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Research Article

Prioritization of the Forest Species Most Exploited by the Communities Bordering the Natural Forests of Pobè and Dogo-Kétou in Southeastern Benin, West Africa: An Ethnobotanical Approach

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Benin is not a big forest country, and the sustainable management of forest relics and their resources is a priority for the managers. This study was conducted in the forest regions of Pobè and Kétou located in Southeast Benin with the objective of characterizing the ethnobotanical forest species prioritized by the local populations for their different uses. Specifically, it aimed to identify the ethnobotanical priority species for conservation, characterize the ethnobotanical value of these priority species, and analyze the tree organ harvesting methods used for the sustainable management of the forest species. Data have been collected from 287 local populations investigated and on the specimens collected on the field, which allowed to identify the scientific name. The combination of the citation frequencies, the method of reproduction, the vulnerability scores, and the IUCN status of the species has allowed to identify five priority ethnobotanical species per forest. The software R_{i386}_3.5.1 has been used for the different analysis such as the calculation of the various frequencies and the correspondence factor analysis to show the relationships between socioethnic groups, organs used, and the categories of use. The priority species identified in the forest of Pobè are *Milicia excelsa*, *Khaya senegalensis*, *Anogeissus leiocarpa*, *Ceiba pentandra*, and *Adansonia digitata*. The priority species identified in the forest of Dogo-Kétou are *Vitellaria paradoxa*, *Prosopis africana*, *Pterocarpus erinaceus*, *Khaya senegalensis*, and *Anogeissus leiocarpa*. This study has revealed 54 tree species gathered into 47 genera and 25 botanical families. Their different parts have been harvested for many kinds of utilization such as medicinal, commercial, feeding, medico-magic, and artisanal. The most commonly used organs were leaves, fruits, seeds, barks, roots, and wood. The harvesting methods include cutting poles, cutting twigs and branches to harvest leaves, debarking the trunk, felling trees for wood, cutting roots, picking and harvesting fruits and seeds, and harvesting of flowers. Cutting down trees and picking flowers, fruits, and seeds have been the methods of harvesting, which affect negatively regeneration of the tree populations. It is then important to sensitize the local people on the sustainable management of their forest resources through the conception and implementation of a project program focused on forest conservation.

1. Introduction

Forest resources occupy an important place in the life of people and influence the national socioeconomic development in many countries of all continents in the world [1–4]. Forests provide food products (fruits, vegetables, insects, etc.) during lean periods common in seasonally dependent farming systems [5]. Additionally, much of health care depends heavily on medicinal plants and the local knowledge associated with them [6–8]. Thus, the traditional use of plants is inevitable for the provision of traditional medicines in the healthcare system and in terms of food source for low-income social classes and for rural communities [8–12]. Despite the importance of plants in general and forest species in particular, forests are under threat.

In the world, forests currently occupy 30.8% of the world's land area, equivalent to 4.06 billion hectares of forests, while the average rate of net loss of forest area between 2010 and 2020 is 4.74 million hectares per year; the main cause of this loss is agricultural expansion to meet human needs; Africa experienced the highest net loss of forest area during this period with 83% of global losses equivalent to 3.94 million hectares [13]. In fact, in West Africa, precisely in Benin, 1,093,000 ha of forest areas is allocated mainly to the conservation of biodiversity while at the same time, 50,000 ha of forest is devastated yearly [14] mainly for reasons arising from anthropogenic activities [15]. The National Remote Detection Center (CENATEL) estimates that Benin's forest covered 20% of the national territory in 1949, but today it represents less than 12%. In consequence, the forest area per resident, which was 1.63 ha in 1980, decreased to 0.87 ha in 1995 and is expected to decline to 0.29 ha in 2025, if the current trends continue [16]. This persistent degradation of the national forest cover makes Benin one of the ten most forest-destroying countries in the world [17]. It is imperative to emphasize efforts to conserve the forest resources to ensure their availability for future generations. This requires an updated knowledge of existing resources and the problems they face. As for ethnobotanical and ethnopharmacological studies, they provide insight into human harvesting of forest resources for shelter, food, and treatment. To this end, numerous studies have been carried out, for example, on medicinal species, their recipes, and their categories of use by local populations [18, 19], in order to understand what already exists and to promote it.

Indeed, the forests are very important for the populations because they provide many services on the ethnobotanical level. Therefore, there is an urgent need to carry out additional ethnobotanical studies for a good understanding of the local uses of forest resources [20–23] and highlight the impact of these uses on the sustainability of the forests to derive and recommend sustainable practices of uses and conservation of forest resources. It therefore appears that prioritization is one method widely used by researchers to select the most priority species for the conservation. Prioritizing species for conservation is an obvious and key step in designing a realistic and effective biodiversity conservation strategy [24]. Priority species are those that contribute very strongly relative to their low density to improve the economic and social well-being of populations [25, 26]. The exploitation of use values proves to be a basic tool in the selection of priority species with socioeconomic and cultural interest subject to strong anthropogenic pressure [27]. Prioritization has been heavily used in many studies with different methods, to identify the species most under high pressure or biodiversity hotspots that should be considered as priorities in forest and ecosystem management while contributing to sustainable economic and sociocultural well-being of local populations [28–31]. The use value is an index that has allowed several authors to achieve this prioritization of species based on the use that local populations make with the resources which are able to influence their sustainability in the future. The ethnobotanical use value of species makes it possible to highlight locally qualified species to be included as priority species to be conserved in different forests over the world [27]. However, the identification of priority species concern is only effective when it requires the development of clear and specific species selection criteria, such as economic importance, level of use, species patterns, and user population [32].

Thus, as a result of forest overexploitation, the threats on the ethnobotanical resources of the forests, as revealed in [33], reside in the progressive rarity of the populations of the forest resources, highly valued by local populations as well as the forests that shelter them. This study showed from an ethnobotanical view that the natural forests of Southern Benin are losing biodiversity and the resources highly appreciated by the local people. This raised our concern in the following specific questions addressed in this study. (i) What are the characteristics of the priority forest species primarily used by the populations of Pobè and Kétou around the forests? (ii) Do their harvesting methods guarantee their sustainability? Our paper will answer these key questions and therefore contribute to the sustainable conservation and uses of the natural resources of the forests located in the municipalities of Pobè and Kétou in Benin. In this work, we assessed the forest species most used by local populations and the most threatened in order to highlight the highest priorities for short-term conservation actions.

2. Materials and Methods

2.1. Study Area. The study was carried out in Southeastern Benin in the municipalities of Pobè and Kétou (Figure 1). In Pobè, the study was conducted around the classified dense semideciduous forest of Pobè, managed by the Center for Agricultural Research on Perennial Plants (CRAPP) and located between 6°57′20″ and 6°58′04″ north latitude and 2°39′46″ and 2°40′45″ east longitude. In Kétou, the study was conducted around the classified forest of Dogo-Kétou which is a block of two large forest sectors; the sector of Kétou is located between 7°23′30″ and 7°33′02″ north latitude and 02°23′30″ and 02°30′30″ east longitude, and the sector of Dogo is located between 7°30′40″ and 7°41′ north latitude and 02°28′3″ and 02°41′31″ east longitude. These two municipalities have several forest reserves. There are also sacred forests in the two municipalities. The ethnics such as *Nagot*, *Yoruba*, *Holli*, *Fon*, and *Mahi* mainly inhabit the municipalities. In 2013, the municipalities of Pobè and Kétou had, respectively, 123,740 and 157,352 inhabitants [34].

