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Diversity and uses of woody forest resources in the eastern part of the Benoué riverbank (north Cameroon)

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ABSTRACT

Introduction: Woody plant resources play a central role in meeting the food, energy, health, and other livelihood needs of rural populations in the Sudano-Sahelian zone. However, these resources are increasingly threatened by anthropogenic pressures and deforestation. Understanding their diversity and patterns of use is therefore essential for identifying priority species for conservation and sustainable agroforestry practices. **Methods:** An ethnobotanical survey was conducted among local ethnic groups in the eastern part of the Benoué River,

specifically in Bibemi and Rey-Bouba districts, North Region, Cameroon. Data were collected in 20 villages from 328 respondents selected using a non-probabilistic quota sampling method based on gender and age. The diversity and importance of woody plant resources were assessed according to the response rate associated with the plant organs solicited and their reported uses.

Results: Farmers represented 80.45% of respondents, reflecting the predominantly agricultural character of the study area. A total of 72 exploited woody plant species were recorded across six main use categories

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Food uses involved 28 species valued for their fruits, seven for their leaves and flowers, and five for their seeds, with food plants cited by 88.22% of respondents. Fuelwood and charcoal involved 28 species and were reported by 98.48% of respondents. Traditional medicine involved 38 species, notably *Khaya senegalensis* and *Faidherbia albida*. Service wood involved 26 species, while handicrafts involved 32.22% of respondents. Various plant organs, including leaves, roots, fruits, seeds, flowers, wood, and bark, were exploited. Use intensity varied markedly among species and use categories, reflecting differences in resource availability and cultural preferences. **Conclusion:** The findings demonstrate the high diversity and socio-economic importance of woody plant resources for local livelihoods in the Sudano-Sahelian zone of northern Cameroon. The intensive use of several species highlights the need for targeted conservation measures, particularly for the most heavily exploited species, while promoting their sustainable integration into agroforestry practices.

What this study adds

- 1- It provides the first systematic ethnobotanical inventory of exploited woody species along the eastern Benoué riverbank, documenting 72 species across six use categories in a zone previously undercharacterized despite intense anthropogenic pressure.
- 2-It quantifies use intensity by organ and category (food, fuelwood/charcoal, medicine, service wood, fodder, handicrafts) through response-rate analysis across 328 respondents in 20 villages, offering a replicable methodological framework for similar Sudano-Sahelian contexts.
- 3-It identifies priority species notably *Khaya senegalensis* and *Faidherbia albida* for medicinal use whose exploitation pressure signals conservation urgency, providing an evidence base for targeted agroforestry promotion.
- 4-It links species-use patterns to respondent socio-demographic profile (predominance of farmers, 80.45%), clarifying how livelihood dependence on woody resources should inform local natural-resource management and conservation planning.

Editorial query: Please confirm whether there are six or seven use categories: the abstract and this section state six, whereas the conclusion states seven.

1. Introduction

Human beings have maintained age-old relationships with plants for their various needs (Ezebilo and Mattsson, 2010). In West Africa, because of their multiple uses in food, construction, domestic energy and traditional medicine, plant resources play an important role in the daily lives of rural populations (Theilade *et al.*, 2007; Zerbo *et al.*, 2011; Mangambu *et al.*, 2012). Today, plant formations are undergoing increasing degradation and the sustainable use of plant resources remains a challenge (FAO, 2013). The loss of these resources could lead to a weakening of the local potential and capacity of the communities that depend on them for

income and food. Despite the crucial role played by woody species in socio-economic development and in meeting the multiple needs of populations and issues of sustainability, the high rate of deforestation on the African continent remains worrying (FAO, 2012). In this context, it is important to know the state of available plant resources and to determine how they are used by local populations (Singh and Samant, 2009; Vodouhê *et al.*, 2009). There has often been a lack of scientific research initiatives to support the actions of managers. Recent scientific studies have shown that the quantitative ethnobotanical approach is a powerful tool for identifying species with high potential for use in the conservation of plant resources exploited by communities (Amusa *et al.*, 2012; Ahoyo *et al.*, 2017). Several studies have been carried out on useful plants, but they often focus either on a specific species, or on a precise use, or on the socio-cultural value of food plants (Gouwakinnou *et al.*, 2011; Houessou *et al.*, 2012; Koura *et al.*, 2011; Assogba *et al.*, 2017). Given the anthropogenic pressure on useful woody species and their importance in the socio-economic life of populations, it is necessary to explore the diversity of these species and the uses they have for these populations. This study therefore fills such gaps in the specific case of the eastern part of the Benoué riverbank. The objective of this study is to contribute to a better understanding of the woody plant resources exploited by the population living to the east of the Benoué river bank with a view to sustainable management of the woody potential of this zone. Specifically, the study aims to (i) make an inventory of the various woody plant species and their forms of use, and (ii) assess the extent to which the various plant organs are used.

2. Materials and methods

2.1 Study area

The study was conducted in the eastern part of the Benoué river bank located in the North Region and more precisely covers two Departments, namely the Department of Benoué and the Department of Mayo-Rey (figure 1). It is bordered to the north by the department of Mayo-Louti, to the south by the Adamaoua region, to the east by Chad and Central Africa, and to the west by Nigeria. It is located at latitude 9°04'28.69" North, longitude 13°45'52.38" East and altitude 250m. The climate is tropical, of the Sudano-Sahelian type, with a long dry season from October to April and a short rainy season from May to September. Average annual rainfall reaches 956 mm of water in 54 days of rainfall (MINADER, 2014). Temperatures remain high, with an average of 31°C, and maximums reaching 42 to 45°C in April. However, there are major irregularities from one year to the next and even from one month to the next, with temperatures concentrated mainly around August as a result of climate change, the effects of which are being felt as elsewhere on the planet (PDC commune de Bibemi, 2014 and commune de Rey-Bouba 2015). The eastern part of the Benoué riverbank is characterised by the coexistence of agro-pastoral and mining activities. This diversity of socio-economic activities leads to degradation of the vegetation cover in this area.

