Ethnobotanical study of medicinal plants used to treat bone fractures around the Pendjari Biosphere Reserve, Benin

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Abstract:
The present study was carried out in Natitingou and Tanguiéta, two districts bordering the Pendjari Biosphere Reserve in Benin. Its overall aim was to assess traditional knowledge of medicinal plants used by communities living along the Pendjari Biosphere Reserve to treat bone fractures and the degree of vulnerability of these plants to exploitation. A total of 20 traditional bone fracture healers (THBF) were identified and surveyed using snowball sampling. The data collected during the semi-structured interviews were analyzed and processed using the citation frequencies and vulnerability indices for the medicinal plants inventoried. A total of 29 medicinal plant species, divided into 26 genera and 18 plant families, were used to treat bone fractures in the Natitingou-Tanguiéta zone (NTZ). Among these species, *Ochna rhizomatosa* (RFC = 60%), *Raphia sudanica* (RFC = 40%), *Flueggea virosa* (RFC = 35%) and *Digitaria exilis* (RFC = 30%) were the most widely used. The availability of most medicinal plants used to treat bone fractures had considerably declined, especially in natural ecosystems. 16 of these species were vulnerable, of which *Ochna rhizomatosa* was the most vulnerable, with a vulnerability index of 2.63. The factors influencing this availability were mainly logging/NTFPs (36%), uncontrolled bush fires (32%) and extensive agriculture (26%). These results can be considered as the preliminary database for the conservation of plants used in the treatment of bone fractures and their valorization in pharmacology.

Key words: Natitingou-Tanguiéta, medicinal plant, bone fracture, vulnerability index, local conservation strategies.

Etude ethnobotanique des plantes médicinales utilisées pour le traitement des fractures d'os autour de la Réserve de biosphère de la Pendjari, Bénin

Résumé:
La présente étude a été menée dans les communes de Natitingou et de Tanguiéta, deux communes riveraines de la Réserve de Biosphère de la Pendjari au Bénin. Elle vise de façon globale à évaluer les connaissances traditionnelles liées aux plantes médicinales utilisées par les communautés riveraines de la Réserve de Biosphère de la Pendjari dans le traitement des fractures d'os et le degré de vulnérabilité à l'exploitation de ces plantes. Un total de 20 guérisseurs traditionnels de fractures d'os (GTF) a été recensé et enquêté à partir d'un échantillonnage par boule de neige. Les données collectées lors des entretiens semi structurés ont été analysées et traitées à travers des estimations de fréquences de citation et des indices de vulnérabilité des plantes médicinales inventoriées. Au total 29 espèces de plantes médicinales reparties entre 26 genres et 18 familles botaniques, sont utilisées pour le traitement des fractures d'os dans la Zone Natitingou-Tanguiéta (ZNT). Parmi ces espèces, *Ochna rhizomatosa* (FRC = 60%), *Raphia sudanica* (FRC = 40%), *Flueggea virosa* (FRC = 35%) et *Digitaria exilis* (FRC = 30%) sont les plus utilisées. La disponibilité de la plupart des plantes médicinales utilisées pour le traitement des fractures d'os a considérablement baissé surtout dans les écosystèmes naturels. 16 de ces espèces sont vulnérables parmi lesquelles *Ochna rhizomatosa* se révèle être plus vulnérable avec un indice de vulnérabilité égal à 2,63. Les facteurs qui influencent cette disponibilité sont majoritairement l'exploitation forestière/PFNLs (36%), les feux de brousse incontrôlés (32%) et l'agriculture extensive (26%). Ces résultats peuvent être considérés comme une base de données préliminaires pour la conservation des plantes utilisées dans le traitement des fractures d'os et leur valorisation en pharmacologie.

Mots-clés : Natitingou-Tanguiéta, plante médicinale, fracture d'os, indice de vulnérabilité, stratégies de conservation locales.

Introduction

Les Today, with the advance of science, technology and industrialization, human health is becoming increasingly fragile, and it's almost self-evident that the majority of people suffering from traumatic motor disability are those who have previously suffered a traumatic injury, most often as a result of a road, work or free-fall accident. In its World Report on Disability, World Health Organization (WHO, 2001) estimates that between 10% and 15% of the world's population is disabled. Most disabled people live in poor countries, particularly in Africa and Asia. In Benin, the proportion of people suffering from motor disabilities is 16.4% (amputees: 5.1% and paralyzed : 11.3%) (INSAE, 2016).

However, in African societies, and particularly in Benin, the disabled, especially those with motor disabilities, are the most often marginalized members of society. In Benin, disabled people

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face multiple levels of exclusion and discrimination in all sectors. There is a lack of access to public buildings, public transport, education, vocational training, employment and healthcare (PNPIPH, 2012; Séverin, 2018). Moreover, modern treatment of bone fractures is not always effective. According to the study of Dresse et al., (2013), simple fractures can heal in as little as three weeks using traditional techniques, compared to several months with modern medicine. In addition, modern medicine is often geographically, culturally or financially inaccessible to most of the population in poor countries like Benin (Dresse et al., 2013). In such conditions, people turn to medicinal plants for treatment. According to WHO (2000), nearly 80% of the Beninese population uses traditional medicine (Dougnon et al., 2016) and there are over 10 999 traditional healers in Benin, compared with just 518 doctors for a population of nearly 12 million (Ministère de la Santé, 2020). Moreover, medicinal plants are often harvested unsustainably and, in some cases, overexploited for commercial purposes, according to Tabuti et al., (2003). Forests are thus threatened by over-exploitation and uncontrolled logging. As a result, the medicinal plants in their natural habitat are rapidly disappearing, often forever, and biodiversity is considerably diminished (Palomo Nadja, 2010).

Much endogenous knowledge on the use of medicinal plants in the treatment of various diseases and bodily disorders were already documented in Benin : Aguia, 2020; Fachola, et al., 2018; Kouchadé et al., 2016; Dougnon et al., 2016; Ouachinou et al., 2017; Koudokpon et al., 2017, Lougbégnon et al, 2015. Unfortunately, none of these studies were focused either the conservation or valorization of medicinal plants used specifically for the treatment of bone fractures and associated traditional knowledge. It is therefore crucial to find options for the conservation and valorization of medicinal plants in general, those used in the treatment of bone fractures in particular, and associated traditional knowledge, in order to maintain the well-being of the local communities that depend on them.

The present study aims to assess traditional knowledge related to medicinal plants used in the treatment of bone fractures by local communities in the Pendjari Biosphere Reserve, and the degree of vulnerability to exploitation of these plants. The specifics objectives were to (i) identify medicinal plants and their modes of use for the treatment of bone fractures in the Natitingou-Tanguiéta zone (NTZ); (ii) analyze the perceptions of local communities regarding the pressures and vulnerability of medicinal plant species used for the treatment of bone fractures (MPTBF) in the NTZ and (iii) assess local strategies for the conservation and valorization of MPTBF in the NTZ.

1. Study materials and methods

1.1. Study area

The study was carried out in two communes, Natitingou and Tanguiéta, located in north-west Benin in the Atacora department. They cover an area of 8,501 Km2 (7.5% of the department's total surface area). Tanguiéta lies between latitudes 10°37' and 11°46' north and between longitudes 01°07' and 02° east and is bounded to the north by the Pendjari River. (CENAGREF, 2014). The commune of Natitingou lies between 10°00′0″ and 10°29′00″ north latitude and 1°10′00″ and 1°35′00″ east longitude. The relief of these two communes ranges from mountainous areas to the plateaus and peneplains of the surrounding villages. They are characterized by a rugged terrain, consisting mainly of the Atacora mountain range, plateaus and hills, with valleys that are often steeply sloping (Figure 1).

1.2. Sampling

Surveys were conducted in the two target communes (Natitingou and Tanguiéta). Non-random snowball sampling was used, and the sample was essentially made up of 20 traditional bone fracture healers. The aim was to identify a traditional bone-fracture healer in each of these communes. After being interviewed, the healer has to recommend another traditional bone-fracture healer in the same commune, or even in another commune. The process was thus continued until all 20 traditional bone fracture healers in the two target communes were investigated (Houehanou et al., 2015).