The study area is covered by the subequatorial climate characterized by a succession of well differentiated dry and wet seasons. According to [35], the region of Pobè is located in the Guinean-Congolese region. The region of Pobè has a humid tropical climate with four seasons. Pobè is a part of a region with particular climatic characteristics in the Dahomey Gap, with an average annual rainfall up to 1180 mm [36]. The soil of Pobè shows both weakly ferrallitic

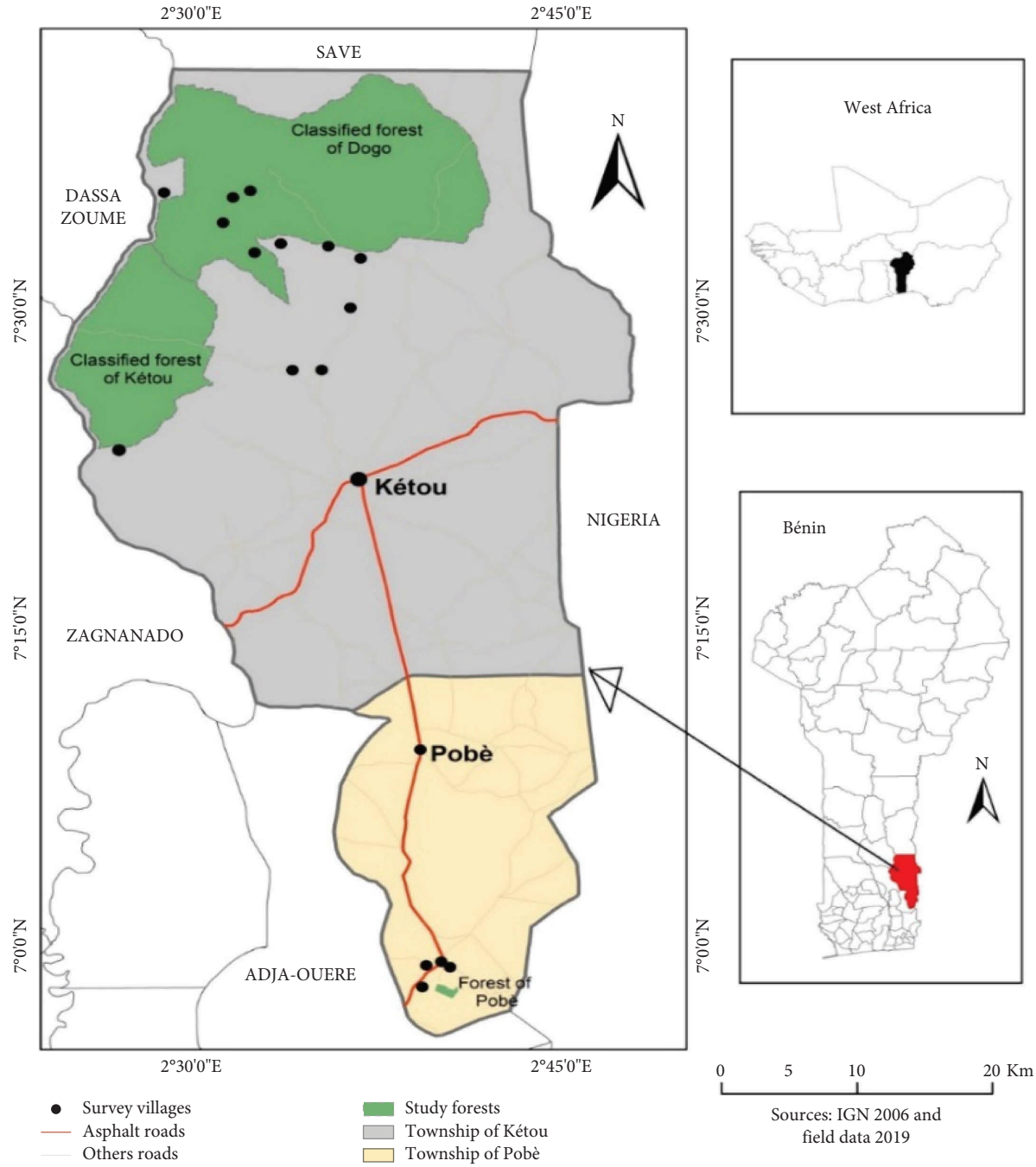


Figure 1: Map of the study area (source: IGN 2006 and field work data 2019).

and hydromorphic soils, and the soil of Kétou is located on a low altitude plateau (between 100 and 200 m) fragmented by more or less pronounced depressions. In some places in Kétou, depleted (slightly desaturated ferrallitic) and indurated soils have been developed and associated with vast layers of ferruginous armor bearing short vegetation. On the terminal plateau, well-drained tropical ferruginous soils have developed which support a wooded savanna with *Daniellia oliveri*, *Lophira lanceolata*, and *Parkia biglobosa* [37].

2.2. Data Collection. Investigation and ethnobotanical data were collected from the local populations living around the forests of Pobè and Kétou. The ethical approval has been obtained from the populations surveyed before the survey in order to develop a positive mindset between the informants and the researchers. The sampled population was randomly selected from rural households living around and in forests in both localities. The households surveyed were randomly surveyed according to the availability of the heads of household in order to produce

reliable estimates. The size of the sampled population (n) has been obtained following the formula of Dagnelie [38] with the relation

$$n = \mu^2\left(1 - \frac{\alpha}{2}\right)\frac{p(1-p)}{\delta^2}, \quad (1)$$

where n is the number of households sampled; $\mu^2(1 - (\alpha/2))$ is the value of the reduced centered normal distribution for a confidence level of 95%, which corresponds to 1.96; P is the estimated proportion of rural populations to the total population of each municipality because the rural populations are the main users of forests species; and δ is the margin error of all estimated parameters that could be calculated in the study, and the value of 8% has been considered.

Two hundred eighty-seven respondents, mainly heads of agricultural households or their representatives, have been surveyed (148 in Pobè and 139 in Kétou). The socioethnic characteristics taken into account have been related to age, sex, ethnic groups, and the main activities of each respondent. The types of information collected from the respondents were related to the vernacular name/local name of the species or their common names, as well as the uses of the species (medicinal, medico-magic, veterinary, cultural and religious, art, food or alimentation, construction, and commercial). The respondents have cited the species primarily used and showed the trees in the forest or related areas from a line transect. Then, the specimens of each species shown by the respondent were recorded to confirm its identity common and scientific names in the binomial nomenclature at the National Herbarium of Benin or by referring to the studies of [39–41] and the web site of the Global Biodiversity Information Facility (GBIF: https://www.gbif.org/). Other information relative to the type of organs used (fruits, pulp, seeds, leaves, flowers, roots, bark, and wood) has been also collected.

The data on the importance of the use of tree species were also collected. The survey allowed to obtain from each interviewee, five categories of trees in order of ethnobotanical importance. These five categories were proposed as part of this study to allow each respondent to choose 5 priority forest species in descending order for the needs of his household. The five categories are as follows: $A1$ = very high priority ethnobotanical valuable species for the interviewee; $A2$: high priority ethnobotanical valuable species; $A3$: medium priority ethnobotanical valuable species; $A4$: low priority ethnobotanical valuable species; and $A5$: very low priority ethnobotanical valuable species for the interviewee. For each category of species ($A1$, $A2$, $A3$, $A4$, and $A5$) the degree of citation, the mode of reproduction (fast, slow, or very slow), and the scores corresponding to its use value by the populations were calculated. The status according to the red list of threatened species in Benin [42] and over the world (IUCN: https://www.iucnredlist.org/) was also recorded.

The harvesting methods (barking, picking, or cutting) with their consequences on the sustainability of forest resources have been collected for the different organs. The source of the species (wild or cultivated) has been collected from the people investigated and complemented with the information of [39–41]. All information collected has been done through structured individual interviews based on survey forms.