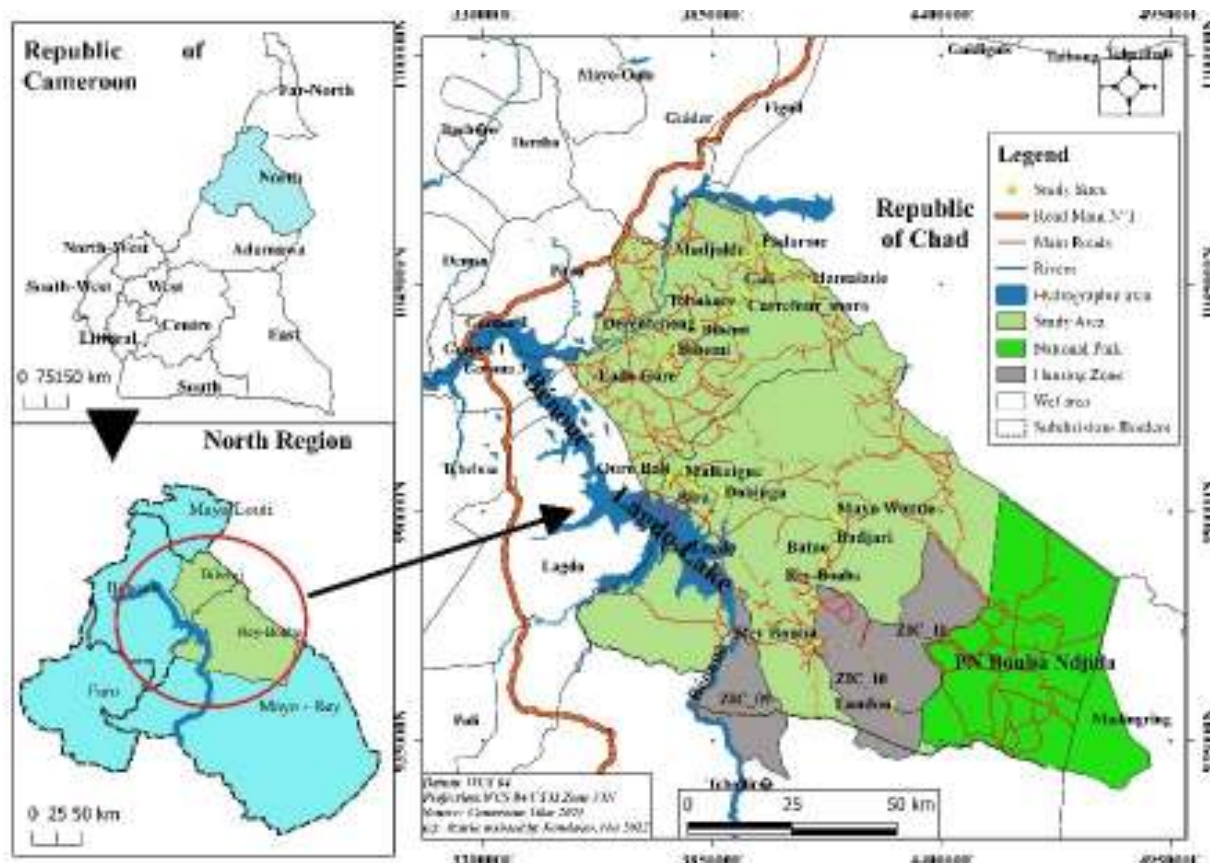


Figure 1: Location map of the study area

Figure 1A/1B: compiled from the image (1A = location map: Cameroon/Northern Region/Mayo-Rey Department; 1B = detailed map showing study sites, watercourses, Bouba Ndjida National Park and the ZIC).

2.2 Data collection

2.2.1. Study Area and Survey Period

The ethnobotanical investigations were conducted from December 2021 to March 2022 in two subdivisions of the North Region of Cameroon, Bibemi and Rey-Bouba, which constitute the study area. Twenty villages were selected, at a rate of ten villages per subdivision. The choice of villages was based on three combined criteria: accessibility (existence of communication routes), the presence of exploited plant formations, and the diversity of ethnic groups involved in the exploitation and marketing of forest products. The surveys targeted four categories of actors: households, local actors involved in the exploitation of woody resources, traditional authorities, and administrative authorities of the localities concerned.

2.2.2. Household and Wood Resource Operator Surveys

The investigations were conducted among households, local actors, and the traditional and administrative authorities of the areas concerned. A total of 2 subdivisions were taken into

account in this study, corresponding to a total of 20 villages, at a rate of 10 villages per subdivision.

2.2.3. Sampling Method

In the absence of an exhaustive sampling frame listing all survey units, probability sampling was not feasible. The non-probability quota sampling method was therefore adopted, with two cross-cutting quotas: sex and age (minimum threshold set at 30 years). The sample size was determined and a quota was then applied to it. These two quotas were selected not only because perceptions vary according to sex and age, but also because individuals aged 30 years and above are more likely to provide reliable information by drawing on their memory.

2.2.4. Determination of Sample Size

The sample size was determined using the method of SCHWARTZ (2002). It was calculated with a 95% confidence level and a margin of error of $\pm 5\%$.

$$N = (Z\alpha^2 \times P \times Q) / d^2$$

Where N = sample size per village;

$Z\alpha$ = fixed deviation of 1.96, corresponding to a 95% confidence level;

P = number of households in the village / number of households in the commune;

Q = 1 - P;

d = margin of error, equal to 5%.

The proportion of the target parent population was obtained either from the commune's Communal Development Plan (CDP) document, from the chiefs of the targeted villages, or from 2010 National Institute of Statistics (NIS) data.

Application of the formula to each of the 20 villages produced the sample sizes presented in Table I, giving a total of 165 people surveyed in the Bibemi subdivision and 163 in the Rey-Bouba subdivision, for a grand total of 328 people (Table I).

Table 1. Sample size by subdivision and village

Subdivisions	Villages	Number of households	Sample size
Bibemi	Padarmé	542	38
	Madjolde	276	21
	Gali	100	8
	Carrefour Mora	36	3
	Hamalade	163	13

	Tchakare	45	4
	DERENTCHENG	194	15
	MAFALÉ	123	9
	Ladde goré	268	21
	BIBEMI	447	33
Total	10	19606	165
	Ouro-Bali	50	4
	Malkaigue	57	6
	Homa malyaya	58	5
	Dobinga	541	34
	Mayo-wonde	180	15
Rey-Bouba	Baldjari	6	2
	Batao	233	16
	Kongrong Est	386	25
	Rey-Bouba	1182	40
	Landou	235	16
Total	10	17776	163

2.3. Data Analysis

The response rate by type of exploited plant organ was calculated according to the formula proposed by Maregesi et al. (2007):

$$F = (S/N) \times 100$$

Where F: calculated response rate; S: number of persons who gave a positive response (Yes) for the use of the organ concerned; N: total number of persons interviewed.

3. RESULTS

3.1 Characterisation of stakeholders involved in the exploitation of non-timber forest products.

Harvesters refer to the entire village community responsible for gathering and collecting edible products, wood, fodder, etc. in the bushes and fields. These actors are the key elements in the exploitation of non-timber forest products. They are generally those who control the circuit and flow of the distribution of these products. They are of various kinds, depending on the functions they perform in this circuit. Analysis of Figure 2 shows that six players are

involved in the exploitation of timber resources in this zone. In Bibemi, as in Rey-Bouba, the main users of non-timber and timber forest products are farmers. They represent 80.45% of those surveyed in the zone. They practise extensive agriculture in all the villages and cultivate several specialisations: maize, cotton, red millet, cowpeas and groundnuts. Livestock farmers represent 8.48% of farmers in the zone, and are the second largest group. Those who make little use of non-timber and timber forest products are traders, resourceful people and civil servants, representing respectively 2.95%, 2.70% and 5.43% of the population surveyed (Figure 2). This situation is understandable in the sense that most of the population surveyed is essentially agricultural, and this helps to feed the locality in particular and the region in general. Wood resources are therefore an additional source of income for farmers. However, in the interests of diversification, there are some who also rely on trade and livestock farming.