1.3. Field data collection

For data collection, we conducted semi-structured interviews in which opened questions were individually addressed to traditional bone fracture healers, some in the local languages and others in French, using an interview guide drafted for the purpose. These interviews were accompanied by visits on the field with the traditional healers themselves or people with a good knowledge of these plants

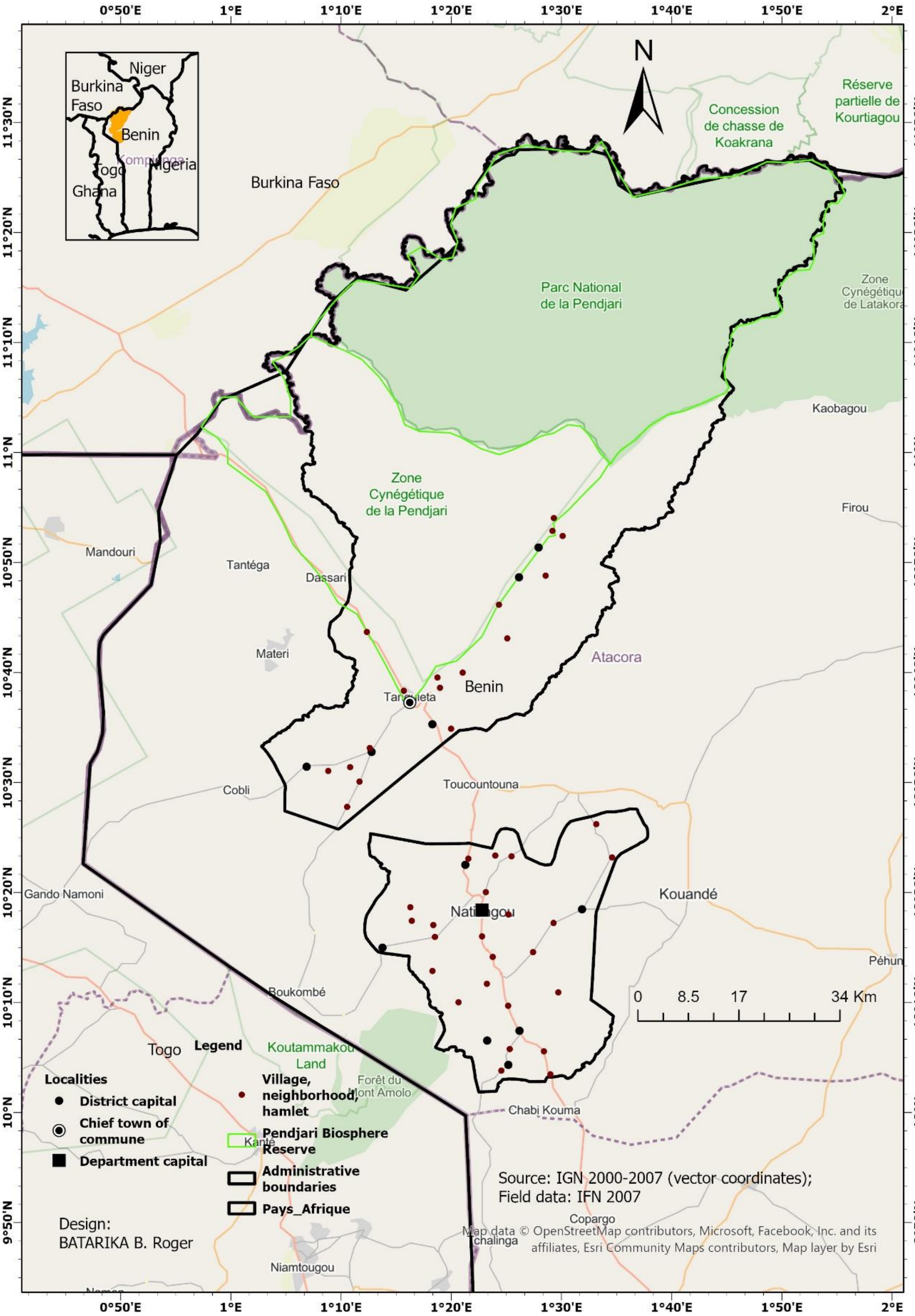

Figure 1 : Geographical location of study area

(especially their names in local languages) and designated by the healers for this purpose. This enabled us to identify and compile a herbarium of the medicinal plant species inventoried during the interviews.

1.4. Taxonomic identification

The taxonomic identification of certain plant species was based on Akoègninou et al. (2006) « Flore Analytique du Bénin » and Arbonnier (2000) « Arbres arbustes et lianes des zones sèches d'Afrique de l'Ouest ». Other species were identified in Benin's national herbarium.

1.5. Collected data

The data collected were as follows:

- Profile of respondents (age, gender, socio-cultural group, religion, level of education, main activities, origin of knowledge, length of time as a traditional bone fracture healer);
- Medicinal plant species (local names, scientific names) and parts used to treat bone fractures;
- Method of preparation and administration of remedies;
- Stages and harvesting methods of medicinal plants used to treat bone fractures;
- Habitat and abundance of medicinal plant species used to treat bone fractures;
- Sources of pressure on medicinal plants used in the treatment of bone fractures;
- Preservation techniques for medicinal plants used to treat bone fractures.

1.6. Data processing and analysis methods

- ***Relative frequency citation (RFC)***

The local importance of each species in the treatment of bone fractures was calculated using relative citation frequency (Javier et al., 2008) as follows:

$$RFC = Fc/N$$

Where **Fc** = number of respondents mentioning use of the species; **N** = total number of respondents.

- ***Life forms***

The life forms selected are those defined by Raunkiaer (1934) and used by Lougbégnon, et al., (2015) :

- Megaphanerophytes (MPh): trees over 30 m;
- Mesophanerophytes (mPH): trees 10 to 30 m;
- Microphanerophytes (mph): shrubs 2 to 10 m
- Nanophanerophytes (nph): under shrubs 0.4 to 2 m
- Chamephytes (chm): woody or suffrutescent perennial species whose renovation buds or persistent shoot tips are located close to the ground (maximum 50 cm above ground level).
- Hemicrophytes (He): plants that dry out completely in the off-season, with persistent buds at ground level.

- ***Vulnerability index (Iv)***

To assess the vulnerability of medicinal plants used to treat bone fractures (MPTBF) in the Natitingou-Tanguiéta zone (NTZ), the vulnerability index for each of the species inventoried was calculated.

The vulnerability index determination method was developed in 2001 in Cameroon and approved by the Central African Forest Ecosystem Project (ECOFAC) (Betti, 2001), and later adopted by Traore et al. (2011), Dassou et al. (2014) and Nzuki (2016). This method is based on the identification of a number of characteristics or factors called "**constraints**", which are used to measure the vulnerability index of medicinal plants (Betti, 2001). It should be noted that the term "**vulnerable**" assigned by this technique does not correspond to that of the IUCN Red List. Thus, to assess the vulnerability of the medicinal plants inventoried, a three-level vulnerability scale, from N1 to N3 (Betti, 2001; Traore et al., 2011; Dassou et al., 2014 and Nzuki, 2016), was used (Table I). In this scale, an N1 level corresponds to a species with low vulnerability for the parameters indicated, an N2 level represents medium vulnerability and an N3 level characterizes a highly vulnerable species. The species vulnerability index (Iv) was estimated according to the procedure used by Ouedraogo (2008), Traore (2011) and Nzuki, (2016) by averaging the scores or values (C) corresponding to the various plant species characteristics, namely frequency of use (c1), plant organ used (c2), organ or plant development stage (c3), collection method (c4), pharmaceutical form (c5), biotope (c6), morphological types (c7) and perceived abundance (c8). These scores range from 1 to 3, depending on the level of vulnerability (N1, N2 and N3) (Table I). Thus, the vulnerability index (Ivx) for a given species x was estimated as follow:

$$\mathbf{Ivx = C/8}$$

with $C = c1 + c2 + c3 + c4 + c5 + c6 + c7 + c7 + c8$.

If $\mathbf{Ivx < 2}$, the plant is said to be weakly vulnerable; if $\mathbf{2 \leq Ivx < 2.5}$, the plant is said to be moderately vulnerable;

if $\mathbf{Ivx \geq 2.5}$, the plant is said to be very vulnerable (Nzuki, 2016).

Table I shows the levels of vulnerability defined and the characteristics studied for the determination of the MPTBF vulnerability index.

C	Features	N1, low vln.	N2, medium vuln.	N3, strong vln.
External constraints				
C1	Frequency of use	Low, Fu < 20%	Average : 20% ≤ Fu < 60%	High : Fu≥ 60
C2	Plant organs	Leaves, sap, branches, rhytidomes	Fruit, seed	Stem barks, root barks, wood, stems
C3	Plant development stage	Old or senescent	Adult	Young
C4	Collection method	Picking	Partial section of the affected area	Total removal of the affected part
C5	Shapes Pharmaceuticals	Ash, powder, Ointment, dry organ, compress	-	Macerated, decocted, fresh organ, pestle, juice, softened, triturated, grated, poultice,
Internal constraints				
C6	Biotope	Ruderal, gardens, Crops, fallow/field	Grassy savannah, forest edge	Shrub/shrubby savannah, Saxicolous formation, Open Forest, Gallery Forest, Forest gallery edge
C7	Morphological types	Annual herbaceous	Perennial herb, Under shrub	Tree, shrub, liana
C8	Abundance of the species in the environment, as perceived by the THBF	High (very abundant)	Medium (Abundant)	Low (Rare)

Table I legend: **Fu** = relative frequency of use of species (20%-60%): in relation to the species with the highest frequency of use, considered as 100%; **C** represents the set of parameters c1, c2, and c8. These parameters each correspond to values ranging from 1 to 3 and are used to measure species vulnerability. **Vuln.** = vulnerability; N1, N2 and N3 represent the different levels on the vulnerability scale.

