5.12	3.12	18.26
	<i>Lannea acida</i>	7.52	2.45	4.68	14.65
	<i>Lannea fruticosa</i>	3.27	8.68	3.12	15.08
	<i>Sclerocarya birrea</i>	18.80	6.23	12.5	37.54
Annonaceae	<i>Annona senegalensis</i>	1.03	11.58	4.68	17.29
	<i>Hexalobus monopetalus</i>	5.88	8.69	7.81	22.38
Balanitaceae	<i>Balanites aegyptiaca</i>	29.78	33.40	9.37	72.56
Caesalpiniaceae	<i>Tamarindus indica</i>	4.36	2.22	4.68	11.27
Ebenaceae	<i>Diospyros mespiliformis</i>	2.08	3.12	10.33	15.53
Rhamnaceae	<i>Ziziphus mauritiana</i>	2.86	11.13	9.37	23.36
Ulmaceae	<i>Celtis integrifolia</i>	7.94	0.44	1.56	9.94

Source: Author

Table 10. Density and basal area by formation type in the study area.

Plant formations	Dendrometrical parameters	
	Density (trees/ha)	Basal area (m ² /ha)
Woody savannah	28.24±0.01 ^c	0.70±0.01 ^d
Shrubby savannah	16.77±0.02 ^d	0.94±0.01 ^b
Forestry gallery	28.76±0.01 ^b	0.81±0.01 ^c
Hills	38.24±0.02 ^a	1.95±0.01 ^a

Source: Author

**Figure 2.** Horizontal structure of all edible fruit trees in different plant formations.

Source: Author

and tree savannahs, the highest rate is observed in *B. aegyptiaca* (44 and 68.75%, respectively) (Table 11). In the forest gallery, the highest value is found in *Z.*

mauritiana (66.67%), whereas in the hill, the highest regeneration rate is observed in *A. senegalensis* (74.04%).

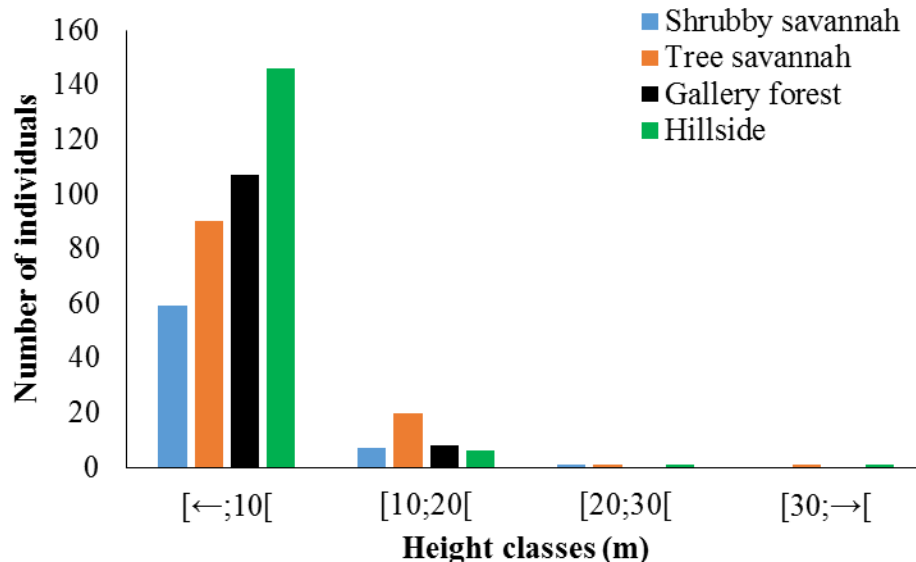


Figure 3. Vertical structure of all edible fruit trees in the different plant formation.
Source: Author

DISCUSSION

Medicinal plants reported and diseases treated

The high use of the pulp by the local people can be explained by the fact that fruits in the form of pulp are the most represented in the study site. Moreover, the fruits most suitable for preservation are in pulp form. These different results corroborate those of Todou et al. (2017) who found 50 species used by local populations in the Mandara Mountains in Cameroon. Nyakabwa (1994) in the DRC also found that the pulp is the most used part of the fruit.

Edible plants used in traditional pharmacopoeia

The interest in leaves and bark can be explained by the fact that these plant organs are the seat par excellence of biosynthesis and even storage of secondary metabolites which is responsible for the plant's pharmaco-biological properties (Nacoulma Ouedraogo, 1996). Furthermore, Bitsindou (1986) attests that the high frequency of use of leaves is due to the ease of harvesting. These results are similar to those obtained by Ngbolua et al. (2019) who showed that leaves and bark were the most used. In addition, Saoting et al. (2011) obtained 34% of the leaves commonly used in recipes. On the other hand, Gueye (2012) found in their respective works a high frequency of use of barks and roots. In general, all organs of medicinal plants relieve and cure diseases or ailments but uncontrolled use of certain organs such as roots and bark could cause damage to the plant and even its ecosystem. So, it would be better to use good

harvesting techniques to preserve it for us and even for future generations.