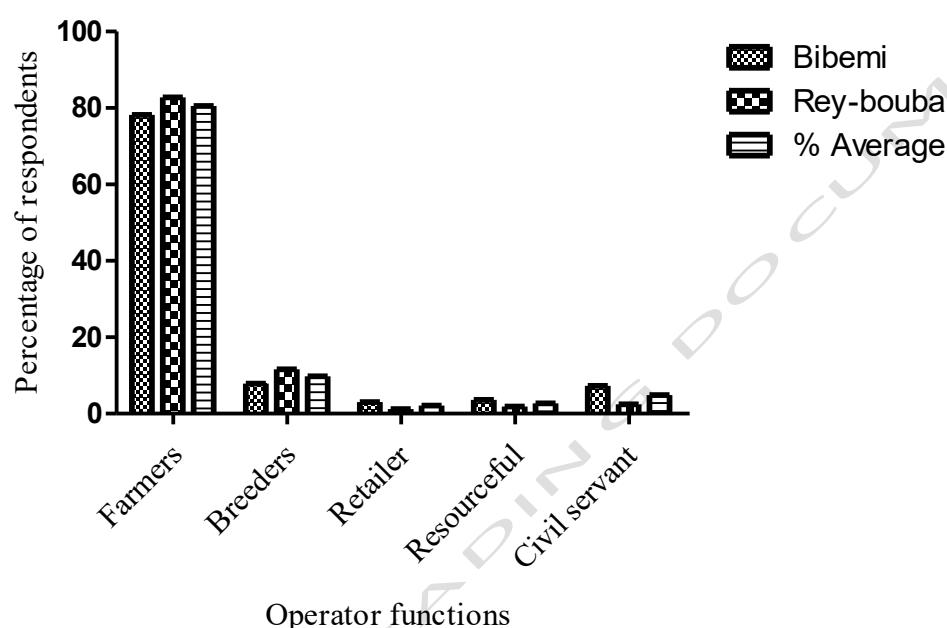


Figure 2: Operator functions

3.2. Different uses of plant products

The results of our surveys show that various products from plant species are exploited by local people and used in different ways depending on their needs. Figure 3 shows that products from plant species are used for several purposes: Food refers to the parts that produce edible products, in particular fruit, leaves, flowers and tubers. This is why 88.22% of our surveys say that various plant species are used for food of respondent's report that. The same applies to firewood and charcoal, which accounts for 98.48% of the plant products exploited in the study area, and includes all types of dead wood collected or cut. It is used in the kitchen to cook food, is used to prepare the local beer ("bil-bil"), and is also used to fire bricks made from earth. As for the use of plant species in the pharmacopoeia, the results of our surveys show that all parts of the plant are used to treat various illnesses. Several plant species are used for this purpose. This reflects the importance of plant species in the daily lives of the population, particularly those who do not have sufficient means to afford high-quality hospital treatment.

With regard to the use of plant species for handicrafts, 32.22% of the respondents say that certain plant species are used to make pestles, mortars, couscous cookers, animal troughs, axe handles, stools, etc., among other things.

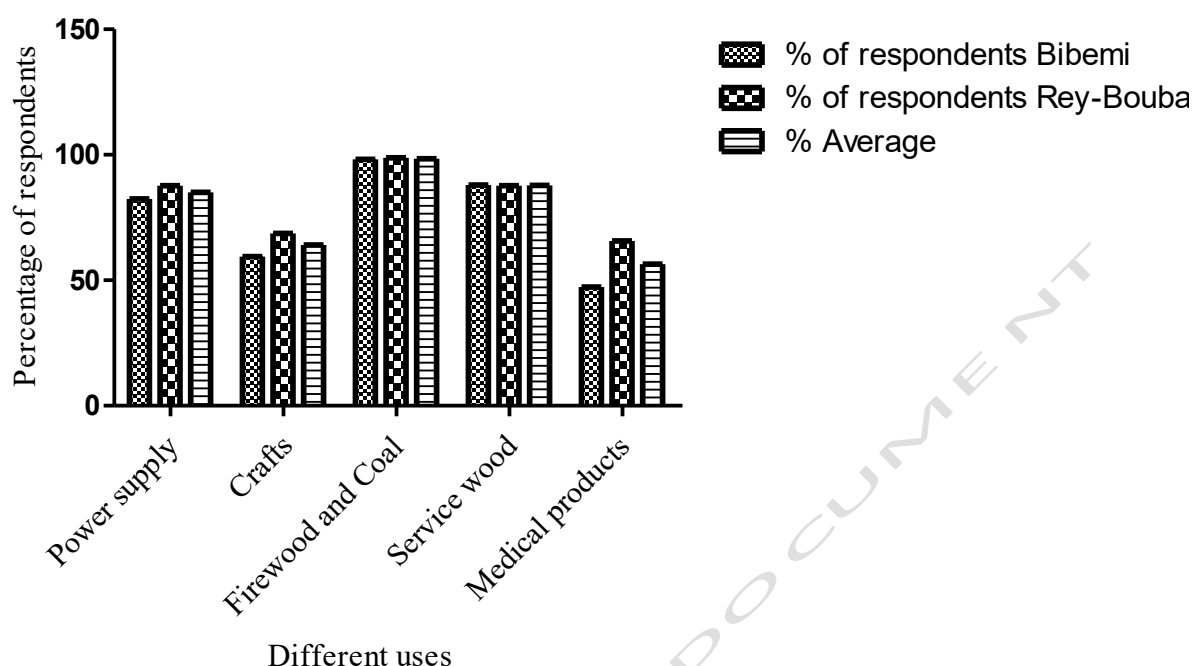


Figure 3: Uses made of plant species

3.3. Importance of non-timber and timber forest products for the population

3.3.1. Food use of timber species

Exploited fruit species

In the eastern part of the Benoué river bank, 28 fruit species whose fruit is appreciated by the local population have been identified. Their use by local people varies and depends on their value and availability. The most popular fruit species are : *Adansonia digitata* (100.00 ± 0.00%), *Balanites aegyptiaca* (100.00 ± 0.00%), *Diospyros mespiliiformis* (100.00 ± 0.00%), *Ficus platyphylla* (100.00 ± 0.00%), *Mangifera indica* (100.00 ± 0.00%), *Psidium guajava* (100.00 ± 0.00%), *Tamarindus indica* (100, 00 ± 0.00%), *Vitex doniana* (100.00 ± 0.00%), *Vittelaria paradoxa* (100.00 ± 0.00%), *Ximenia americana* (100.00 ± 0.00%), *Ziziphus mauritiana* (100.00 ± 0.00%), *Ziziphus spina-christi* (100%), *Annona senegalensis* (97.57 ± 1.70%), (table II). Most of these fruits are eaten when ripe, whether fresh, dried, raw, cooked or processed, and consumers come from all social strata. The fruit is also often dried and preserved for later consumption or sale. Consumption of the fruit means that very little agricultural produce is needed to provide food throughout the year. The fruits can be appreciated and exploited for their sweet or sour pulp.