2. Results

2.1. *Socio-demographic and cultural profile of respondents*

A total of 20 people was inventoried as traditional healers of bones fractures (THBF) in the NTZ: 8 in villages of Natitingou commune and 12 in villages of Tanguiéta commune. The 20 THBF surveyed included both men and women. However, the results showed that 18 men (90%) were the most represented. Women, numbering 02 (10%), were less represented (Figure 2). The age groups recorded were adults aged between 30 and 60, and the elderly aged over 60. Young people aged 30 and under were absent, while the elderly were the most recorded (55%). They were followed by adults (45%). The average age of the respondents was 68.3 ± 13.9, with a minimum of 39 and a maximum of 90 (Figure 2). Most of these traditional practitioners were involved in THBF activity for so long time. In fact, those with more than 30 years' seniority were the most represented, with a number equal to 15 (75%); followed by those with between 10- and 30-years' seniority, numbering 04 (20%). Only one person (5%) was involved in the business for 10 years or less and was described as a beginner in the THBF business (Figure 2). The results showed that THBF was not the main activity of the tradipraticians surveyed. Their main activities were agriculture, practiced by 17 people, or 85% of the 20 THBF practitioners surveyed (Figure 2). A total of 13 (65%) practiced traditional religion. Only 5 (25%) were Christians and 2 (10%) were Muslims (Figure 2). They belong to a total of 06 socio-cultural groups. The Ditammaris (30%) were the most represented, followed by the Waamas (20%) and the Bialis (20%). The Natenis (15%), Gourmatchés (10%) and Peulhs (5%) were respectively the least represented socio-cultural groups (Figure 2). The distribution of THBF by level of education showed that 85% were uneducated and only 15% have primary education.

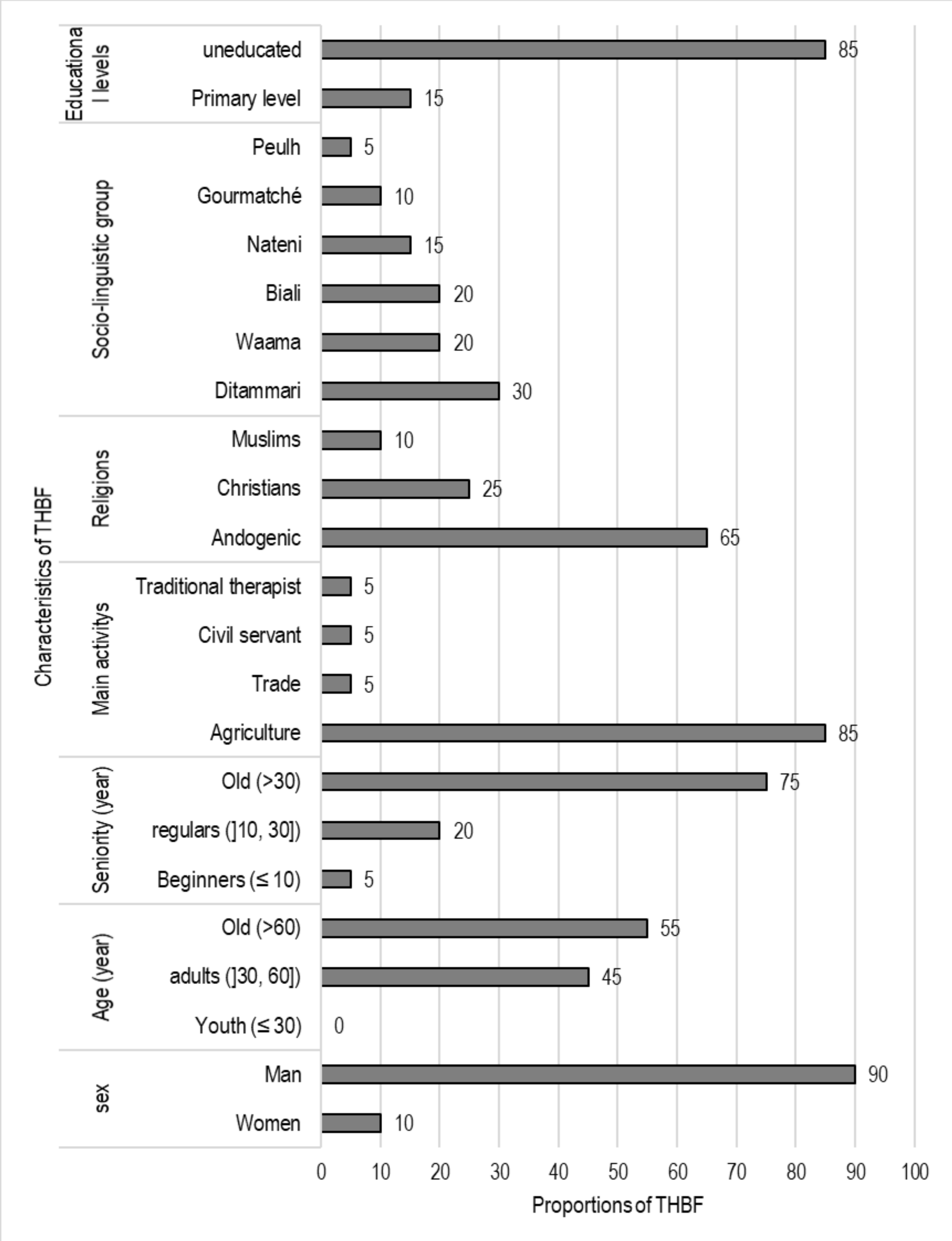

Figure 2: Socio-demographic and cultural profile of respondents

2.2. *Mode of knowledge acquisition and age of initiation into traditional bone fracture treatment*

Surveys showed that there were two ways of acquiring traditional knowledge of bone fracture treatment (STTF) in the NTA: acquisition within the family and acquisition in another setting (through a friend or through a personal decision to help others following the healing of an illness by a traditional practitioner). Most THBF (90%) in the area acquired this knowledge from their families. Only a minority (10%) acquired it in another setting. However, for the latter, the acquisition of THBF knowledge remained implicitly or explicitly conditional on the payment of copyright by the transmitting traditional practitioner. With regard to the age of initiation of bone fracture treatment, the results showed three age categories. Young people (70%) aged 15 to 25 were the most represented, followed by adolescents (25%) aged 15 or under. Only one adult (5%) was initiated at the age of over 25. It should be pointed out that the latter's initiation at the age of 30 can be explained by the fact that he acquired the knowledge in another place and not within the family. The majority of THBF in the NTZ were therefore introduced to fracture treatment at an early age.

2.3. Identification of medicinal plants and their modes of use for the treatment of bone fractures in the Natitingou-Tanguiéta area

- ***Diversity and local importance of medicinal plants used by traditional bone fracture healers in the Natitingou-Tanguiéta***

Twenty-nine (29) species of plants used in the treatment of bone fractures were identified around the Pendjari Biosphere Reserve. These species belong to twenty-six (26) genera and eighteen (18) plant families. Among the eighteen MPTBF families recorded, the Fabaceae was the best represented, (14%). It is respectively followed by Combretaceae (10%), Poaceae (10%), Arecaceae (7%), Vitaceae (7%), and Loranthaceae (7%) and others families represent 5% of all (Figure 3).

- ***Most important MPTBF species used by THBF in the NTZ (RFC ≥ 0.1)***

The MPTBF species surveyed according to their Relative Citation Frequencies (RFC) are displayed on Figure 4.