2.3. Data Analysis

2.3.1. Sociodemographic Characteristics of the Population Surveyed. The sociodemographic characteristics of the sampled population have been achieved in order to bring out the number of people surveyed by category of ethnic groups, sex, age, and by the education level at school. All the analyses were analyzed using the software R_{i386}3.5.1.

2.3.2. Diversity of Forest Species in Southeast Benin and Their Ethnobotanical Value Characterization. The number of tree species cited and collected from the forest per family has been assessed and the list of the species cited or identified was followed by local names, common names, and scientific names, the parts of organs used by the populations, the forms of uses made with the parts of trees and the type of resource (wild or domestic), etc. A database of all the species cited during the survey was filled with information on their families, their full scientific names, their common names, their local names, their organs used, the harvesting methods of the organs, the categories of uses listed during the survey, and the type of resource.

2.3.3. Identification of Priority Ethnobotanical Forest Species. The data analysis was based mainly on the importance of the use of tree species on the categories $A1$, $A2$, $A3$, $A4$, and $A5$, the degree of citation, the mode of reproduction (fast, slow ,or very slow), the scores corresponding to its use value by the populations, and the status according to the red list of threatened species in Benin. All these kinds of information made it possible to prioritize all the valuable tree species of ethnobotanical importance and retain only 5 species per forest studied with only one species per category. The highest citation percentage associated with a slower growth rate and a more critical conservation status according to the IUCN (national and global) allowed the choice of species of high ethnobotanical importance value by category of species ($A1$, $A2$, $A3$, $A4$, and $A5$).

The frequency of use (FU) was calculated for each species using the following formula: FU = number of citations of the species/number of respondents.

The vulnerability index (VI) was calculated in order to identify the priority species more used and threatened in the area of the study. The vulnerability assessment parameters are adapted from [9]: the popularity of the species, the plant organ used, the pharmaceutical forms used, the biotope, the mode of dissemination of the diaspores, the morphological type, and the frequency of the plant in the study area according to the interviewee's appreciations. In the framework of this study, all these vulnerability assessment parameters were explained to each respondent in order to

allow him to give with credit his vulnerability score linked to each tree species according to his perception. For each tree species, the vulnerability assessment scale was as follows: 1: nonvulnerable species for all the parameters considered, 2: medium vulnerable species, and 3: very vulnerable species. The combined consideration of the various parameters made it possible to define a vulnerability index (VI) specific to each species. This index is obtained by calculating the average of the different values for each species. A species for which $VI < 2$ will be said to be nonvulnerable for a category of use concerned, species for which $2 \leq VI < 2.5$ will be considered as vulnerable, and a species with $VI \geq 2.5$ will be very vulnerable [43].

2.3.4. Characterization of Priority Ethnobotanical Species. The ethnobotanical investigation data were collected to characterize the ethnobotanical value of each identified species, the importance of the uses made by the different ethnic groups, and the impact of the methods of organ harvesting on tree sustainability as in the study of Koura et al. [44]. The database was built, in a cross-tabulation; on one hand, the list of the organs was codified for the 5 trees linked to the codified uses of each species, for example, for *Ceiba pentandra*: Ce_fr (fruits), Ce_gr (seeds), Ce_fe (leaves), Ce_fl (flowers), Ce_r (roots), Ce_éc (bark), and Ce_b (wood), and on the other hand, the different uses were codified as follows : medicinal = Med, medico-magic = Medmag, veterinarian = Vet, cultural and worship = cult, Artisanal = Art, food = Alit, commercial = Com, and building = Const).

The sex groups are male (*M*) and female (*F*); the age groups are under 40 (1) and over 40 (2). Four ethnic groups were obtained in this study for the two municipalities because they are very close at the cultural and religious levels: Nagot (Na), Hollis or Hollidjè (Ho), Fon and Assimilated including Mahi (Fm), and minority groups (Gm) including Adja, Idatcha, Ditammari, and Goun. The combination of sexes, ages, and ethnic groups gave 16 ethnic subgroups as presented for Nagot (4 subgroups): Nagot men aged under 40 (NaM1), Nagot men aged over 40 (NaM2), Nagot women aged under 40 (NaF1), and Nagot women aged over 40 years (NaF2). The same grouping was done for the three other ethnic groups.

The chi-square independence test was run to check whether there was dependence between organs, different uses, and ethnic groups. A factorial correspondence analysis was done with the software R 3.5.1 to highlight the organs most solicited for the categories of use and the organs most exploited by ethnic groups according to their age categories.

2.3.5. Effects of Harvesting Techniques Used for Tree Organs. The ethnobotanical database was analyzed with the software *R* to bring out the types of harvesting methods by organ category of the most exploited trees. The different consequences on the renewal of the tree population were highlighted from the people surveyed in order to establish the impacts on the sustainability of the tree species and their regeneration.

3. Results

3.1. Sociodemographic Characteristics of the Respondents. The sociodemographic characteristics of the population investigated are presented in Table 1. During the survey, 48.43% of the respondents were surveyed in Kétou and 51.57% in Pobè. Around 44% of the respondents were from the ethnic group Fon and Assimilated; thirty-three percent of the respondents belonged to the ethnic group of Hollis in the two municipalities; and 21.60% respondents were from the ethnic group of Nagot. The minority groups including Adja, Idatcha, Ditammari, and Goun accounted for 1.74% of the respondents. Fourteen percent of the surveyed were women, who have been often heads of household after the death of their husbands or after divorces. Thus, 246 people surveyed were men, which represented 85.71%. In the municipality of Kétou, 32 people surveyed were women, which represented 11.15% of all the respondents against 9 women in the municipality of Pobè which represented 3.14% of all the respondents.

3.2. Diversity of Forest Species in Southeast Benin Cited in the Survey. The family diversity graph of the forest species cited during the investigation is presented in Figure 2. Fifty-four forest species have been cited and divided into 47 genera and 25 botanical families. The species of the family of Fabaceae were the most cited by the local population with 10 species followed by Moraceae with 6 species. At the third position was family Combretaceae with 4 species cited, and at the fourth place, three families were cited with 3 species for each.

The different species recorded from the investigation with the information relative to their common name in French, their local name in Nagot, their different parts used, the harvesting method used, the different categories of uses, and the resource types are presented in Table 2. Each species corresponded to a variety of names in the different languages. The majority of the species listed in the survey (90.7%) were wild whose silviculture and domestication were not under control. For these species, they were more at risk due to their overexploitation, and this will threaten their sustainability. Almost all parts of the trees were useful for humans especially fruits, bark, leaves, seeds, flowers, roots, and wood.

3.3. Identification of Priority Ethnobotanical Tree Species. The prioritization results of five tree groups (*A*1, *A*2, *A*3, *A*4, and *A*5) in Pobè and Kétou are presented in Table 3, followed by the score of the vulnerability index, the frequency of citation of each tree species, their mode of reproduction, and their conservation status according to the IUCN.

Analyzing Table 3, in the municipality of Pobè, the five valuable species prioritized in the forest were *Milicia excelsa*, *Khaya senegalensis*, *Anogeissus leiocarpa*, *Ceiba pentandra*, and *Adansonia digitata*, respectively, in categories *A*1, *A*2, *A*3, *A*4, and *A*5. These species have a high percentage of citation and a high vulnerability score, and their growth rate was very slow according to the population with a more critical conservation status according to the International Union of Conservation of Nature (National and International).

Table 1: Sociodemographic characteristics of the population surveyed.