Floristic composition of woody plants

The highest number of species, genera and families is found in the hills while the lowest number is found in the shrubby and tree savannas. This difference may be due to the existence of permanent anthropic actions in the shrub and tree savannas while the hills are difficult to access. The dominance of Combretaceae can be explained by the fact that it is a characteristic family of savannas and easily adapt to water stress. Oumarou (2012) has shown that the Combretaceae family represents the most diverse and abundant family in the savannas. Considering the high number of species and individuals inventoried in the Laf-Madjam forest reserve and its surroundings, it can be said that this locality is rich in woody species. These results are similar to those of Todou et al. (2016) who found 75 species, divided into 54 genera and 28 families in the same locality. Similarly, Teicheugang (2000) recorded 75 species, divided into 46 genera and 24 families in the Zamay reserve. Froumsia et al. (2019) also found 66 species in 46 genera and 26 families in the unprotected Sudano-Sahelian zone in Cameroon. The similarity of these results may be due to similar microclimatic factors and anthropogenic pressures.

Taxonomic richness of edible fruit trees

The variation in species richness in the different plant formation observed can be explained by climate variation

Table 11. Regeneration of edible fruit species in different plant formation.

Species	Shrubby savannah	Woody savannah	Forestry gallery	Hillside
<i>Balanites aegyptiaca</i>	44.44	68,75	25.00	0.00
<i>Ximenia americana</i>	11.11	0.00	0.00	0.00
<i>Ziziphus mauritiana</i>	22.22	12,50	66.67	0.00
<i>Capparis sepiaria</i>	11.11	6,25	0.00	0.00
<i>Sclerocarya birrea</i>	11.11	0.00	0.00	0.00
<i>Hexalobus monopetalus</i>	0.00	0.00	8,33	0.00
<i>Annona senegalensis</i>	0.00	12,50	0.00	74.04
<i>Sarcocephalus latifolius</i>	0.00	0.00	0.00	0.96
<i>Diospyros mespilliformis</i>	0.00	0.00	0.00	0.96
<i>Ficus platyphylla</i>	0.00	0.00	0.00	0.96
<i>Hexalobus monopetalus</i>	0.00	0.00	0.00	23.08

Source: Author

(Sarr, 2008), interspecific competition, resource availability and the level of disturbance (Palmer, 1994). It is also observed following the existence of permanent anthropic actions in the shrubby and tree savannahs while the hill is difficult to access. This specific richness was similar to the work of Todou et al. (2017) who found 38 wild edible fruit species grouped into 29 genera and 19 families in the Far North of Cameroon. These results showed a significant wealth of edible fruit trees in the Laf-Madjam forest reserve, hence the need to valorise them in order to use them rationally.

Species diversity

Based on the calculated diversity indices, the study area had high diversity because the Shannon index was high and the Pielou evenness is near to 1. These values indicate a homogeneity of the stand. In the different vegetation formations, it can be seen that diversity is important everywhere because the Shannon index varies from 3.66 to 4.22 with the hill having a higher diversity.

Considering the values of the different diversity indices, it appears that the diversity of edible fruit species is moderate in the study area, but in each plant formation it is found to be very low, slightly less in the hills. This index is different from that found by Mapongmetsem et al. (2016) in the agroforests of the peri-urban area of the city of Bafia in the Central Cameroon Region (3.33 bits). In terms of Pielou equitability, it is 0.67 across the study area (0.50 for hill and tree savannah, 0.47 for forest gallery and 0.43 for shrub savanna). These values are lower than those of Todou et al. (2016) who found 0.82 in the uncultivated plain of Moutourwa located in the Sahelo-Sudanese sector of Cameroon. These results suggest that edible fruit species are equitable in the study area. Sorensen's coefficient of similarity for all woody plants was $\geq 50\%$ for all plant formations and confirmed that these plant formations belong to the same plant

communities while for fruit trees only, the values were $\leq 50\%$ all plant formations and confirmed that these plant formations belong to different plants communities.

Rarity index and species importance value index

In the North Cameroon Region, 55 indigenous edible fruits were identified by Mapongmetsem et al. (2012). Among these fruits, *B. aegyptiaca* was one of them. These 55 fruits were among the most prized and traded in the region. Similarly, Kristensen and Balslev (2003) in Gourounsi, Burkina Faso, note that the availability of most fruits coincides with a decline in food supplies. At this time, the availability and consumption of wild fruits is a considerable contribution to household diets. Furthermore, Guinko and Pasgo (1992) state that wild fruits contribute to a varied diet in terms of vitamin intake. These results suggest that the consumption of these fruits therefore saves on very low agricultural produce to ensure year-round feeding. For this reason, it would be important to preserve the reserve's highly endangered fruit trees.