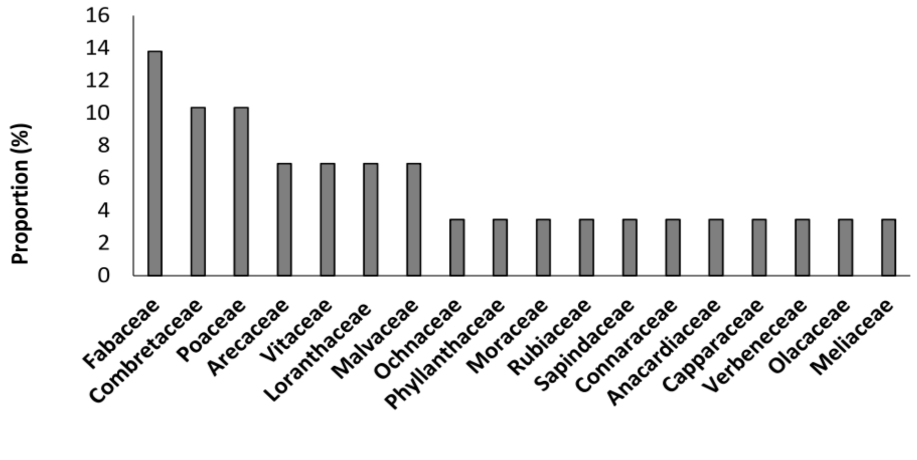

Figure 3: Species proportions within the MPTBF families surveyed

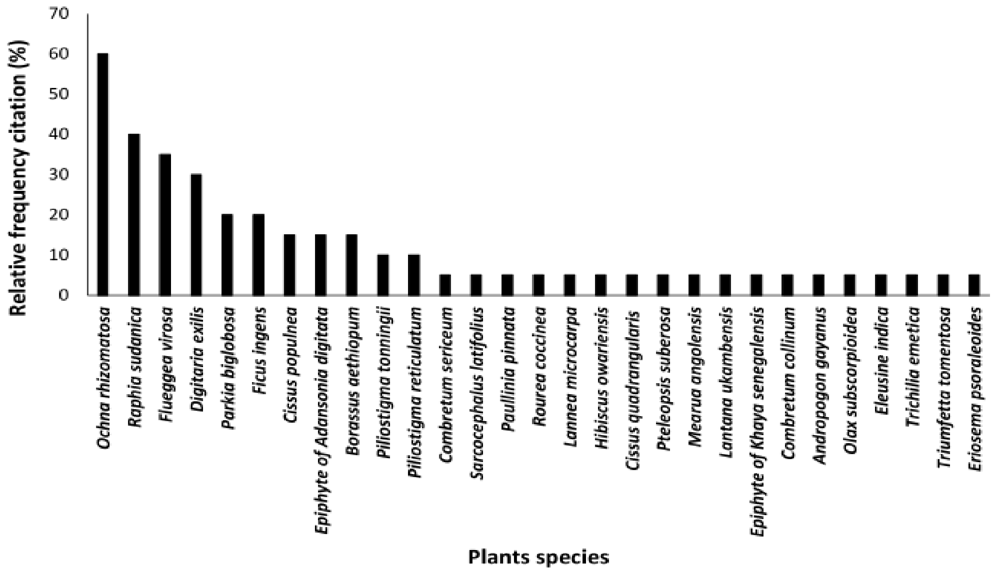

Figure 4: Relative frequencies of plant species used for bone fracture treatment

Among the species inventoried, eleven were the most frequently used. This testifies to their great usefulness and effectiveness or their importance in the treatment of bone fractures in this area. The species with a RFC greater than or equal to 0.1 were, in order of importance, *Ochna rhizomatosa*: (RFC = 0.6), *Raphia sudanica* (RFC = 0.4), *Flueggea virosa* (RFC = 0.35), *Digitaria exilis* (RFC = 0.3), *Parkia biglobosa* and *Ficus ingens* (each with an RFC = 0.2), *Cissus populnea*, *Adansonia digitata* epiphyte and *Borassus aethiopum* (each with RFC = 0.15) and *Piliostigma tonningii* and *Piliostigma reticulatum* (each with RFC = 0.1). The remaining eighteen species were less widely used, with a RFC equal to 0.05 each (Figure 4).

- ***Life forms and morphological spectra of inventoried medicinal plant species***

Seven biological types were recorded. Micrphanerophytes (34%) and therophytes (21%) were the most dominant (Figure 5). They were followed by mesophanerophytes (17%) and megaphanerophytes (14%). Chamephytes (7%), nanophanerophytes (3%) and hemicryptophytes (3%) were very poorly represented. The majority of MPTBF plants were shrubs (28%), trees (24%) and herbaceous plants (24%) (Figure 6). The other types were poorly represented: lianas (10%), palms (7%) and shrubs (7%).

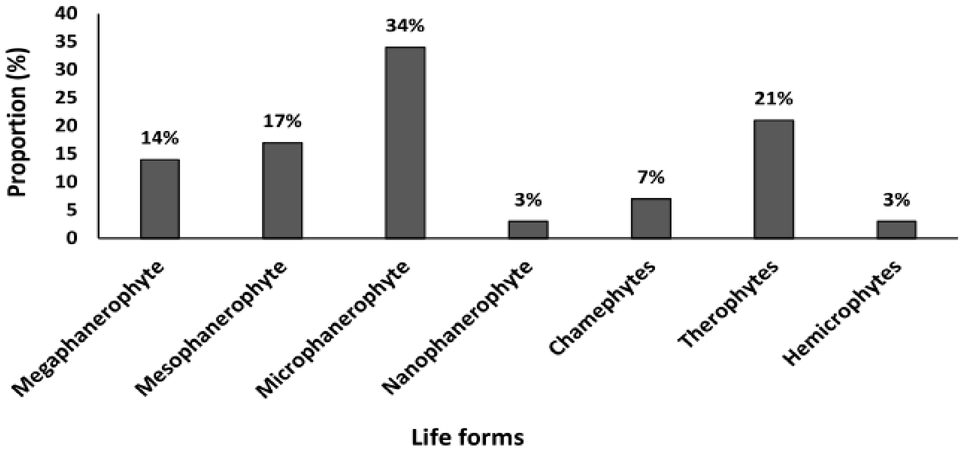

Figure 5: Spectrum of Life forms

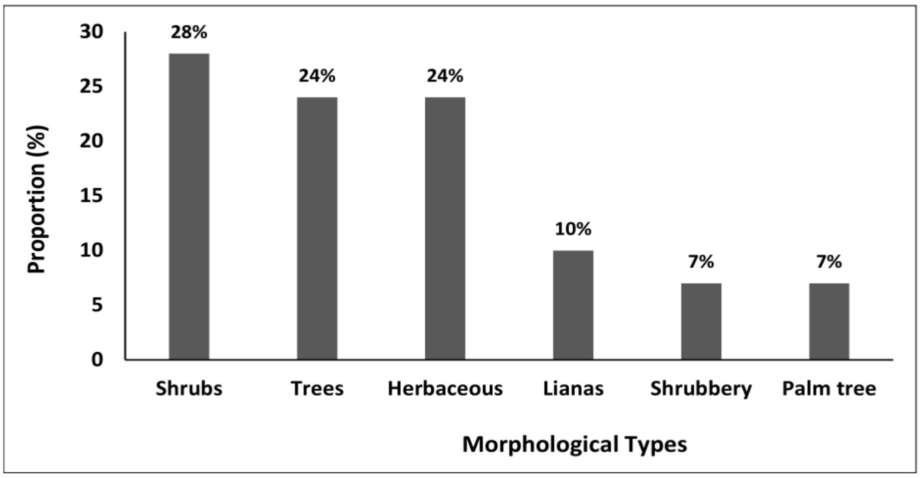

Figure 6: Spectrum of morphological types

2.4. How medicinal plants are used to treat bone fractures in the area?

- ***Plant organs or parts of MPTBF***

Different parts of the medicinal plant were used by THBF for bone fracture treatment. Leaves/leafy shoots (59%) and stems (14%) were the most commonly used parts of plant (Figure 7).

They were followed by the use of the root bark/whole bark (11%) and whole plant (11%). The stem bark (5%) was poorly used by THBF in bone fracture treatment.

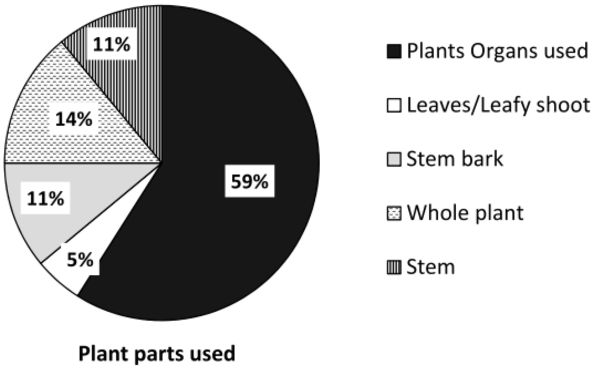

Figure 7: Proportions of medicinal plant parts used by THBF in the NTZ

- ***How to prepare MPTBF***

Three techniques for preparing MPTBF were identified: decoction, cataplasm and compress/tourniquet. Decoction was the most widely used preparation method (70%). It was followed by compress/tourniquet (21%) (Figure 8). Few MPTBF were prepared using cataplasm (9%). The root barks of species such as *Ochna rhizomatosa*, *Maerua angolensis* and *Olax subscorpioidea* were ground or crushed fresh, or dried, crushed and ground to obtain a poultice. The stems of *Flueggea virosa* or the main veins of *Borassus aethiopum* were woven with ropes made from the bark of species such as *Piliostigma tonningii*, *Piliostigma reticulatum*, *Pteleopsis suberosa* or *Hibiscus owariensis* to make a tourniquet, and the leaves of all the other species inventoried in this study are used for decoction.