Municipalities	Sex	*F*1	*F*2	*M*1	*M*2	Total
Kétou	Fm	17	12	47	27	103
	Gm	0	0	1	0	1
	Ho	2	1	10	19	32
	Na	0	0	1	2	3
	Total Kétou	19	13	59	48	139
Pobè	Fm	0	1	7	14	22
	Gm	0	0	2	2	4
	Ho	2	1	34	26	63
	Na	2	3	23	31	59
	Total Pobè	4	5	66	73	148
Total		23	18	125	121	287

Fm = Fon and Assimilated; Gm = minority group; Ho = Holli; Na = Nagot; *F*1 = women under 40 years; *F*2 = women over 40 years; *M*1 = men under 40 years; *M*2 = men over 40 years.

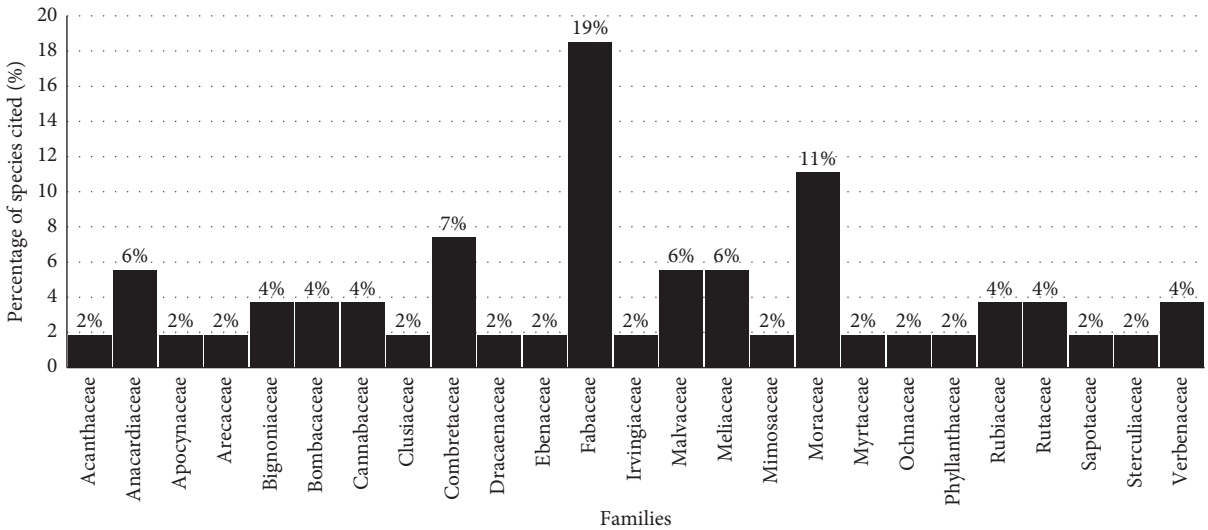


Figure 2: Top dominant tree families recorded from the investigation.

In the municipality of Kétou, the five valuable species prioritized orderly were *Vitellaria paradoxa*, *Prosopis africana*, *Pterocarpus erinaceus*, *Khaya senegalensis*, and *Anogeissus leiocarpa*, respectively, in categories *A*1, *A*2, *A*3, *A*4, and *A*5. These species have been cited with a high percentage and reproduced with difficulty with a critical status according to the IUCN accompanied by a high vulnerability score between 2 and 3 (Table 3).

3.4. Ethnobotanical Characteristics of Valuable Species in Each Municipality. The data on the five priority species per forest were analyzed according to the uses made of the different organs in order to highlight the most used organs of these species and implicitly identify the uses, which could not facilitate the in situ conservation of these species.

3.4.1. Relation between the Organs of the Trees and the Uses in the Municipalities of Pobè and Kétou. Analyzing Figure 3, in the municipality of Pobè, the test of independence of χ^2 between the most used organs and the uses made was equal to 539.6864 with a probability p value = $5.506477e-63$, implying that there was a dependence between these variables at the threshold of 5%. It emerges from the factorial map of Figure 3(a) that the sum of the contribution of the axes 1 and 2 corresponded to 73.19%. The leaves, barks, and roots of *Milicia excelsa* as well as the bark of *Anogeissus leiocarpa* were the most used organs in traditional medicine in Pobè municipality. The seed and wood of *Milicia excelsa* were also used in medico-magic practices. The woods of species such as *Afzelia africana*, *Anogeissus leiocarpa*, and *Ceiba pentandra* were the most commercialized timber and service woods. In terms of food, the fruit, the pulp, and the leaves of *Adansonia digitata* were well consumed by the populations as well as the fruit of *Ceiba pentandra* because the seeds were oleaginous and the cattle consumed the cakes after extraction of the oil.

In the municipality of Kétou, the value of the test of independence of χ^2 between the most used organs and the uses made was equal to 380.4272 with a probability p value = $1.730622e-43$, implying that there was also dependencies between variables. The factorial map of Figure 3(b) with a contribution of the axes equal to 76.19% showed that on the medicinal and medico-magic utilization,

Table 2: List of forest species with ethnobotanical value used by the communities living in the fringe villages of the forests in Southeast Benin.

No.	Families	Scientific name	Common name	Local name	Parts used (fruits/barks/leaves/seeds/flowers/roots/wood)	Harvesting method	Ethnobotanical uses (med/medmag/vet/cult/alit/com/const)	Resource types
1	Fabaceae	*Acacia auriculiformis* A. Cunn. ex Benth., 1842	Acacia	—	Leaves/wood	Picking/cut	Med/com/const	Cultivated
2	Bombacaceae	*Adansonia digitata* L., 1759	Baobab	Oshe	Fruits/bark/leaves/roots	Barking/picking/cut	Med/medmag/vet/cult/alit/com/const	Wild/cultivated
3	Fabaceae	*Afzelia africana* Sm. & Pers., 1798	Haricot acajou	Akpa igbo	Bark/leaves/wood/root	Picking/cut	Med/com/const/com	Wild/cultivated
4	Fabaceae	*Albizia lebbeck* (L.) Benth., 1844	Langue de la femme		Wood	Cut	Const/com	Wild
5	Anacardiaceae	*Anacardium occidentale* L., 1753	Cajou	Kaju	Fruits/seeds/wood	Picking/cut	Alit/com/const/	Cultivated
6	Combretaceae	*Anogeissus leiocarpa* (DC.) Guill. & Perr., 1832	Bouleau d'Afrique	Anyi	Fruit/bark/wood	Barking/cut	Med/com/const	Wild
7	Moraceae	*Antiaris toxicaria* (Pers.) Lesch., 1810	Faux iroko	Oɔro	Bark/wood	Barking/cut	Med/com/const	Wild
8	Meliaceae	*Azadirachta indica* A. Juss., 1830	Neem	Dogɔn yaro	Fruits/leaves/seeds/wood	Picking/cut	Med/alit/const/	Wild/cultivated
9	Acanthaceae	*Brillantaisia madagascariensis* T. Anderson ex Lindau	—	ɔwɔ	Leaves/wood	Picking/cut	Med	Wild
10	Bombacaceae	*Ceiba pentandra* (L.) Gaertn., 1791	Fromager	ɛgun	Fruits/wood	Picking/cut	Med/com/const	Wild/cultivated
11	Cannabaceae	*Celtis brownii* Rendle, 1915 syn Celtis prantlii Priemer ex Engl	—	Amako	Wood	Cut	Const	Wild
12	Cannabaceae	*Celtis mildbraedii* Engl.	—		Roots/wood	Crop/cut	Med/const	Wild
13	Malvaceae	*Cola millenii* K. Schum., 1903	Kola du singe	Kime lakao	Fruits/leaves/wood	Picking/cut	Med/alit/const	Wild
14	Fabaceae	*Daniellia oliveri* (Rolfe) Hutch. & Dalziel, 1928	Copalier africain	Iya	Wood	Cut	Com/const	Wild
15	Fabaceae	*Dialium guineense* Wiild., 1796	Tamarinier noir	Anwin	Fruits/wood	Picking/cut	Alit/const	Wild/cultivated
16	Ebenaceae	*Diospyros mespiliformis* Hochst. ex A. DC., 1844	Ebène	Kanran	Fruits/wood	Picking/cut	Med/alit/com/const	Wild
17	Dracaenaceae	*Dracaena arborea* (Willd.) Link, 1821		Peregun	Leaves	Picking/Cut	Med	Wild/cultivated
18	Arecaceae	*Elaeis guineensis* Jacq., 1763	Palmier	Okpɛkin	Fruits/leaves/wood	Picking/cut	Alit/com/const	Cultivated
19	Myrtaceae	*Eucalyptus camaldulensis* Dehnh., 1832	Eucalyptus	—	Leaves/wood	Picking/cut	Med/com/const	Wild/cultivated
20	Rutaceae	*Fagara zanthoxyloides* Lam., 1789 syn *Zanthoxylum zanthoxyloides* (Lam.) Zepern. & Timler		Igi ata	Root/bark/leaves	Picking	Med	Wild
21	Moraceae	*Ficus exasperata* Vahl	Arbre papier de verre	Igi ikpin	Leaves	Picking	Med	Wild
22	Moraceae	*Ficus macrophylla* Desf. ex Pers		—	Leaves	Picking	Med	Wild
23	Moraceae	*Ficus mucuso* Ficalho 1884		—	Leaves	Picking	Med	Wild
24	Moraceae	*Ficus umbellata* Vahl 1805		Boti	Leaves	Picking	Med	Wild