Table 2 : Different edible fruit species,

Species names	% Bibemi	% Rey-Bouba	% Average/ Standard deviation
<i>Adansonia digitata</i>	100	100	100.00 ± 0.00
<i>Balanites aegyptiaca</i>	100	100	100.00 ± 0.00
<i>Diospyros mespiliformis</i>	100	100	100.00 ± 0.00
<i>Ficus platyphylla</i>	100	100	100.00 ± 0.00
<i>Mangifera indica</i>	100	100	100.00 ± 0.00
<i>Psidium guajava</i>	100	100	100.00 ± 0.00
<i>Tamarindus indica</i>	100	100	100.00 ± 0.00
<i>Vitex Doniana</i>	100	100	100.00 ± 0.00
<i>vittelaria paradoxa</i>	100	100	100.00 ± 0.00
<i>Ximenia americana</i>	100	100	100.00 ± 0.00
<i>Ziziphus mauritiana</i>	100	100	100.00 ± 0.00
<i>Ziziphus spina-christi</i>	100	100	100.00 ± 0.00
<i>Annona senegalensis</i>	96.36	98.77	97.57 ± 1.70
<i>ficus sycomorus</i>	95.76	88.96	92.36 ± 4.81
<i>Parkea biglobosa</i>	93.94	97.55	95.74 ± 2.55
<i>Ficus injens</i>	89.09	90.18	89.64 ± 0.77
<i>Hyphaene thebaica</i>	80.61	60.12	70.36 ± 14.48
<i>Ziziphus mucronata</i>	77.57	74.84	76.20 ± 18.58
<i>Strychnos spinosa</i>	74.55	86.5	80.52 ± 8.46
<i>Sarcephalus latifolus</i>	73.33	58.28	65.81 ± 10.64
<i>Detarium microcarpum,</i>	59.39	82.82	71.11 ± 16.57
<i>Borassus aethiopium</i>	57.58	38.65	48.11 ± 13.38
<i>Hexalobus monopetalus</i>	52.73	47.85	50.29 ± 3.45
<i>Andira inermis</i>	47.27	21.47	34.37 ± 18.24
<i>Sclerocarya birrea</i>	47.27	69.33	58.30 ± 15.59

<i>Hematostaphis barterii</i>	34.55	28.22	31.38 ± 4.47
<i>Gardenia aquala</i>	27.27	21.47	24.37 ± 4.10
<i>Piliostigma reticulatum</i>	20.61	26.38	23.49 ± 4.08

3.3.2. Wild species with edible leaves and flowers

Our ethnobotanical survey results show that a total of 7 species are the most sought-after by local people for their leaves and flowers. The leaves of these species, dried or not, are used in traditional cooking for sauces or other purposes (condiments and additives because of their mucilaginous quality). The percentages below represent the overall utilization rates for the zone. These are: *Balanites aegyptiaca* (52.71 ± 8.60%), *Bombax costatum* (38.67 ± 12.17%), *Adansonia digitata* (67.77 ± 21.28%), *Crateva adansonii* (23.77 ± 3.24%), *Celtis integrifolia* (20.74 ± 1.04%), *Tamarindus indica* (40.55 ± 0.08%), *Leptadenia hastata* (7.30 ± 3.39%), (Table III). People in this area are often faced with a lack of vegetables during the year due to the long dry season. The leaves and flowers of woody species are used to make sauces. It should be noted that the juice obtained from *Tamarindus indica* leaves is used as vinegar to give flavour to boiled food when there is a shortage of fruit from this species.

Table III: Wild species with edible leaves and flowers

Species names	Parts consumed	% Bibemi	% Rey-Bouba	% Average/Standard deviation
<i>Balanites aegyptiaca</i>	Leaves	58.79	46.63	52.71 ± 8.60
<i>Bombax costatum</i>	Leaves and Flowers	47.27	30.06	38.67 ± 12.17
<i>Adansonia digitata</i>	Leaves	52.73	82.82	67.77 ± 21.28
<i>Crateva adansonii</i>	Leaves	26.06	21.47	23.77 ± 3.24
<i>Celtis integrifolia</i>	Leaves	20	21.47	20.74 ± 1.04
<i>Tamarindus indica</i>	Leaves and flowers	40.61	40.49	40.55 ± 0.08
<i>Leptadenia hastata</i>	Leaves	9.7	4.91	7.30 ± 3.39

3.3.3. Exploited seed species

The results of the ethnobotanical surveys revealed two different ways of using woody seeds in the zone: eating the seeds raw or prepared, and extracting oil from the seeds. Thus, 5 woody species exploited for their seeds were identified in this zone (Table IV). The seeds of *Balanites aegyptiaca*, locally known as "Pouyadi", are highly appreciated and consumed like groundnuts

after cooking, with a solicitation rate of $57.92 \pm 2.09\%$. The same applies to *Sclerocarya birrea* seeds ($23.76 \pm 4.97\%$), which this time are eaten raw. The oil extracted from *Azadirachta indica* seeds ($97.56 \pm 0.84\%$), *Vittelaria paradoxa* ($48.16 \pm 3.03\%$) and *Khaya senegalensis* ($43.63 \pm 7.71\%$) is used in food and as a pharmacopoeia by the local population.

Table IV: Species whose seeds are used by local populations.

Species names	Products	% Bibemi	% Rey- Bouba	% Average/Standard deviation
<i>Azadirachta indica</i>	Oil from seeds	96.97	98.16	97.56 ± 0.84
<i>Balanites aegyptiaca</i>	Seeds and oil	59.39	56.44	57.92 ± 2.09
<i>Vittelaria paradoxa</i>	Oil from seeds	50.30	46.01	48.16 ± 3.03
<i>Khaya senegalensis</i>	Oil from seeds	38.18	49.08	43.63 ± 7.71
<i>Sclerocarya birrea</i>	Seeds	27.27	20.25	23.76 ± 4.97

3.3.4. Medicinal uses

Table V shows the species used by people in this area in their traditional pharmacopoeia. The 38 medicinal plant species listed in this table show the importance attached to the pharmacopoeia by the people living in this locality. The most commonly used species is *Khaya senegalensis* (97.25% of respondents), followed by *Acacia albida* (91%). The high rate of use of these species could be due to their various curative virtues and their availability in the locality. With regard to the districts, it should be noted that rey-bouba (97%) comes first in the use of medicinal species. This could be due to the fact that there are a large number of people involved in the practice of pharmacopoeia who do not have access to modern care, and to the distance of certain villages from the centre. In second place comes the population of the Bibemi district (70%), who make little use of medicinal plants. With a wide range of medicinal plants, everyone is their own therapist and can be cured by the wonders that nature has to offer. A number of illnesses are traditionally treated by people in the districts surveyed, including stomach ache, flu, malaria, coughs, stomach ache, diarrhoea, intestinal worms, tooth decay, amoebae, fever, toothache, sexual impotence, gonorrhoea and syphilis. The results of the survey and observations made in the field showed that local people use non-timber forest products (roots, bark and leaves) in traditional medicine (to treat themselves). This information was provided by resource people (traditional healers) during the surveys. The greatest danger for this species lies in the destructive harvesting techniques used, which, by removing the various parts of these species in an anarchic manner, such as repeated uprooting and total debarking, and its illegal exploitation, undoubtedly contribute to the fragmentation of wild flora habitats.

Table V: different species used by the local population for medicinal purposes.