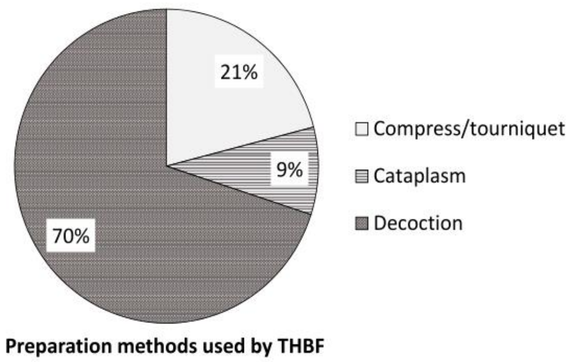

Figure 8: Proportions of medicinal plant preparation methods used by THBF in the NTZ

- ***Administration of MPTBF preparations***

The different modes of administration identified by the respondents were massage, application to the skin, dabbing on the skin and tourniquet application. Massage was the most common method of administration (58%). It was followed by dabbing on the skin (22%), and tourniquet application (11%) (Figure 9). Application to the skin (8%) was the least used.

The decoction (Figure 8) was used to massage the fractured part of the body after a preliminary massage with shea butter. This massage was more physical and helps to straighten the fractured bone. The leaves boiled to obtain the decoction was in some cases taken as a compress and used for dabbing during massage, while in other cases a clean cloth was used. The cataplasm (Figure 8) was applied or lightly passed over the fractured area. Finally, the tourniquet (Figure 8) was used to tie up the fractured part to keep the fractured bone in its normal position. The same treatment was repeated every day without removing the tourniquet (the cataplasm was then applied directly to the tourniquet). After 1 to 2 weeks at most, a loosening of the tourniquet was observed due to the reduced swelling of the muscular tissues following the "welding" of the bone in question. The tourniquet was then removed, and decoction massage and application of the cataplasm can be used to pursue the treatment. A week later at the most, the patient was cured, his bone solidly welded and stronger than before", according to the NTZ's THBF.

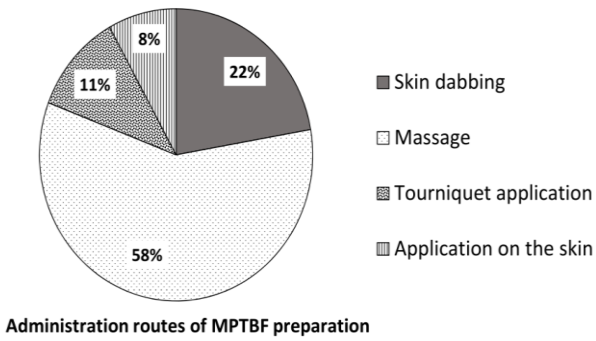

Figure 9: Proportion of the different administration route of medicinal plants used by THBF

- ***Methods of sampling or harvesting MPTBF***

THBF harvested MPTBF in three different ways. For some plants, the desired parts were partially cut off, while other plants were completely torn off. The third harvesting method was simple collection in wild. The dominant methods of MPTBF harvesting within the study area was partial cutting of the desired plant part (66%) (Figure 10). This was followed by the combination of partial cutting or total uprooting of the plant (17%) and total uprooting of the plant (14%).

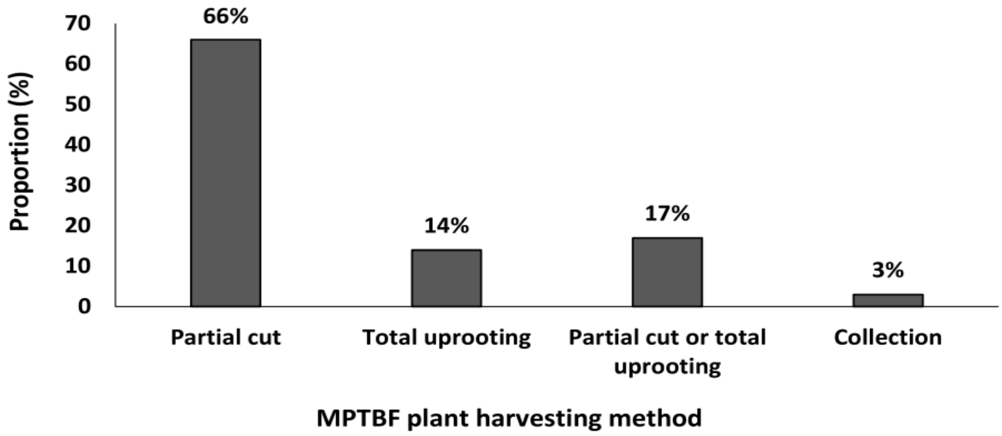

Figure 10: Proportions of different MPTBF harvesting methods

- ***Stage of MPTBF harvesting***

MPTBF in the study area were harvested as young, mature or at old stage. MPTBF in the study area were harvested at all stage of plant development (young, mature, old stage). MPTBF within the NTZ area were mostly collected in the young or adult stage (62%) and in the mature stage (34%) (Figure 11). These plants were rarely collected in the old stage (3%). The high frequency harvesting of the "young or adult" is explained by the relationship between sampling/development stage and abundance.

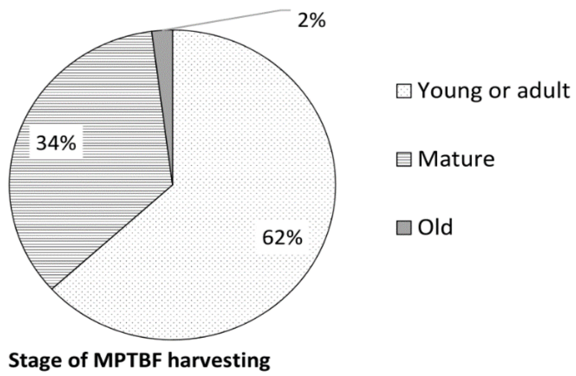

Figure 11: Proportions of different stages of MPTBF development

2.5. *Local communities' perceptions of the pressures and vulnerability of populations of medicinal plant species used to treat bone fractures*

The aim was to estimate the perceived vulnerability of each of the species inventoried by determining their vulnerability index based on the external and internal factors or constraints mentioned in the methodology, and to identify the sources of pressure on these species.

- ***PTBF vulnerability index***

From the MPTBF species recorded in the study area, 16 species were found as vulnerable. Ochna rhizomatosa (Iv = 2.63 > 2.5) was the only species found to be highly vulnerable. The remaining 15 species were moderately vulnerable, with vulnerability indices between 2 and 2.5. Table II presents the diversity, use patterns, factors and vulnerability indices of the 29 MPTBF species inventoried.

- ***Sources of pressure on medicinal plants used to treat bone fractures***

According to the THBF of Natitingou-Tanguiéta zone (NTZ), the factors influencing the availability of MPTBF in the NTZ were : logging/NTFPs, vegetation fire, extensive farming and pastoral pressures. According to the THBF, the main source of pressure on MPTBF in the NTZ was logging/PFNLs (36%). It was followed by uncontrolled bush fires (32%) Extensive farming (26%) (Figure 12). Pastoral pressure (6%) was recorded as the factor with low pressure on the availability of MPTBF in the area.

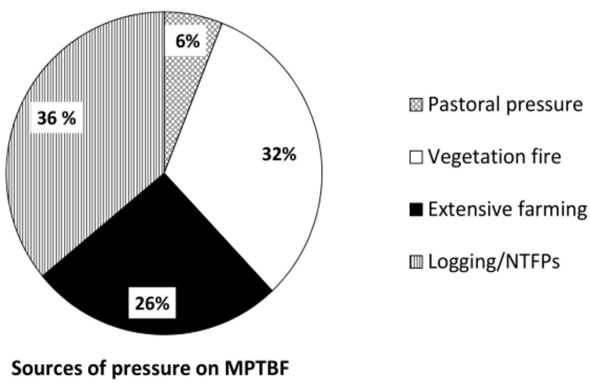

Figure 12: Proportion of different sources of pressure on MPTBF in the NTZ

Table II: Diversity, use patterns, factors and vulnerability indices of MPTBF species inventoried in the NTZ.