Table 2: Continued.

No.	Families	Scientific name	Common name	Local name	Parts used (fruits/barks/leaves/seeds/flowers/roots/wood)	Harvesting method	Ethnobotanical uses (med/medmag/vet/cult/alit/com/const)	Resource types
25	Verbenaceae	*Gmelina arborea* Roxb. ex Sm., 1810	Arbre à allumettes	—	Leaves/wood	Picking/cut	Med/const	Cultivated
26	Apocynaceae	*Holarrhena floribunda* (G. Don) T. Durand & Schinz, 1896	Faux caoutchouc	Ako ire	Leaves/wood	Picking/cut	Med	Wild
27	Fabaceae	*Hymenaea courbaril* L., 1753		—	Leaves/wood	Picking/cut	Med	Wild
28	Phyllanthaceae	*Hymenocardia acida* Tul., 1851		Orukpa	Leaves/wood	Picking/cut	Med	Wild
29	Irvingiaceae	*Irvingia gabonensis* (Aubry-Lecomte ex O'Rorke) Baill., 1884	Pomme sauvage	Anpɔn	Fruits/seeds	Picking	Med/alit	Wild/cultivated
30	Fabaceae	*Isoberlinia doka* Craib & Stapf, 1911		—	Wood	Cut	Med/com/const	Wild
31	Meliaceae	*Khaya senegalensis* (Desr.) A. Juss., 1830	Cailcédrat	ɔganwo	Fruits/bark/seeds/leaves/wood/root	Picking/cut	Med/com/const	Cultivated
32	Bignoniaceae	*Kigelia africana* (Lam.) Benth	Saucissonnier	Kpandoro	Fruits/bark/leaves/seeds	Picking/cut	Med	Wild
33	Anacardiaceae	*Lannea acida* L., 1753 syn *Lannea microcarpa* Engl. & K. Krause, 1911		Aso gidoka	Wood	Picking/cut	Com/const	Wild
34	Anacardiaceae	*Lannea barteri* (Olïv.) Engl.		—	Wood	Picking/cut	Com/const	Wild
35	Ochnaceae	*Lophira lanceolata* Tiegh. ex Keay, 1954	Méné	Ipɔnhɔn	Leaves	Picking	Med	Wild
36	Malvaceae	*Mansonia altissima* (A. Chev.) A. Chev., 1912		—	Leaves/wood	Picking/cut	Com/const	Wild
37	Moraceae	*Milicia excelsa* (Welw.) C. C. Berg, 1982	Iroko	—	Fruit/seeds/bark/leaves/roots/wood/flower	Barking/picking/cut	Med/medmag/com/const	Wild
38	Bignoniaceae	*Newbouldia laevis* (P. Beauv.) Seem., 1864	Hysope africaine	Igi akoko	Leaves/wood/flower	Picking/cut	Med/medmag/com/const	Wild/cultivated
39	Mimosaceae	*Parkia biglobosa* (Jacq.) R. Br. ex G. Don, 1830	Néré	Ayidan abata	Fruits/seeds	Picking	Alit	Wild
40	Rubiaceae	*Pavetta crassipes* K. Schum			Leaves	Picking	Med	Wild
41	Clusiaceae	*Pentadesma butyracea* Sabine (1824)	Arbre à beurre	Ewe odo	Leaves	Picking	Med	Wild
42	Fabaceae	*Prosopis africana* (Guill. & Perr.) Taub., 1893	Prosopis	Kakakanyi	Fruits/bark/seeds/wood	Cut	Med/com/const	Wild
43	Meliaceae	*Pseudocedrela kotschyi* (Schweinf.) Harms	Cèdre de zone sèche	Emigbegbi	Wood	Cut	Med/com/const	Wild
44	Fabaceae	*Pterocarpus erinaceus* Poir., 1804	Palissandre du Sénégal	Apepe	Bark/leaves/wood/root	Picking/cut	Med/com/const	Wild/cultivated
45	Rubiaceae	*Sarcocephalus latifolius* (Sm.) E. A. Bruce, 1947		—	Leaves/roots	Picking/crop	Med	Wild
46	Fabaceae	*Senna siamea* (Lam.) H. S. Irwin & Barneby, 1982	Acacia	—	Leaves/bark/flowers/wood	Picking/crop/cut	Med/const	Wild/cultivated
47	Sterculiaceae	*Sterculia tragacantha* Lindl.	Tragacanthe africain	Omurun	Wood	Cut	Com/const	Wild
48	Verbenaceae	*Tectona grandis* L. f.	Teck	Ikpatomu	Leaves/wood	Crop/cut	Com/const	Cultivated
49	Combretaceae	*Terminalia laxiflora* Engl.	—		Roots/wood	Crop/cut	Med	Wild
50	Combretaceae	*Terminalia mollis* M. A. Lawson (en), 1871	—		Roots/wood	Crop/cut	Med	Wild
51	Combretaceae	*Terminalia superba* Engl. & Diels, 1900	Limba	Afan	Wood	Cut	Com/const	Cultivated

Table 2: Continued.

No.	Families	Scientific name	Common name	Local name	Parts used (fruits/barks/leaves/seeds/flowers/roots/wood)	Harvesting method	Ethnobotanical uses (med/medmag/vet/cult/alit/com/const)	Resource types
52	Malvaceae	*Triplochiton scleroxylon* K. Schum., 1900	Samba	Arere	Bark/leaves/roots/wood	Picking/crop/cut	Med/medmag/com/const	Wild
53	Sapotaceae	*Vitellaria paradoxa* C.F. Gaertn., 1807	Karité	Lumɔlapa	Fruits/seeds/bark/seeds/wood/root	Picking/cut	Med/alit/com	Wild
54	Rutaceae	*Zanthoxylum gilletii* (De Wild.) P. G. Waterman, 1975	—		Wood	Cut	Const	Wild

Med = medicinal; medmag = medico-magic; vet = veterinary; cult = cultural; alit = alimentation or feeding; com = commercial; const = building.