Species	Diseases treated	Use part	% Bibe mi	% Rey- Bouba	% average/ standard deviation
<i>Acacia albida</i>	Rum	bark	95.7 6	88.96	92.36±4.81
<i>Acacia hockii</i>	Asthma, bronchitis, diarrhea, cough	Root and bark	13.3 3	21.47	17.40±5.76
<i>Acacia nilotica</i>	Asthma, cough, gastric, diarrhea, intestinal glass, toothache	Fruit, bark et leaves	78.1 8	69.33	73.75±6.26
<i>Adansonia digitata</i>	Diarrhea	fruit pulp	40.6 1	55.21	47.91±10.33
<i>Aloes vera</i>	Stomach aches, gastric, jaundice	Whole plant	63.6 4	72.39	68.01±6.19
<i>Annona senegalensis</i>	Fever, Gonococcal disease, Diarrhea,	leaves, bark, racine, young shoot	35.1 5	47.85	41.50±8.98
<i>Anogeissus leiocarpus</i>	Jaundice, fever	Root and bark	38.1 8	52.15	45.16±9.88
<i>Azadirachta indica</i>	Fever, malaria, stomach aches, AIDS	leaves, seeds, the oil	75.7 6	62.58	69.17±9.32
<i>Balanites aegyptiaca</i>	Diarrhea, stomach aches, amoeba, fever, toothache	Fruits, seeds ,root and bark	40.6 1	55.83	48.22±10.76
<i>Bombax costatum</i>	Diarrhea, fever	Root and bark	33.3 3	37.42	35.38±2.89
<i>Boscia senegalensis</i>	Sexual impotence, gastric, gonococcal disease, syphilis	Root, leaves and bark	42.4 2	20.25	31.33±15.68
<i>Burkea africana</i>	wound/injury	Bark	56.9 7	66.26	61.61±6.57
<i>Calotropis procera</i>	itching, wound	Root, bark, seve	50.3 0	42.33	46.32±5.64
<i>Combretum fragrans</i>	wound	leaves,	55.1 5	48.47	51.81±4.73
<i>Crossopteryx febrifuga</i>	Diarrhea, toothache	Bark	31.5 2	52.15	41.83±14.59
<i>Daniellia oliveri</i>	Migraine, ulcer, wound, toothache , menstrual disorders,	bar, leaves	27.2 7	74.85	51.06±33.64
<i>Detarium microcarpum</i>	Gonococcal disease, diarrhea	bark, root	41.2 1	42.94	42.08±1.23
<i>Diospyros mespiliformis</i>	Hémorrhages, cough, diarrhea, sexual weakness,	bark, root and leaves	34.5 5	20.86	27.70±9.68
<i>Ficus sycomorus</i>	Hyper tension	Bark decoction	57.5 8	47.85	52.71±6.88
<i>Gardenia aqualla</i>	Sore eyes	Seve	40.0 0	83.44	61.72±30.71
<i>Hyphaene thebaica</i>	Internal shock, Bilharzia, hyperTension	bark, root and fruit.	13.9 4	53.99	33.96±28.32

<i>Khaya senegalensis</i>	Jaundice, Dermatoses, stomach aches, diarrhea	root decoction and the oil	97.58	96.93	97.25±0.45
<i>Kigelia africana</i>	wound/injury	Bark	0.00	77.91	38.96±55.09
<i>Leptadenia hastata</i>	Diabète, hyper tension, sexual impotence, cough, diarrhea and fever	Whole plant	38.18	26.99	32.59±7.91
<i>Mangifera indica</i>	yeast, Rheumatism, Hémorrhoids...	Bark decoction	60.00	42.94	51.47±12.06
<i>Maytenus senegalensis</i>	wounds, dysentery, dental carrie, diarrhea	Root ; bark	75.76	68.10	71.93±5.42
<i>Moringa oleifera</i>	Typhoid, Diabete, Hyper tension,	Shade-dried leavess and seeds	95.76	95.09	95.42±0.47
<i>Nauclea latifolia</i>	Intestinal parasites, hernia, diarrhea	Root, bark	0.00	12.27	6.13±8.68
<i>Prosopis africana</i>	wounds, ulcer, rheumatism ,dental carrie, gastric cough, bronchitis, fever,	Root and bark	23.03	26.38	24.71±2.37
<i>Pterocarpus erunaceus</i>	dysentery, Anemia, stérility ulcer, wounds	Root, bark	33.33	37.42	35.38±2.89
<i>Sarcocephalus latifolius</i>	Dental carrie, stomach aches,jaundice	bark, root	93.94	88.96	91.45±3.52
<i>Sclerocarya birrea</i>	Diarrhea, cough	Root and bark	41.82	49.08	45.45±5.13
<i>Sterculia setigera</i>	anemia	bark decoction	74.55	61.96	68.25±8.90
<i>Stereospermum kunthianum</i>	Bilharzia, syphilis, gonococcal dieses, cough, diarrhea	bark, root	46.67	34.36	40.51±8.71
<i>Tamarindus indica</i>	Painful periods, cough	Root, fruit	55.15	24.54	39.85±21.65
<i>Vittelria paradoxa</i>	bilharzia, headaches, fever, cough	Shea butter, bark decoction	40.00	43.56	41.78±2.52
<i>Ximenia americana</i>	Tuberculosis	bark, leaves	52.12	42.94	47.53±6.49
<i>Ziziphus mauritiana</i>	Stomach aches, gastric	Root decoction	83.03	71.78	77.40±7.96

3.4. Consumption of fuelwood and service wood

3.4.1. Plant species most valued for fuelwood by the population

People in the eastern part of the Benoué riverbank recognise that most species can be used for fuel. A total of 28 species are recognised as producing quality fuelwood in this locality. The species most in demand for fuelwood in terms of percentage of respondents include: Table VI: Species used for fuelwood. *Anogeissus leiocarpus* (85.3 ± 10,48%), *Piliostigma sp* (64.5 ± 23.59),

Azadirachta indica (69.8 ± 14.49), *Combretum fragrans* (75.6 ± 1.07), *Ziziphus mauritiana* (41.6 ± 37.15), *Acacia sp.* (68.0 ± 2.74), *Terminalia glaucescens* (66.2 ± 3.59), *Combretum glutinosum* (63.4 ± 5.72), *Balanites aegyptiaca* (43.5 ± 12.99), *Khaya senegalensis* (45.7 ± 8.23), *Tamarindus indica* (47.6 ± 0.41), *Vittelaria paradoxa* (32.9 ± 17.82), *Isobertlinia doka* (30.1 ± 42.51). The high use of these species can be justified by the fact that they are fire-resistant and do not burn quickly. Their ability to withstand fire means that households can use them over a long period, thus saving time and energy in the search for firewood. The increased consumption of fuelwood could be due to the inaccessibility of other alternative energy sources, particularly oil and gas, which are difficult to access in rural areas. The anarchic exploitation of firewood shows a significant degree of fragmentation of the flora.