Family	Scientific name	Common name	Nr. herb.	Tbi	My	Mp (in)	Sp (in)	Mré (in)	Pu (in)	Fu (in)	Tm (in)	Hab (in)	Abce (in)	Total (in)	Iv
Ochnaceae	*Ochna rhizomatosa*	Moukétètié[D]	2	mph	ms/a pp	dc/ca t (3)	Je/ ad (2,5)	cp (2)	fe/ écr (2)	8 (2)	abs (3)	jc/fs (2)	abt (3)	21,5	2,63
Sapindaceae	*Paullinia pinnata*	Dikitinintibou[W]		mph	ms	dc (3)	Je/ ad (2,5)	cp (2)	fe (1)	1 (1)	li (3)	jc/sabs (2.25)	abt (2)	16,75	2,1
Arecaceae	*Raphia sudanica*	Katahou[W]		mph	agrr	Cps (1)	ad (2)	cp (2)	fe (1)	8 (2)	plm (3)	fg(3)	rar (3)	17	2,13
Connaraceae	*Rourea coccinea*	Tchékiridafa[W]	4	mph	ms	dc (3)	Je/ ad (2,5)	cp (2)	fe (1)	1 (1)	abs (3)	jc/sabs (2.25)	abt (2)	16,75	2,1
Vitaceae	*Cissus populnea*	Toctoubou[W]	3	MPh	ms	dc (3)	ad (2)	cp (2)	fe (1)	3 (1)	li (3)	jd/fc (2)	rar (3)	17	2,13
Combretaceae	*Pteleopsis suberosa*	Badjèboli[P]		mph	ms	dc (3)	Je/ ad (2,5)	cp (2)	ect (3)	1 (1)	abs (3)	sabs/fs (2.75)	tabt (1)	18,25	2,28
Loranthaceae	*Tapinanthus* sp. (Epiphyte of *Adansonia digitata)*	Nonritchouantchou ane[N]	13	MPh	ms	dc (3)	Je/ ad (2,5)	cp/at (2.5)	fe/ti (2)	3 (1)	abr (3)	sh/fs (2.5)	rar (3)	19,5	2,44
Moraceae	*Ficus ingens*	Pouanpouane[N]	8	mPH	ms	dc (3)	Je/ ad (2,5)	cp/at (2.5)	fe/ra (2)	4 (2)	abr (3)	jc/sh (1.5)	abt (2)	18,5	2,31
Loranthaceae	*Tapinanthus* sp. (Epiphyte of *Khaya senegalensis)*	Kouwaboumouttét chouane[N]		MPh	ms	dc (3)	Je/ ad (2,5)	cp/at (2.5)	fe (1)	1 (1)	abr (3)	jc/sh (1.5)	rar (3)	17,5	2,19
Olacaceae	*Olax subscorpioidea*	Barawékéré[W]	16	mPH	ms/a pp/tp p	dc and cat (3)	Je/ ad (2,5)	cp (2)	fe/écr (2)	1 (1)	abr (3)	fg(3)	rar (3)	19,5	2,44
Meliaceae	*Trichilia emetica*	Wantamou[N]	10	mPH	ms	dc (3)	Je/ ad (2,5)	cp/at (2.5)	fe (1)	1 (1)	abr (3)	sabs/fs (2.75)	abt (2)	17,75	2,22
Malvaceae	*Triumfetta tomentosa*	douwassihoun[N]	11	chm	ms	dc (3)	Je/ ad (2,5)	at (3)	pe (3)	1 (1)	her (1)	sh/fs (2.5)	abt (2)	17	2,25
Fabaceae	*Eriosema psoraleoides*	Tapèman[W]		chm	ms	dc (3)	Je/ ad (2,5)	at (3)	pe (3)	1 (1)	her (1)	sm/lgf (2.67)	abt (2)	18,17	2,27
Capparaceae	*Mearua angolensis*	Tounanfan[N]	6	mph	ms/a pp	dc and ct(3)	Je/ ad (2,5)	cp/at (2.5)	fe/écr (2)	1 (1)	abs (3)	jc/sh (1.5)	abt (2)	17,5	2,19
Combretaceae	*Combretum sericeum*	Kokoporika[W]	5	nph	ms	dc (3)	Je/ ad (2,5)	at (3)	pe (3)	1 (1)	arb (1)	jc/sh (1.5)	tabt (1)	16	2
Vitaceae	*Cissus quadrangularis*	Boutori[B]		chm	ms/tp p	dc/cp s (2)	Je/ ad (2,5)	cp (2)	fe (1)	1 (1)	li (3)	Jd/sabs (2)	rar (3)	16,5	2,06
Rubiaceae	*Sarcocephalus latifolius*	Kongnonmou[W]		mPH	ms	dc (3)	Je/ ad (2,5)	cp (2)	fe (1)	1 (1)	abr (3)	jc/sabs (2)	tabt (1)	15,5	1,94

Family	Scientific name	Common name	Nr. herb.	Tbi	My	Mp (in)	Sp (in)	Mré (in)	Pu (in)	Fu (in)	Tm (in)	Hab (in)	Abce (in)	Total (in)	Iv
Poaceae	*Digitaria exilis*	Péyi[W]		thr	tpp	cps (1)	Vi (1)	rass (1)	Fe/ti (2)	6 (2)	her (1)	jc (1)	rar (3)	12	1,5
Anacardiaceae	*Lannea microcarpa*	Moussinhoun[N]	14	mPH	agrr	cps (1)	Ad (2)	cp (2)	ect (3)	1 (1)	abr (3)	Jc/sabs /fs (2.33)	tabt (1)	15,33	1,92
Malvaceae	*Hibiscus owariensis*	Ticorti[D]	15	thr	agrr	cps (1)	Je/ ad (2,5)	cp (2)	Fe/ti (2)	1 (1)	her (1)	jd (1)	abt (2)	11,5	1,44
Phyllanthaceae	*Flueggea virosa*	Tchékirifa[W]		chm	agrr	cps (1)	ad (2)	cp (2)	pe (3)	7 (2)	Arb (1)	jc/sh (1.5)	tabt (1)	13,5	1,69
Fabaceae	*Piliostigma tonningii*	Barké[P]		mph	tpp	dc (3)	ad (2)	cp (2)	fe (1)	2 (1)	abr (3)	jc/sh (1.5)	tabt (1)	14,4	1,81
Fabaceae	*Piliostigma reticulatum*	Barké[P]		mph	tpp	dc (3)	ad (2)	cp (2)	fe (1)	2 (1)	abr (3)	Jc/sh/f g (2)	tabt (1)	15	1,88
Fabaceae	*Parkia biglobosa*	Naréhi[P]		mPH	tpp	cps (1)	ad (2)	cp (2)	fe (1)	4 (2)	abr (3)	jc/sh (1.5)	tabt (1)	13,5	1,69
Verbenaceae	*Lantana ukambensis*	Natchinyoka[N]	7	chm	ms	dc (3)	Je/ ad (2,5)	cp (2)	fe (1)	1 (1)	her (1)	jc (1)	abt (2)	13,5	1,69
Arecaceae	*Borassus aethiopum*	Kouwèbou[N]		MPh	tpp/a grr	cps (1)	ad (2)	cp (2)	fe (1)	3 (1)	plm (3)	jc/sh/s abs (2)	tabt (1)	13	1,64
Combretaceae	*Combretum collinum*	Fanpèbou[N]	12	mph	ms	dc (3)	Je/ ad (2,5)	cp (2)	fe (1)	1 (1)	abs (3)	jc/sh/s abs (2)	tabt (1)	15,5	1,94
Poaceae	*Andropogon gayanus*	Yigomoni[N]		hem	ms	dc (3)	Je/ ad (2,5)	cp (2)	fe/ti (2)	1 (1)	her (1)	jc/sh (1.5)	tabt (1)	14	1,75
Poaceae	*Eleusine indica*	Tchouwahoun[N]		thr	ms	dc (3)	Je/ ad (2,5)	cp (2)	pe (3)	1 (1)	her (1)	jc/ru (1)	tabt (1)	14,5	1,81
Ochnaceae	*Ochna rhizomatosa*	Moukétètié[D]	2	mph	ms/a pp	dc/ca t (3)	Je/ ad (2,5)	cp (2.5)	fe/écr (2)	8 (3)	abs (3)	jc/fs (2)	abt (3)	21	2,63
Sapindaceae	*Paullinia pinnata*	Dikitinintibou[W]		mph	ms	dc (3)	Je/ ad (2,5)	cp (2)	fe (1)	1 (1)	li (3)	jc/sabs (2.25)	abt (2)	16,75	2,1
Arecaceae	*Raphia sudanica*	katahou[W]		mph	agrr	csp (1)	ad (2)	cp (2)	fe (1)	8 (2)	plm (3)	fg(3)	rar (3)	17	2,13
Connaraceae	*Rourea cocinea*	Tchékiridafa[W]	4	mph	ms	dc (3)	Je/ ad (2,5)	cp (2)	fe (1)	1 (1)	abs (3)	jc/sabs (2.25)	abt (2)	16,75	2,1
Vitaceae	*Cissus populnea*	Toctoubou[W]	3	MPh	ms	dc (3)	ad (2)	cp (2)	fe (1)	3 (1)	li (3)	jd/fc (2)	rar (3)	17	2,13
Combretaceae	*Pteleopsis suberosa*	Kotika[W]		mph	ms	dc (3)	Je/ ad (2,5)	cp (2)	ect (3)	1 (1)	abs (3)	sabs/fs (2.75)	tabt (1)	18,25	2,28
Loranthaceae	Epiphyte of *Adansonia digitata*	Nonritchouantchou ane[N]	13	MPh	ms	dc (3)	Je/ ad (2,5)	cp/at (2.5)	fe/ti (2)	3 (1)	abr (3)	sh/fs (2.5)	rar (3)	19,5	2,44