Table 3: List of the five priority species identified by forest.

	Municipalities	Species	Score of the vulnerability index (VI)	Frequency (%)	Reproduction mode	Status
*A*1	Pobè	*Milicia excelsa*	2.98	40.82	Very slow	Be: EN; IUCN: VU
	Kétou	*Vitellaria paradoxa*	2.00	23.02	Very slow	Be: VU; IUCN: VU
*A*2	Pobè	*Khaya senegalensis*	3.00	12.16	Slow	Be: EN; IUCN: VU
	Kétou	*Prosopis africana*	2.37	13.67	Slow	Be: EN
*A*3	Pobè	*Anogeissus leiocarpa*	3.00	6.25	Slow	Not reported
	Kétou	*Pterocarpus erinaceus*	3.00	38.41	Slow	Be: EN
*A*4	Pobè	*Ceiba pentandra*	2.00	14,63	Very slow	Not reported
	Kétou	*Khaya senegalensis*	3.00	26.72	Slow	Not reported
*A*5	Pobè	*Adansonia digitata*	3.00	16.28	Very slow	Not reported
	Kétou	*Anogeissus leiocarpa*	2.09	55.00	Slow	Not reported

Be = Benin; EN: critically endangered species; VU = vulnerable species.

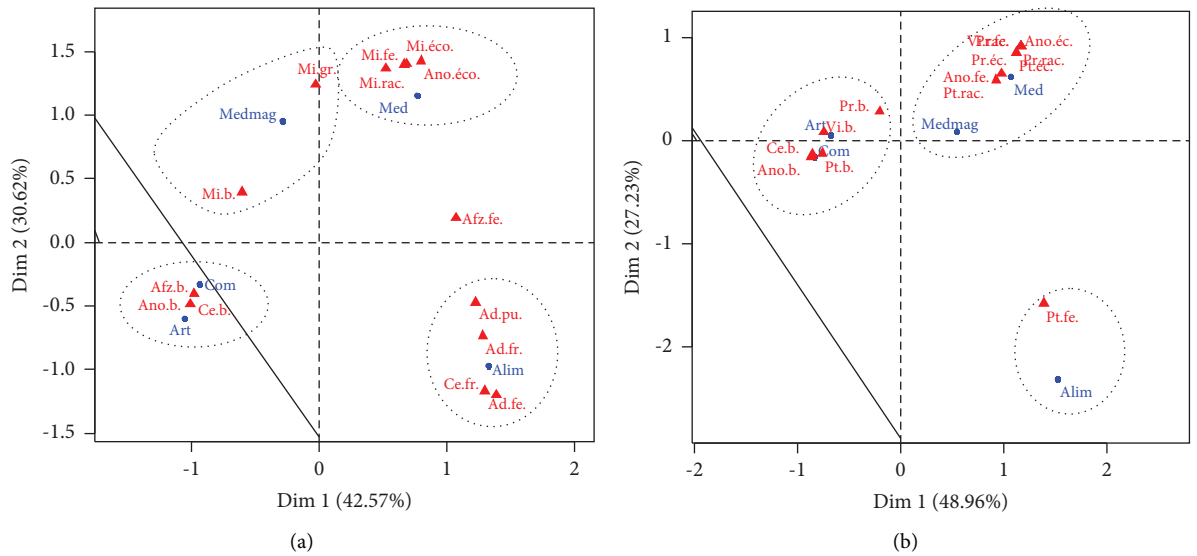


Figure 3: Relation between organs and the category of uses of the priority species corresponding to Pobè (a) and Kétou (b). Species: Ce = *Ceiba pentandra*, Afz = *Afzelia africana*, Mi = *Milicia excelsa*, Ano = *Anogeissus leiocarpa*, Vi = *Vitellaria paradoxa*, Pt = *Pterocarpus erinaceus*, Ad = *Adansonia digitata*, and Pr = *Prosopis africana*. Organs: b = wood, gr = seed, fe = leaf, eco = bark, fr = fruit, and rac = root. Uses: Med = medicinal; Food = food; Medmag = medico-magic, Com = commerce, and Art = artisanal.

the most solicited organs of the forest species are the roots of *Vitellaria paradoxa*, the roots, the leaves, and the barks of *Prosopis africana*, the roots and barks of *Pterocarpus erinaceus*, and the leaves and barks of *Anogeissus leiocarpa*. In terms of food, the population of Kétou used the leaves of *Pterocarpus erinaceus* for food for domestic herbivores. The woods of *Prosopis africana*, *Vitellaria paradoxa*, *Ceiba pentandra*, *Pterocarpus erinaceus*, and *Anogeissus leiocarpa* were widely used at the level of artisanal for the manufacture of art and decoration objects as well as the sale of wood in the form of timber and service wood.

Analyzing Figure 4, in the two municipalities investigated, the medicinal use category was the most diversified with the various organs of ethnobotanical species implied. Indeed 87% of the species have been implicated in the medicinal use with at least one part. The medicinal use category was followed by construction with the use of timber.

3.4.2. Relation between the Organs of the Trees Most Used and the Ethnic Groups. Figure 5 presents the factorial map of the relation between the ethnic groups and the organs of the trees mostused by them in Pobè (A) and Kétou (B).

The value of the independence test of χ^2 in the municipality of Pobè between the most used organs and the ethnic groups was equal to 487.0028 (p value = 2.169992e − 21). These variables are significantly dependent at the threshold of 5%. According to Figure 5(a) with a contribution of 72.09% of the first two axes, Fon and Assimilated women aged over 40 years (FmF2) in the municipality of Pobè used very strongly the roots of *Milicia excelsa* and the leaves of *Afzelia africana* for different needs. Hollidjè women under 40 years (HoF1) had a good knowledge of the use of the wood of *Ceiba pentandra* and the seeds of *Milicia excelsa*.

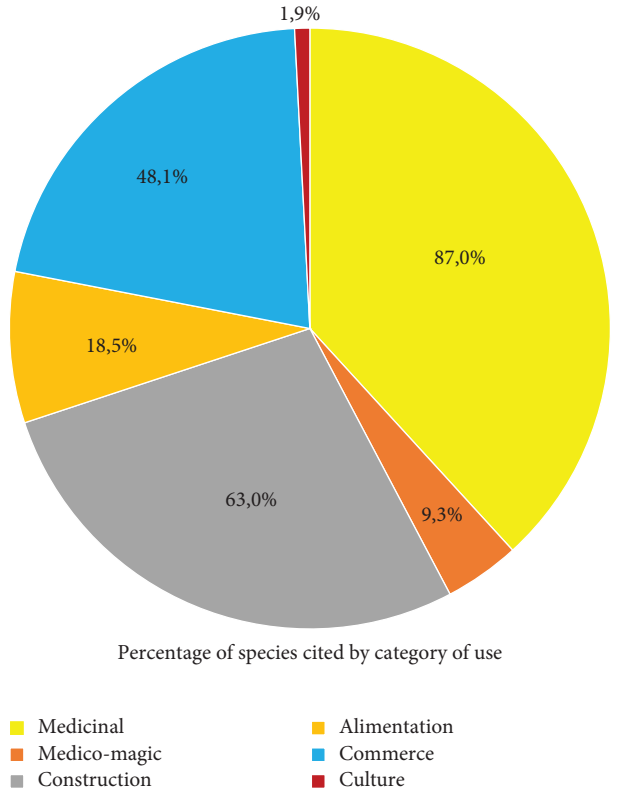


Figure 4: Percentage of species cited by use category.