Table VI: Species used for fuelwood

Species	% Bibemi	% Rey-Bouba	% average/ standard deviation
<i>Anogeissus leiocarpus</i>	92.73	77.91	85.3 ± 10.48
<i>Combretum fragrans</i>	76.36	74.85	75.6 ± 1.07
<i>Azadirachta indica</i>	80	59.51	69.8 ± 14.49
<i>Acacia sp.</i>	66.06	69.94	68.0 ± 2.74
<i>Terminalia glaucescens</i>	63.64	68.71	66.2 ± 3.59
<i>Piliostigma sp</i>	81.21	47.85	64.5 ± 23.59
<i>Combretum glutinosum</i>	59.39	67.48	63.4 ± 5.72
<i>Ziziphus mauritiana</i>	67.88	15.34	41.6 ± 37.15
<i>Balanites aegyptiaca</i>	52.73	34.36	43.5 ± 12.99
<i>Khaya senegalensis</i>	51.52	39.88	45.7 ± 8.23
<i>Tamarindus indica</i>	47.27	47.85	47.6 ± 0.41
<i>Vittelaria paradoxa</i>	45.45	20.25	32.9 ± 17.82
<i>Entada Africana</i>	28.48	10.43	19.5 ± 12.76
<i>Lonchocarpus laxiflorus</i>	27.27	18.4	22.8 ± 6.27
<i>Ficus sycomorus</i>	24.24	7.36	15.8 ± 11.94
<i>Terminalia laxiflora</i>	23.03	42.94	33.0 ± 14.08
<i>Pterocarpus sp</i>	21.82	32.52	27.2 ± 7.57
<i>Steriospermum kuntianum</i>	20	14.11	17.1 ± 4.16
<i>Ficus platifilla</i>	19.39	4.91	12.2 ± 10.24

<i>Prosopis Africana</i>	19.39	26.99	23.2 ± 5.37
<i>Sclerocarya birrea</i>	4.85	28.22	16.5 ± 16.53
<i>Parkea biglobossa</i>	4.24	34.36	19.3 ± 21.30
<i>Dalbergia melanoxylon</i>	3.03	22.09	12.6 ± 13.48
<i>Afzelia Africana</i>	0	28.22	14.1 ± 19.95
<i>Daniellia oliveri</i>	0	53.37	26.7 ± 37.74
<i>Detarium microcarpum</i>	0	40.49	20.2 ± 28.63
<i>Isobertia doka</i>	0	60.12	30.1 ± 42.51
<i>Lophira lanceolata</i>	0	42.94	21.5 ± 30.36

3.4.2. Species most valued for charcoal making

Carbonisation, or charcoal production, in this zone (Table VII) is only carried out by a limited number of farmers for whom this activity is generally secondary. The best charcoal is obtained from species whose wood is resistant to heat, so the species used to make charcoal are as follows: *Anogeissus leiocarpus* (88.41%), *Terminalia spp*(88.39 %), *Pterocarpus sp*(62.83 %), *Vittelaria paradoxa*(57.82 %), *Prosopis africana*(47.85 %), *Vitex sp*(31.39 %), *Khaya senegalensis* (24.67 %), *Balanites aegyptiaca* (23.13 %). Charcoal remains a secondary source of energy, used occasionally, either when wood is in short supply or for specific uses such as heating tea, ironing clothes, etc.

Table VII: Species most frequently used to make charcoal

Species	% Bibemi	% Rey-Bouba	% average/ standard deviation
<i>Anogeissus leiocarpus</i>	89.70	87.12	88.41 ± 1.82
<i>Terminalia spp</i>	92.12	84.66	88.39 ± 5.27
<i>Pterocarpus sp</i>	59.39	66.26	62.83 ± 4.85
<i>Vittelaria paradoxa</i>	74.55	41.10	57.82 ± 23.65
<i>Prosopis africana</i>	0.00	95.71	47.85 ± 67.67
<i>Vitex sp</i>	33.33	29.45	31.39 ± 2.75
<i>Khaya senegalensis</i>	29.09	20.25	24.67 ± 6.25
<i>Balanites aegyptiaca</i>	29.09	17.18	23.13 ± 8.42
<i>Combretum fragrans</i>	19.39	17.18	18.29 ± 1.57
<i>Daniellia oliveri</i>	0.00	23.31	11.66 ± 16.48
<i>Lonchocarpus laxiflorus</i>	13.33	4.91	9.12 ± 5.96

<i>Detarium microcarpum</i>	0.00	14.11	7.06 ± 9.98
<i>Combretum glutinosum</i>	10.91	1.84	6.37 ± 6.41
<i>Acacia polyacantha</i>	1.21	6.75	3.98 ± 3.91
<i>Tamarindus indica</i>	4.85	0.00	2.42 ± 3.43

3.4.3. Plant species used for Wood services.

In addition to plant species used for food and medicinal purposes, the woody flora also grows a range of plant species for various traditional uses. The results of our survey confirmed this, giving a list of species used as building materials and to make various craft items (hats, tablecloths, mortars, pestles, handles, furniture, utensils, etc.). The parts harvested include the trunk, branches, leaves and bark. The table shows that, depending on the species, "*Azadirachta indica* (93.58%), *Tamarindus indica* (91.76%); *Anogeissus leiocarpus* (85.96%) *Balanites aegyptiaca* (83.83%) *Pterocarpus sp.* (78.99%) *Diospyros mespiliformis* (78.65%), *Terminalia sp.* (71.97%), *Vittelaria paradoxa* (71.30%) *Isoberlinia doka* (56%), *Daniellia oliveri* (31%), *Afzelia africana* (13%) are used as poles for building houses and sheds (Table VIII). As far as craft wood is concerned, it should be noted that the choice of species also takes into account the value placed on the object being made, depending on whether it is a mortar, pestle, tom-tom, stool or any other object. The analysis of variance shows that there is a highly significant difference between the species used as service wood (0.05 P). This exploitation shows the population's dependence on forest products. Repeated logging of these species undoubtedly contributes to their degradation and the decline in their populations in the wild.

Table VIII: the different species used for service wood.

Species	% Bibemi	% Rey-Bouba	% average
<i>Azadirachta indica</i>	96.36	90.80	93.58
<i>Tamarindus indica</i>	92.73	90.80	91.76
<i>Anogeissus leiocarpus</i>	87.88	84.05	85.96
<i>Balanites aegyptiaca</i>	86.06	81.60	83.83
<i>Pterocarpus sp</i>	75.15	82.82	78.99
<i>Diospyros mespiliformis</i>	80.61	76.69	78.65
<i>Terminalia spp</i>	68.48	75.46	71.97
<i>Vittelaria paradoxa</i>	77.58	65.03	71.30
<i>Steriospermum kuntianum</i>	80.00	59.51	69.75
<i>Khaya senegalensis</i>	69.70	62.58	66.14

<i>Combretum fragrans</i>	63.64	60.12	61.88
<i>Piliostigma sp</i>	73.94	47.85	60.90
<i>Isobertlinia doka</i>	47.27	73.01	60.14
<i>Combretum glutinosum</i>	64.85	53.99	59.42
<i>Mitragyna inermis</i>	53.94	60.74	57.34
<i>Vitex doniana</i>	49.09	60.74	54.91
<i>Acacia albida</i>	67.27	20.25	43.76
<i>Sclerocarya birrea</i>	56.36	27.61	41.99
<i>Dalbergia melanoxylon</i>	43.03	39.88	41.45
<i>Acacia gerrardii</i>	43.64	27.61	35.62
<i>Daniellia oliveri</i>	13.94	53.37	33.66
<i>Afzelia Africana</i>	20.00	42.94	31.47
<i>Acacia polyacantha</i>	27.27	33.74	30.51
<i>Strychnos spinosa</i>	26.06	33.74	29.90
<i>Acacia hockii</i>	33.94	19.63	26.79
<i>Acacia senegal</i>	38.18	14.11	26.15

3.4.4. Species most commonly consumed as fodder in the zone

Table IX shows the species used as fodder in the eastern part of Rive de la Bénoué. Herders in this area make periodic trips in search of fodder during the dry season. They find woody fodder species in this part of the country, which they use to feed their livestock. Depending on the species and the rate at which they are used, these are: *Khaya senegalensis* (100%), *Faidherbia albida* (95.74%), *Ziziphus mauritiana* (92.97%), *Anogeissus leiocarpus* (90.61%), *Sclerocarya birrea* (80.2%), *Afzelia africana* (47.95%), *Stereospermum kunthianum* (45.18%) *Prosopis africana* (52.16%). This could be explained by the fact that there are enough forage species in the area. All these factors testify to the negative impact of pastoral pressure on natural resources in the eastern part of the Benoué bank. The availability of fodder and the permanent watering places in this zone constitute points of attraction for domestic animals.