Family	Scientific name	Common name	Nr. herb.	Tbi	My	Mp (in)	Sp (in)	Mré (in)	Pu (in)	Fu (in)	Tm (in)	Hab (in)	Abce (in)	Total (in)	Iv
Moraceae	*Ficus ingens*	Pouanpouane[N]	8	mPH	ms	dc (3)	Je/ ad (2,5)	cp/at (2.5)	fe/ra (2)	4 (2)	abr (3)	jc/sh (1.5)	abt (2)	18,5	2,31
Loranthaceae	Epiphyte of *Khaya senegalensis*	kouwaboumouttétc houane[N]		MPh	ms	dc (3)	Je/ ad (2,5)	cp/at (2.5)	fe (1)	1 (1)	abr (3)	jc/sh (1.5)	rar (3)	17,5	2,19
Olacaceae	*Olax subscorpioidea*	Barawékéré[W]	16	mPH	ms/a pp/tp p	dc and cat(3)	Je/ ad (2,5)	cp (2)	fe/écr (2)	1 (1)	abr (3)	fg(3)	rar (3)	19,5	2,44
Meliaceae	*Trichilia emetica*	Wantamou[N]	10	mPH	ms	dc (3)	Je/ ad (2,5)	cp/at (2.5)	fe (1)	1 (1)	abr (3)	sabs/fs (2.75)	abt (2)	17,75	2,22
Malvaceae	*Triumfetta tomentosa*	Douwassihoun[N]	11	chm	ms	dc (3)	Je/ ad (2,5)	at (3)	pe (3)	1 (1)	her (1)	sh/fs (2.5)	abt (2)	18	2,25
Fabaceae	*Eriosema psoraleoides*	Tapèman[W]		chm	ms	dc (3)	Je/ ad (2,5)	at (3)	pe (3)	1 (1)	her (1)	sm/lgf (2.67)	abt (2)	18,17	2,27
Capparaceae	*Maerua angolensis*	Tounanfan[N]	6	mph	ms/a pp	dc and ct(3)	Je/ ad (2,5)	cp/at (2.5)	fe/écr (2)	1 (1)	abs (3)	jc/sh (1.5)	abt (2)	17,5	2,19
Combretaceae	*Combretum sericeum*	Kokoporika[W]	5	nph	ms	dc (3)	Je/ ad (2,5)	at (3)	pe (3)	1 (1)	arb (1)	jc/sh (1.5)	tabt (1)	16	2
Vitaceae	*Cissus quadrangularis*	Boutori[B]		chm	ms/tp p	dc/cp s (2)	Je/ ad (2,5)	cp (2)	fe (1)	1 (1)	li (3)	Jd/sabs (2)	rar (3)	16,5	2,06

Table II legend

[1] Nr. herb. = Herbarium number under which the sample is stored in the Benin national herbarium. [2] Tbi = Biological type: mph = microphanerophyte; mPH = mesophanerophyte; MPh = megaphanerophyte; chm = champephyte. [3] Ma = Mode of administration: ms = massage; ms/app = massage and skin application; agrr = tourniquet application; ms/app/tpp = massage, skin application and skin dabbing. [4] Mp (in) = index of preparation method(s): dc/ct = decoction and ctaplasm; dc = decoction; ct = poultice; cp = compress. [5] Sp (in) = index of sampling stage(s): je/ad = young or adult; ad = adult; vi= old. [6] Mré (in) = harvesting method index: cp/at = partial cutting or total uprooting; cp = partial cutting; at = total uprooting; rass = collection. [7] Pu (in) = index of plant part(s) used: fe/écr = leaves and root bark; fe = leaves; éct = stem bark; fe/ti = leaves and stems; fe/ra = leaves and roots; pe = whole plant. [8] Fu (in) = Frequency of use index. [9] TM (in) = index of morphological type(s): abs = shrub, li = liana, plm = palm, abr = tree, her = herb. [10] Hab (in) = index of habitat type(s): jc/lgf = fallow/field and forest gallery edge, jc/fs = fallow/field and saxicolous formation, jc/sabs = fallow/field and shrub savannah, fg = gallery forest, jd/fc = hut garden and open forest, sabs/fs = shrub savannah and saxicolous formation, sh/fs = grassy savannah and saxicolous formation, jc/sh = fallow/field and grassy savannah, sh/fs = grassy savannah and saxicolous formation, sm/lgf = swamp savannah and forest gallery edge, jd/sabs = hut garden and shrub savannah, jc/sh/sabs = fallow/field, grassy savannah and shrub savannah. [11] Ab (in) = abundance index: abt = abundant, tabt = very abundant, rar = rare. [12] Total (in) = sum of indices. [13] Iv = Vulnerability index. [14] Local names: D = Ditammari, W = Waama, P = Peulh, N = Nateni, B = Bial.

- ***Evaluation of local conservation strategies for medicinal plants used to treat bone fractures***

The aim was to identify and evaluate local strategies for the conservation and valorization of MPTBF and associated traditional knowledge in the NTZ. Table III presents the various local strategies for the conservation and valorization of MPTBF and associated traditional knowledge, according to the frequency with which they are cited. The THBF, were well aware that the MPTBF were facing anthropogenic pressure and that the plant species availability was constantly decreasing. To inverse the MPTBF species decreasing, the THBF adopted a number of strategies to contribute to their conservation and enhancement. Three strategies i.e. sustainable harvesting methods (60%) and agroforestry (25%) and sacralization of some individual tree species were used by the THBF.

- ***Socio-demographic and cultural profile of Healers***

Ethnobotanical surveys carried out around the Pendjari Biosphere Reserve identified a total of 20 traditional healers of bone fracture (THBF) in the Natitingou-Tanguiéta area, the majority of them were men (90%). This predominance of men among THBF could be explained by the fact that bone fracture treatment in this region is external and physical. According to Gbekley et *al.*, (2015), this predominance of men traditional practitioners is observed in most gender studies. In an ethnobotanical survey of medicinal plants used for the treatment of bone fractures conducted in India among 44 people, only 3 were women (Upadhya et *al.*, 2012). On the other hand, according to a survey conducted in the Moroccan commune of Imi n'Tlit, women have slightly more knowledge of medicinal species than men (53% versus 47%) (Mehdioui et al., 2007). Furthermore, the results reveal that the majority of THBF (55%) are over 60 years of age, with an average age of 63.8 years, with a minimum of 39 years and a maximum of 90 years. This average is higher than that presented by Upadhya et al., (2012) who found an average of 55 years and by Nzuki (2016) in his study of traditional healers in the Mbanza-Ngungu Region, DRC that was 49.5 years. This shows that most THBF are elderly confirming that the practice of traditional medicine specifically concerning the treatment of bone fractures, is controlled by mature men (Gnagne et *al.*, 2017) and immediate steps must be taken to explore, collect and document the information they have before it is irretrievably lost. Our findings show that the main activity of the THBF is not traditional medicine. Agriculture was the main activity of most of the respondents (85%). This could be explained by the fact that the treatment of bone fractures for the moment is not an economic activity, as it is almost entirely free of charge. This result is at odds with those of a number of authors who found that the majority of respondents practiced traditional medicine as their main activity. This is the case, for example, for 40% (Akoto et al., 2006) and 46.4% (Sangare, 2011) of traditional practitioners. This study shows that 85% of the people surveyed were not educated. This result is the same as those presented in the studies carried out by Mehdioui et al., (2007) and by Gnagne et al., (2017). Traditional knowledge associated with the treatment of bone fractures is passed down from generation to generation (90%) and initiation into the activity takes place at a young age, between 15 and 25 (70%) in the study area. This result is closed to that presented by Upadhya et *al.*, (2012) according to which found that knowledge related to the treatment of bone fractures are verbally transferred from one generation to the next within the same family and learning to treat bone fractures begins at the age between 15 and 20 and extends over a period of 10 to 15 years. In fact, according to the latter, knowledge of the uses and properties of medicinal plants is generally acquired as a result of long experience accumulated and passed down from one generation to the next.