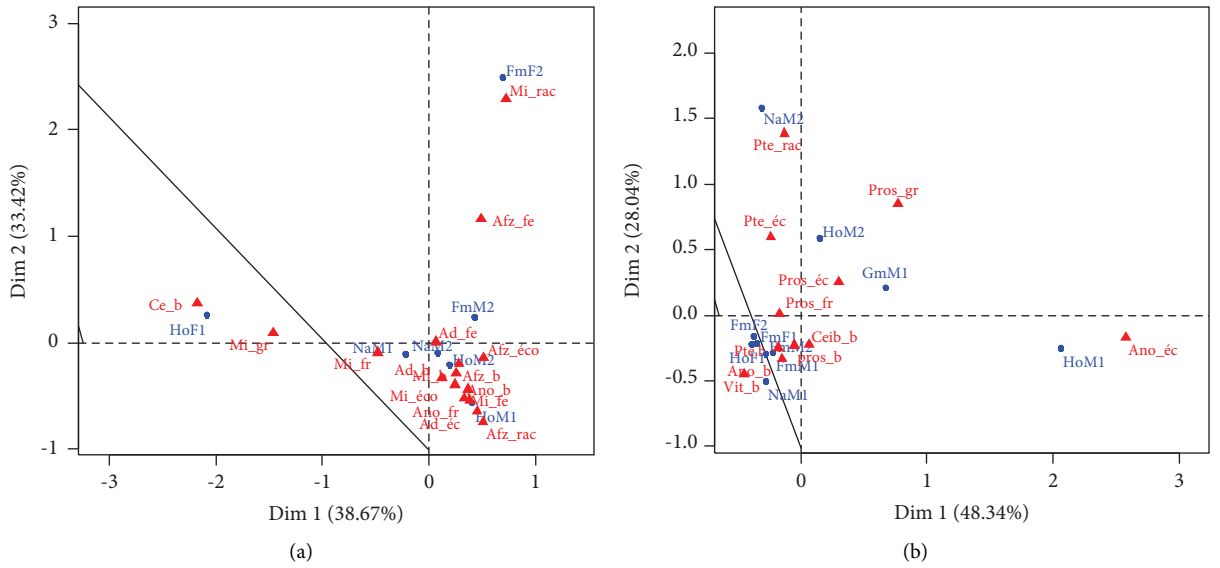


Figure 5: Relation between the ethnic groups and the organs used of the trees most significantly exploited in Pobè (a) and Kétou (b). Species: Ce = *Ceiba pentandra*, Afz = *Afzelia africana*, Mi = *Milicia excelsa*, Ano = *Anogeissus leiocarpa*, Vit = *Vitellaria paradoxa*, Pte = *Pterocarpus erinaceus*, Ad = *Adansonia digitata*, and Pros = *Prosopis africana*. Organ: b = wood, gr = seed, fe = leaf, eco = bark, fr = fruit, and rac = root. Ethnic group: Fm = Fon and Assimilated; Ho = Hollidjè; Na = Nagot; Gm = minority groups. Sexes: *M*1 = male age <40 years; *M*2 = male age ≥40 years; *F*1 female age <40 years; *F*2 = woman age ≥40 years.

In the municipality of Kétou, the value of the test of independence of χ^2 between the most used organs by the local populations of the forests and the ethnic groups was equal to 198.5375 with a probability p value =0.4758831. These variables have been weakly dependent. In the municipality of Kétou (Figure 5(b)), men under 40 years from minority groups (GmM1) and Hollidjè (HoM1) very heavily used the bark of *Prosopis africana* and *Anogeissus leiocarpa*,

respectively. Hollidjè men over 40 years (HoM2) have been exploiting more the seeds of *Prosopis africana*. Nagot males over 40 years old had a good knowledge on the use of *Pterocarpus erinaceus* roots (NaM2). On the other hand, all Fon and Assimilated women and their men over 40 years (FmF1, FmF2, and FmM2) have been exploiting the wood of *Ceiba pentandra* to make canoes and the wood of *Vitellaria paradoxa* for the treatment of diseases, for timber purpose, and for charcoal production.

3.5. Effects of Harvesting Techniques Used for Tree Organs. Analyzing Table 4, the inhabitants in the area have been using all the organs of the priority ethnobotanical species in various ways. Apart from the flowers, which were exclusively intended for medico-magic use, all other organs of these species were used for several purposes. The local residents had different organ harvesting strategies. However, the strategies for harvesting the organs of the trees were identical in the two municipalities. These strategies varied depending on the organs to be harvested and had varying degrees of consequences depending on the type of organ and the appropriate strategy used.

4. Discussion

4.1. Ethnobotanical Uses of Priority Species from Pobè and Kétou Forests. Overall, ten priority species, including five for the forests of Pobè (*Milicia excelsa*, *Afzelia africana*, *Anogeissus leiocarpa*, *Ceiba pentandra*, and *Adansonia digitata*) and five for the forest of Kétou (*Vitellaria paradoxa*, *Prosopis africana*, *Pterocarpus erinaceus*, *Ceiba pentandra*, and *Anogeissus leiocarpa*), were identified. The lists of priority species for the two forests have been the result of the combination of frequency of citations, mode of reproduction, vulnerability scores, and the IUCN status of the species. All of the priority species have been identified on the list of the useful species in Southern and Central Benin [45]. Nine species including *Milicia excelsa*, *Afzelia africana*, *Ceiba pentandra*, *Adansonia digitata*, *Vitellaria paradoxa*, *Pterocarpus erinaceus*, and *Anogeissus leiocarpa* have been also identified on the list of the priority species for populations bordering the classified forest of Wari-Maro in Benin [46]. Four species including *Milicia excelsa*, *Afzelia africana*, *Anogeissus leiocarpa*, and *Pterocarpus erinaceus* have been identified on the list of the ten most important species to conserve in Benin for the quality of their wood [24]. In Burkina Faso, *A. digitata*, *A. leiocarpa*, *V. paradoxa*, and *P. erinaceus* have been identified among the priority species of the country [47] and *M. excelsa* has been also identified among the priority species of Uganda [48]. This has shown the importance of the priority species identified both in Benin and in Africa.

In the municipality of Pobè, for medicinal uses, people have been placing more importance on the leaves, roots, barks, and flowers of *Milicia excelsa*, *Afzelia africana*, and *Anogeissus leiocarpa*. The woods of *Milicia excelsa*, *Afzelia africana*, *Anogeissus leiocarpa*, and *Ceiba pentandra* were more oriented towards the commerce. The fruits of *Ceiba pentandra* and the fruits and seeds of *Adansonia digitata*, to a lesser extent with relative harvesting intensity, were used by populations for food. Medico-magic uses particularly have touched the seeds of *Milicia excelsa*. In the municipality of Kétou, for medicinal uses, local populations have been using the roots, wood of *Vitellaria paradoxa* , or the leaves, roots, and bark of *Prosopis africana*, *Pterocarpus erinaceus*, and *Anogeissus leiocarpa* and have also been using the leaves of Ceiba pentandra for various needs. The leaves of *Pterocarpus erinaceus* have been used as food for domestic herbivores. In the case of artisanal use, the woods of *Prosopis africana*, *Pterocarpus erinaceus*, and *Vitellaria paradoxa* were more appreciated for the manufacture of art and decoration objects. The woods of *Pterocarpus erinaceus*, *Anogeissus leiocarpa*, and *Ceiba pentandra* were used for the commercial category. These results linked with the organs of the priority species used and the categories of use corroborated with the results of similar work carried out in Benin and elsewhere in Africa [24, 45–48].