Table IX: Plant species most eaten by livestock

Species	% Bibemi	% Rey-Bouba	% Average
<i>Khaya senegalensis</i>	100	100	100

<i>Faidherbia albida</i>	94.55	96.93	95.74
<i>Ziziphus mauritiana</i>	95.15	90.8	92.97
<i>Anogeissus leiocarpus</i>	81.21	100	90.61
<i>Sclerocarya birrea</i>	78.18	82.21	80.2
<i>Ficus sp</i>	76.97	79.75	78.36
<i>Pterocarpus sp.</i>	70.61	84.5	77.55
<i>Acacia nilotica</i>	79.39	74.85	77.12
<i>Tamarindus indica</i>	73.94	63.8	68.87
<i>Bauhinia rufescens</i>	74.55	54.6	64.57
<i>Balanites aegyptiaca</i>	60	68.1	64.05
<i>Piliostigma reticulatum</i>	53.94	60.12	57.03
<i>Acacia ataxacantha</i>	61.21	45.4	53.31
<i>Prosopis Africana</i>	47.27	57.06	52.16
<i>Afzelia Africana</i>	34.55	61.35	47.95
<i>Acacia sieberiana</i>	40.61	55.21	47.91
<i>Acacia polyacantha</i>	57.58	33.74	45.66
<i>Stereospermum kunthianum</i>	35.15	55.21	45.18
<i>Capparis sepiaria</i>	33.94	53.37	43.66
<i>Daniellia oliveri</i>	19.39	61.96	40.68
<i>Detarium microcarpum</i>	26.67	47.85	37.26
<i>Terminalia sp.</i>	40.61	33.74	37.17
<i>Lochocarpus laxiflorus</i>	20.61	52.15	36.38
<i>Acacia seyal</i>	33.33	38.65	35.99

3.5. Variation in uses according to species

Figure 4 shows that the first two axes explain 53.66% of the information, with 28.80% for axis F1 and 24.85% for axis 2. Consequently, only these two axes were used to identify the different uses of the species. This shows that:

The F1 axis concentrates information relating to human food, fruit, leaves and flowers consumed, and plants used in traditional medicine. The species on the positive side of the axis

are mainly used for human consumption for their leaves and flowers. On the other hand, species on the negative side of the axis are used for human consumption, more specifically species with edible fruit, and traditional medicine;

Axis F2 is correlated with forage species, species used for fuelwood, service wood and species exploited for their seeds. These species are all located on the positive side of this axis, indicating that they are used for a variety of purposes.

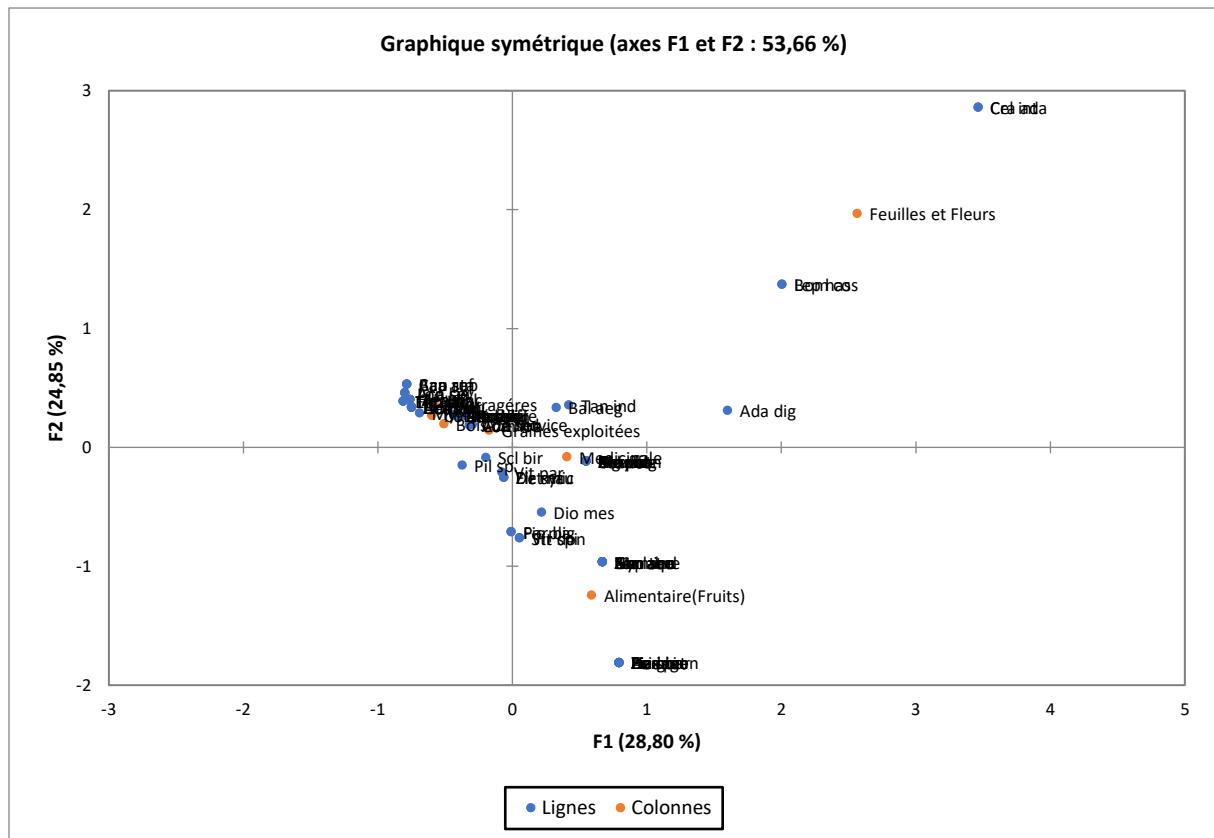


Figure 4: Correspondence factor analysis of species and their different uses

DISCUSSION

Characterisation of stakeholders in the exploitation of forest products

Stakeholders are the key elements in the exploitation of non-timber forest products. They control the circuit and flow of the distribution of these products. They are recruited at various levels of the social stratum and consist mainly of farmers and herders. The work of Sandjong et al (2013) and Kemeuze (2011) in the Far North of Cameroon is along the same lines and also certifies that farming and livestock rearing are the main daily activities of the population.