- ***Diversity of medicinal plants and bone fracture treatment***

This study in the Communes of Natitingou and Tanguiéta enabled us to record a total of 29 species grouped into 26 genera and 18 plant families. The most represented families are Fabaceae (14%), Combretaceae (10%), Poaceae (10%), Arecaceae (7%), Vitaceae (7%) and Loranthaceae (7%). The high representation of the Fabaceae could be justified by the grouping of three subfamilies into one botanical family. Indeed, phyllogenetic classification has associated the Caesalpinioideae, the Mimosoideae and the Faboideae or Papilionoideae. Their all belong to the Fabales order (APG III, 2009) cited by Gnagne et *al.*, (2017) and this group forms the Fabaceae family. The number of species recorded in this study is close to the results of Upadhya et *al.* (2012), who inventoried 38 species in two districts (Belgaum and Uttara Kannada) of India for an ethnobotanical study of plants used to treat bone fractures. This result is also close to that presented in the study conducted by Jayanth et *al.*, (2018) on the internal application of medicinal plants to treat bone fractures, where they inventoried 23 species divided into 21 genera and 18 families. Among the species inventoried, Cissus quadrangularis was cited by several authors, such as Upadhya et *al.* (2012) and Jayanth et *al.* (2018), as being involved in the treatment of bone fractures. Most of these species are phanerophytes (68%) made of Micrphanerophytes (34%), Mesophanerophytes (17%), Megaphanerophytes (14%) and Nanophanerophytes (3%). They are followed by Therophytes (21%). These results reflect the state of vegetation in tropical and equatorial zones, where the proportion of phanerophytes is estimated at between 80% and 90% (Ambé et al., 2015) and concur with those presented in the study on medicinal plants used in the treatment of diabetes in the Zouénoula Department in Côte d'Ivoire (Gnagne et *al.,* 2017). The results show that most of the medicinal plants identified are shrubs (28%), trees (24%), and herbaceous plants (24%). This was also noted by Upadhya et *al.*, (2012); Nzuki, (2016); Béné et al, 2016) and Gnagne et al, (2017). Concerning the mode of use of MPTBF, leaves/leave twigs (59%), stems (14%) and root/root bark (11%) are the most widely used plant parts. Plants are also used in their entirety (11%). This frequent use of leaves, stems and underground parts in traditional medicine were also reported by several authors (Mehdioui et *al.,* 2007; Upadhya et *al.*, 2012; Gbekley et *al.*, 2015; Béné et *al.,* 2016 and Nzuki, 2016). There may be concern about the excessive use of leaves in medicinal plants, but studies by Poffenberger et *al.* (1992) showed that removing 50% of a tree's leaves does not significantly affect its survival. As for the roots, however, their removing compromises the possibility of supplying the plant with nutrients, affecting its vegetative aspect as well as its physiology (Yapi, 2013). All these plant parts are prepared either as a decoction (70%), as a compress (21%) or as a cataplasm (9%). This predominance of decoction may be explained by the fact that it enables more complete extraction of a plant's active principles (or plant organs) when the mixture (solvent plus plant material) is boiled. It is particularly applicable to underground plant parts, such as roots and root barks, which have difficulty releasing their active ingredients during infusion (Nogaret-Ehrhart, 2003). These results are in line with those presented by other authors such as: Upadhya et *al.*, (2012); Lougbégnon et *al.*, (2015); Kouchadé et *al.*, (2016) and Gnagne et *al.*, (2017). Furthermore, all these preparations are essentially administered either by massage (59%), by dabbing on the skin (22%), by application as a tourniquet (11%) or either by application to the skin (8%). These modes of administration are specific to the external application of medicinal plants for the treatment of bone fractures. The same results were presented by Upadhya et al, (2012) and differ from those presented by Jayanth, et *al.*, (2018) who focused on the internal application of medicinal plants for the treatment of bone fractures.

- ***Vulnerability of medicinal plants used to treat bone fractures (MPTBF) in the NTZ***

The results show that sixteen species, or 55%, are vulnerable. Ochna rhizomatosa (Iv = 2, 63 > 2.5) was the only species found to be highly vulnerable. The other fifteen species were moderately vulnerable, with vulnerability indices between 2 and 2.5 (Table II). The high proportion of vulnerable species obtained in this study indicates that the anthropogenic pressure on these resources is very high. The factors or parameters to which this vulnerability is most closely linked are preparation method, stage and method of harvesting, morphological types, abundance and habitat specificity of MPTBF. This point was already presented by Dassou, et al. (2014). According to these authors, the vulnerability of a plant depends largely on its morphological type, its frequency in the environment and its uses type. Indeed, the results of the present study show that 70% of MPTBF are prepared as an aqueous decoction, which is characterized on the vulnerability scale by a value of 3, corresponding to a high level of vulnerability. Unlike dry preparations such as compresses and ashes, recipes based on aqueous solutions must be used immediately after preparation. According to Bourobou Bourobou (2004), aqueous decoction can be stored for no more than five to seven days. More than ashes, their will cause more frequent harvests and affect plant survival, especially as the traditional practitioner is obliged each time to harvest plant species when he receives a request from a patient. Furthermore, 62% of these MPTBF were harvested in the young or adult stage, 66% by organ cutting and 14% by total uprooting. Medicinal plants harvested in their young or adult stage and harvested by partial cutting or total uprooting are characterized, on the vulnerability scale, by scores of between 2.5 and 3, corresponding to a medium to high level of vulnerability. According to the THBF, on the one hand there is a relationship between the stage of harvesting/development and abundance, and in the other, between the harvesting method and the stage of harvesting/development of the species. When the plant found by the healers is at its young stage and although the species availability in the area is low, the THBF is often obliged to harvest the young plant. Even if the organs or plant parts of a young plant are not yet fully developed, the plant is completely uprooted. However, when it's a mature plant, and the species is abundant in the environment, the THBF will partially cut the desired part. This is the rationale behind the "partial cut or total uprooting" harvesting method. Our results also showed that 59% of MPTBF are woody species (shrubs: 28%, trees: 24% and shrubs: 7%), which are characterized on the vulnerability scale by a value of 3, corresponding to a high level of vulnerability. Trees are more vulnerable than grasses, as they grow more rapidly and annually (Betti, 2001) and establish successfully in disturbed environments such as cultivated and ruderal areas (Nzuki, 2016). Turner (2007) places abundance among the most important factors affecting plant survival. With regard to the perceived abundance of MPTBF, many of the species used are fallow/field plants (30%) and grass savannas (30%). In this study, there are classified as very abundant and abundant plants. Rare MPTBF are mainly those harvested by THBF far from the villages, outside the study area. These include: *Ochna rhizomatosa*, *Raphia sudanica*, *Cissus quadrangularis*, *Cissus populnea* and *Olax subscorpioidea*. In terms of perceived abundance, each of these MPTBF is characterized on the vulnerability scale by a value of 3, corresponding to a high level of vulnerability (Table II). Furthermore, the THBF are more closely linked to the "forest-savannah" group (66% of quotes), including saxicol plant communities, than to cultivated and ruderal areas. And yet, compared with the latter, forest and savannah would require a longer transition period in the event of disturbance. These latter biotopes would therefore be more vulnerable as quoted by Nzuki (2016). The same would apply to plants that can only grow in such habitats (Betti, 2001), such as Ochna rhizomatosa, Raphia sudanica, Olax subscorpioidea, Eriosema psoraleoides and epiphytes such as Adansonia digitata epiphytes and Khaya senegalensis epiphytes, which are characterized on the vulnerability scale by values between 2 and 3. According to Turner (2007), habitat is an important factor affecting plant survival and should always be taken into account in plant species conservation program.

- ***Strategies for local conservation and enhancement of MPTBF in the NTZ***

To reduce the pressures/threats to MPTBF in the NTZ, the THBF have mainly adopted two strategies: 60% of them developed sustainable harvesting methods, 25% used agroforestry and the others used plant sacralization. These strategies consist respectively in partially cutting of the desired part plant that can allow the plant to continue growing, and in conserving some individuals of species in the fields when clearing. Other strategies, such as the sacralization of certain plants, are also used by these THBF. Although the role of this prohibition of exploitation is mainly spiritual, it aims to contribute to the reduction of pressures on MPTBF and optimize their conservation. The work carried out by Traoré et *al.*, (2011) in Burkina Faso shows that the Sénoufo have no culture of conserving local species in their fields, apart from Vitellaria paradoxa, Parkia biglobosa and Tamarindus indica. This divergence in strategy of plant conservation could be explained by the fact that the latter authors focused their studies on woody plant resources. However, it was found that the above-mentioned strategies available to these THBF are highly inadequate for the effective conservation and valorization of MPTBF. It is therefore urgent to develop other strategies for the conservation and valorization of MPTBF in the NTZ zone. One way would be to set up an integrated system: inventories-culture-conservation and/or environmental, ecological and health education-sustainable development of the population, as mentioned by Makumbelo et *al.* (2008).

Conclusion

This study helps to build a database of medicinal plants used to treat bone fractures in the communes bordering the Pendjari reserve biosphere, particularly in the Natitingou-Tanguiéta area. Species very frequently used as medicinal plants in the treatment of bone fracture (MPTBF) were Ochna rhizomatosa, Raphia sudanica and Flueggea virosa. Anthropogenic pressures on all these MPTBF can be summed up as habitat destruction. Furthermore, the popularity of MPTBF combined with unsustainable exploitation and use patterns, habitat specificity, general appearance and low abundance increase their vulnerability. The most vulnerable species was Ochna rhizomatosa. Strategies developed by the THBF for the conservation and valorization of these plants and associated traditional knowledge remain insufficient. It is therefore crucial to find options for developing other strategies for the conservation and valorization of MPTBF. Furthermore, pharmacological studies could be carried out on the plants most frequently used to treat bone fractures, so that they can be tested tested in modern medicine.

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Authors' contributions

All authors have read and approved the final manuscript.

Conflicts of interest

The authors declare no conflicts of interest.

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