For the medicinal uses, the populations of Kétou have been using the leaves of *Anogeissus leiocarpa* while for this same category of use, the populations of Pobè have been using the leaves and roots of the same species. There was therefore a consensus between the populations of the two municipalities on the uses of *Anogeissus leiocarpa* leaves to treat diseases.

This diversity of uses showed that the populations of each of the two municipalities have their own perception and conception of the use made with each organ [49]. These differences may be linked to the cultural heritage of the populations of the two municipalities, knowledge being transmitted from generation to generation between communities of the same sociocultural group. However, a transmission of knowledge between different sociocultural groups living in the same geographical area was also possible thanks to the bonds of friendship that these communities maintained or interethnic marriages [50]. A study of Coe [51] identified the geographic proximity of communities as the main factor influencing the similarity in plant use between Rama and Miskitu, two indigenous groups from Nicaragua (Central America). But two other studies [52, 53] found opposite results, respectively, in the investigated populations of Andean and Amazonia in Bolivia and in the populations of Matsigenka and Nahua in Amazonia, communities which are nevertheless geographically adjacent.

4.2. Analysis of Use Diversity of the Species and Their Harvesting Strategies. The different categories of uses identified have been similar to those identified by several researchers, who had carried out similar work in Benin [24, 45, 46]. In the municipalities of Pobè and Kétou, the medicinal category of the various organs of the species has been the most diversified as shown in Figure 4. Indeed, the medicinal category affected the majority of the trees and their parts such as fruit, flower, seed, leaf, bark, wood, and root of all the priority species identified for the two municipalities.

Table 4: Categories of uses of organs from trees harvested by populations for various needs.

Organs	Categories of uses	Organ harvesting methods	Possible consequences of the harvesting methods
Flower	Medico-magic, medicinal	Use of pole, climbing, and use of knife or machete to cut the branches	Prevents fruiting and therefore the production of seeds which ensure the sexual reproduction of the species. When use deteriorates the seed, the reproduction of the species may slow down if the harvest is very intense.
Fruit	Medico-magic, food, commercial	Use of pole, climbing, and use of knife or machete to cut the branches	When use deteriorates the seed, the reproduction of the species may slow down if the harvest is very intense
Pulp	Food	Use of pole, climbing, and use of knife or machete to cut the branches	When use deteriorates the seed, the reproduction of the species may slow down if the harvest is very intense
Seeds	Medico-magic, food, medicinal	Use of pole, climbing, and use of knife or machete to cut the branches	Reproductive organ of the tree. Its overexploitation decreases the availability of the seeds for tree reproduction
Leaves	Medico-magic, food, medicinal	Use of poles and machete for cutting branches	Causes injuries and parasite attacks
Bark	Medicinal	Use of machete and knife for removing the bark of the trunk	Injury to the trunk that can lead to infection and attack by parasites or insect attacks especially termites
Wood	Medicinal, medico-magic, commercial	Saw, chainsaw	Systematic felling of the tree, cause of the deforestation
Roots	Medicinal, medico-magic	Hoe, axe, and machete to dig and reach the roots	Can cause the death of the tree when the removal from the main vital roots of the tree is especially important

These organs were also the most used for the woody species with the higher overall ethnobotanical uses in South Tyrol, Northern Italy [54]. As for the other category of use identified, the inhabitants target well-defined organs of each species. For the use of wood of different species by the residents, it led to the systematic felling of the trees, often of large diameters and on a large scale. The felling of trees promotes deforestation, and its consequences are exacerbated by the exploitation of seeds which are known to ensure the sustainability of each species. Thus, it emerged from this study that the inhabitants have certain organ harvesting practices from species that have proven to be less good for the sustainability of the species identified as priority, most of which are vulnerable, threatened with a high priority for the conservation in Benin [24, 35].

The strategies for harvesting the various organs of the identified species have been the same for the populations of the two municipalities. However, the strategies have varied depending on the organs to be removed, on the one hand, but also the uses for which the organs removed were intended, on the other hand. The consequences for the species from which organs were removed depend on the organ removed, but also on the method of removal. Indeed, the harvesting methods identified in the study area were the use of the pole, climbing, and use of a knife or machete to cut the branches, use of a machete and knife for scarifying the trunk, use of saw, chainsaw, and axe to cut the trees, and use of a hoe and machete to dig and reach roots. These different methods of harvesting the organs of the species had many consequences. One of the consequences was the inhibition of fructification and therefore the production of seeds, which ensured the sexual reproduction of the species. The second was the unavailability of the seeds of the tree for its reproduction. The third was the occurrence of injuries favoring attacks by parasites or insects (termites for instance) and finally a systematic felling and death of the tree caused by a significant removal of the roots and the harvest of wood.

Taking into account the organs of the species harvested, the fruits were used the most for four categories of uses (medicinal, medico-magical, food, and commercial) while the flowers were just used for the medico-magic categories of use. The fruits of the various priority species identified were the organs most requested for many categories of use. Therefore, the fruit has been the organ whose use will be creating more destruction of the priority species while the flower was an organ whose use has created less destruction of the priority species in the study area because flowers were just used for medico-magic. However, the use of the wood in the treatment of diseases and for medico-magical and commercial uses also presents a destructive effect in the end because the tree must be felled first in general. Wood trade for human needs in Benin is carried out particularly for three categories of wood use such as fuelwoods, service woods, and the timbers. The woods are still and will always be essential for the needs of people linked to the increase of population and economy and the expansion of cities and building [55]. These results related to the threats of harvesting methods were also confirmed in Europe and the Mediterranean Region [56], where the overexploitation and destructive harvesting techniques have been identified as two critical threats affecting the sustainable harvesting and use of wild medicinal plant species.

5. Conclusion

The results of this study have facilitated the identification of the first five priority species in the municipalities of Pobè and Kétou. For the forest of Pobè, the five species were *Milicia excelsa*, *Afzelia africana*, *Anogeissus leiocarpa*, *Ceiba pentandra*, and *Adansonia digitata*. For the forest of Kétou, the five priority species identified were *Vitellaria paradoxa*, *Prosopis africana*, *Pterocarpus erinaceus*, *Ceiba pentandra*, and *Anogeissus leiocarpa*. The study has identified the most used organs as well as the organs whose use created more damage to the priority ethnobotanical trees and impeded sustainability. The harvesting methods practiced by the populations according to the organs and the category of use were also inventoried. These various results have made it possible to establish a link between the harvesting methods and the probable consequences that these methods of harvesting can engender. Based on the results obtained, it is urgent for the forest resource managers to set up a project program aimed at sensitizing the populations on the risks that some harvesting methods in the forest could generate if we are not careful very early. This project will also make it possible to identify the active principles sought in these organs and to find other fast-growing plants capable of supplying said active principles or to find a synthetic strategy to reproduce them. Such a program could take charge of the species conservation component by popularizing and encouraging the populations of Southeast Benin living particularly in subhumid climate area than the rest of the country, on modern or traditional efficient techniques of reproduction of priority species identified as part of this research.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Ethical Approval

The ethical approval has been obtained from the populations surveyed before the survey was conducted.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

Armand Kingbo was responsible for conceptualization, methodology, software, formal analysis, investigation, data curation, original draft preparation, review and editing, visualization, project administration, and funding acquisition. Dr. Kourouma Koura was responsible for conceptualization, validation, review and editing, draft preparation, and supervision. Professor Jean Cossi Ganglo was

responsible for conceptualization, validation, draft preparation, editing, supervision, and project administration. All authors have read and agreed to the published version of the manuscript.

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