Uses of products derived from plant species

Plant species are used in different ways depending on the needs expressed by the population. Products from plant species are used for a number of purposes, including consumption of fruit, leaves, flowers and tubers; exploitation for firewood and charcoal; service wood, including species providing materials for the construction of sheds, the building of houses, the

construction of buildings, etc.; and the production of foodstuffs. the roofs of houses and the frames of doors and windows; species used in crafts and in pharmacopoeia. Roothaert & Franzel (2001); Elseed et al, (2002); Chahad et al. (2015) attest that all parts of the plant (roots, leaves, fruit, bark, thorns, wood) are used for food, therapeutic, economic or socio-cultural purposes.

Several plant species are used in traditional medicine to treat various ailments. All parts of the plant are used. Results relating to the use of plants in traditional pharmacopoeia are also reported by Dongock et al (2018) in the Moundou area of Chad, who state that *Annona senegalensis* and *Mangifera indica* are used respectively to treat arterial hypertension. Woody species also play an important role in crafts. Certain plant species are used to make certain objects, such as pestles, mortars, couscous turners, animal troughs, axe handles and stools. It should also be noted that the choice of species takes into account the value placed on the object being made, whether it is a mortar, pestle, tam-tam, stool or any other object. These selection criteria are reported by (Thiombiano *et al.*, 2002), (Lykke *et al.*, 2004), and (Bognounou, 2009). Still referring to the work of these authors, *Anogeissus leiocarpus* is preferred in construction for the hard consistency and resistance of its wood to termites. *Piliostigma thonningii* (60.90%) is used as rope. Nizesete (2013), in a similar vein, states that the flora is made up of a heterogeneous range of species, whose wood's diverse physical and mechanical potential allows it to be used for a variety of purposes, including exterior and interior architecture, kitchen utensils and small indoor furniture, agricultural tools and other everyday objects.

Food use of ligneous species

Food uses include species exploited for their fruit. Most of these fruits are eaten when ripe, whether fresh, dried, raw, cooked or processed, and consumers come from all social strata. The nutritional value of the fruit and its use in human nutrition are recognised by several authors (Mapongmetsem *et al.*, 2012); (Froumsia, 2013), and (Hamawa, 2015); in the Sahelian zone. However (Kristensen and Balslev, 2003) in Gourounsi in Burkina Faso notes that the availability of most fruits coincides with the start of field work and the drop in food supplies. At this time, the availability and consumption of wild fruit makes a considerable contribution to household diets, since according to (Guinko and Pasgo, 1992), wild fruit contributes to a varied diet in terms of vitamins.

Exploited seed species

The consumption of raw or prepared seeds and the extraction of oil from the seeds of certain species are encountered daily by the population in rural areas. The use of the kernels and the oil extracted from the kernels of these species in human food is also reported by (Belge *et al.*, 2006) and (Mohammed *et al.*, 2002). This result also corroborates those of (Froumsia, 2013) who prove that the seeds of *Balanites aegyptiaca* and *Sclerocarya birrea* are exploited for consumption and oil extraction. They are consumed directly after grinding of the lignified kernel (*Sclerocarya birrea*) or undergo treatment to make them edible (*Balanites aegyptiaca*) in the Kalfou reserve in Cameroon.

Medicinal uses

Several plant species are used by the local population in traditional medicine. The medicinal plants listed testify to the importance attached to pharmacopoeia by the local population. The high rate of use of these plant species could be due to their various curative virtues and their availability in the locality. These results corroborate those of Toirambe (2007), who shows that nature is endowed with a mosaic of medicinal plants that people can use for health care. He adds that, with the diversity of medicinal plants, everyone is their own therapist. Mapongmetsem et al (2006), in their study of the use of NTFPs in the Sudano Guinean savannahs, showed that there is a multitude of species of local and international importance.

Consumption of fuelwood and service wood

Most species can be used for fuel, but some produce quality fuelwood in this locality. Households remain highly dependent on fuelwood. Ali Madi et al (2003) support this finding, stating that the level of wood consumption, despite the use of other energy sources, remains high, making wood the dominant energy source in households. These results complement those obtained by Tchobsala (2011) in the peri-urban savannahs of Ngaoundéré, who showed that several species such as *Annona senegalensis*, *Daniellia oliveri*, *Khaya senegalensis* and *Securidaca longepedunculata* are used as fuelwood.

Conclusion

This study aimed to analyze the socioeconomic importance of plant resources for the local population. Our surveys reveal that the majority of surveyed households are primarily engaged in agriculture. The role played by plant resources for the population in this area is well established. With population growth, woody species are used for multiple purposes in the population's daily life. These various uses include: fuelwood, timber and service wood, traditional pharmacopoeia, and fodder for livestock and human consumption. Today, given their steadily growing food, social, economic, and therapeutic importance, it is necessary to advocate for the conservation of these species. At the end of this ethnobotanical study conducted among 328 individuals across 20 villages on the eastern bank of the Benoué River, 72 woody species exploited by local populations were recorded, distributed across seven use categories. Twenty-eight species are harvested for their edible fruits, among which *Adansonia digitata*, *Balanites aegyptiaca*, *Diospyros mespiliformis*, *Ficus platyphylla*, *Mangifera indica*, *Psidium guajava*, *Tamarindus indica*, *Vitex doniana*, *Vitellaria paradoxa*, *Ximenia americana*, *Ziziphus mauritiana*, and *Ziziphus spina-christi* are all cited at 100%. Seven species are sought for their edible leaves and flowers, and five for their seeds, while 38 species are used in traditional medicine, 28 for fuelwood, 26 for service wood, and 24 for fodder. Correspondence factor analysis showed that these uses are structured along two axes, respectively opposing species with edible leaves and flowers to those exploited for fruits and pharmacopoeia, and grouping fodder species together with those sought for firewood, service wood, and seeds. Farmers constitute the main group exploiting these resources (80.45% of respondents), followed by livestock breeders (8.48%), with traders, informal workers, and civil servants intervening only marginally. These results confirm the diversity and socioeconomic importance of woody resources for populations living along the Benoué River and call for a sustainable, well-managed exploitation of this woody heritage.

Declarations

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Author Contributions (CRediT)

Djosebe Azaria: Conceptualization; Formal analysis; Investigation; Validation; Writing - original draft; Methodology; Writing - review & editing; Data curation; Software. **Tezore Bakary Prudence:** Investigation; Methodology. **Froumsia Moksia:** Software; Visualization; Supervision; Writing - review & editing. **Kamblaba Pierre:** Investigation; Formal analysis; Resources. **Pa Ai Vivien Nenwala:** Investigation; Conceptualization; Data curation. **Danwang Djaowe Bernard:** Investigation; Visualization; Methodology; Funding acquisition.

Ethics Approval and Consent to Participate

The study was conducted with participants' free and informed consent in accordance with the ethical principles of the International Society of Ethnobiology (ISE). All participants received clear information about the study and gave informed consent before taking part.

Consent for Publication

Participants gave verbal consent to publication of the research results.

Competing Interests

The authors declare that they have no competing interests.

Data Availability Statement

The original data used for this study are available from the corresponding author upon reasonable request.

Declaration of Generative AI Use

To be confirmed by the authors during proof verification.

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