Density and basal area of fruit trees

These results are confirmed by Birnbaum (2017) who indicated that savannah tree formations are subject to anthropic influences. The high human pressure in the formations could explain the low presence of breeding individuals due to abusive logging. Comita et al. (2007) agree, saying that the higher the number of breeding individuals, the higher the overall density.

Horizontal structure of edible fruit trees

The general diametric distribution of edible fruit trees in

the Laf-Madjam reserve showed that individuals with a diameter ≥ 21 cm were in the majority. It shows an "inverted L" distribution in some plant formations and a bell-shaped distribution in others. This type of distribution is similar to that obtained by Mapongmetsem et al. (2011) in *Vitellaria paradoxa* in the high Guinean savannahs. In the first case, this type of distribution shows that individuals with a large diameter are in the majority; this can be explained by anthropogenic actions such as bush fires and grazing, as juvenile species are destroyed at the expense of adults. In the second case, there is a dominance of individuals with a small diameter; this may show the good regeneration of these species. This may also be due to the strong anthropic pressure on this group and therefore the death of adult plants as a result of poor management or overexploitation. Thus, numerous studies carried out in the Sahelian and Sudanian zones have also confirmed this structural variability of species (Rabiou et al., 2015; Idrissa et al., 2017; Amadou et al., 2020). According to Sandjong et al. (2018), adaptations to ecological conditions, competition for resources and exploitation would underlie this structural variability. The low presence of adult individuals with a diameter greater than 15 cm was observed in species with an inverted J-shape that embodies secure regeneration. This indicates that large individuals are heavily exploited as highlighted by Idrissa et al. (2017). The 'inverted J' shape type has been observed in *T. indica* (Fandohan et al., 2011), *Dialium guineense* (Assongba et al., 2013), *Prosopis africana* (Houëtchégnon et al., 2015) and *Lophira lanceolata* (Lankoandé et al., 2017). The predominance of young individuals can be explained by the relationship between the temperament of the species and their diameter distribution. However, the survival of these young individuals is problematic due to bushfires and overgrazing. On the contrary, species that are resistant to bushfires have a high proportion of mature individuals (Nkongmeneck et al., 2010) in their distribution, such as species with a bell-shaped distribution. This type of distribution is characteristic of mono-specific stands with very low regeneration potential.

Vertical structure of edible fruit trees

These results are in agreement with those of Sani (2009), in a revegetated site and a degraded site in the department of Mirriah and confirm one of the characteristics of savannah ecosystems. However, the L-shaped structure is a sign that the whole ecosystem is in a state of degradation as concluded by Jiagho et al. (2016) who worked in Waza National Park. In addition, Tchobsala et al. (2010) found the same structure in the peri-urban area in Ngaoundéré, Cameroon. These results are also in line with those of Faber-Langendone and Gentry (1991), who obtain decreasing distributions of structural parameters in a hut field and justify that these

distributions are characteristic of formations containing mature stands with many small individuals and a low representation of large trees.

Regeneration of species

This result can be justified by the adverse effects of man whose actions impact on the survival of many seedlings. In addition, several authors report that the regeneration of many woody species is made difficult by the harmful action of bush fires and grazing (Mbaiyetom et al., 2021, Nangndi et al., 2021). The species with a high regeneration rate were: *A. senegalensis*, *H. monopetalus*, *B. aegyptiaca* and *Z. mauritiana*, which together represent more than 80% of the regeneration rate of edible fruit trees. However, it should be noted that some species, although well present at the adult stage, have a low regeneration rate, or even none at all, at the seedling stage, while others are only present at the seedling stage and absent at the adult stage. According to Froumsia (2013), three quarters of seedlings live only 3 months at most. The results showed that the higher regeneration rate, the better the regeneration. The decrease in the overall regeneration rate of the species in the forest reserve would be attributed to the high density of species in this location negatively influencing the survival of natural regeneration due to insufficient light. Several research studies have indicated that the high regeneration rate is recorded in species suitable for suckering and layering (Douh et al., 2014).

Conclusion

The availability of edible fruit trees was highlighted in the Laf-Madjam forest reserve and its surroundings. The inventory revealed that Combretaceae, Mimosaceae and Anacardiaceae are the most represented families in the plant formations studied. The diversity of edible fruit species is moderate in the study area, but very low in some plant formations, somewhat less so in the hills. The highest basal area is observed in the hills and the lowest in the shrubby savannah. The highest rate of natural regeneration is found in *B. aegyptiaca* in the shrubby and tree savannahs, the highest value in the forest gallery is found in *Z. mauritiana* and in the hill it is observed in *A. senegalensis*. The analysis of diametric structure of the edible fruit trees in the Laf-Madjam reserve shows us that individuals with a diameter ≥ 21 cm is the most represented. It shows an "inverted L" distribution in some plant formations and a bell shape in others. The vertical structure of the plant population in the different formations, as well as in the formations as a whole, shows L-shaped curves. Strategies need to be developed to ensure conservation, survival of natural regeneration and to enable low-cost propagation activities of wild

edible fruit species to improve their availability.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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