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Kouassi Apollinaire Kouakou
a) University Jean Lorougnon Guédé, Training and Research Unit in Environment, BP 150 Daloa, Côte d'Ivoire
b) Interdisciplinary Research Group in Environment and Landscape Ecology (GRIEPE)

Karidia Traore
University Jean Lorougnon Guédé, Training and Research Unit in Agroforestry, BP 150 Daloa, Côte d'Ivoire

Yao Charles Sangne
a) University Jean Lorougnon Guédé, Training and Research Unit in Environment, BP 150 Daloa, Côte d'Ivoire
b) Interdisciplinary Research Group in Environment and Landscape Ecology (GRIEPE)

Yao Sadaiou Sabas Barima
a) University Jean Lorougnon Guédé, Training and Research Unit in Environment, BP 150 Daloa, Côte d'Ivoire
b) Interdisciplinary Research Group in Environment and Landscape Ecology (GRIEPE)

Corresponding Author:
Kouassi Apollinaire Kouakou
a) University Jean Lorougnon Guédé, Training and Research Unit in Environment, BP 150 Daloa, Côte d'Ivoire
b) Interdisciplinary Research Group in Environment and Landscape Ecology (GRIEPE)

Vulnerability of source species of non-timber forest products of plant origin exploited by riparian owners of protected areas: The case of the classified forest of Haut-Sassandra, in the Centre-West of Côte d'Ivoire

Kouassi Apollinaire Kouakou, Karidia Traore, Yao Charles Sangne and Yao Sadaiou Sabas Barima

Abstract
In Côte d'Ivoire, rural populations living on the periphery of classified forests depend in part on several species as sources of non-timber forest products (NTFPs) to meet their daily needs. In a context of anthropogenic pressures, this study aims to identify vulnerable plant species that are sources of commonly used NTFPs and riparian populations of FCHS, with a view to preserving and sustainably managing these natural resources. To achieve this, semi-structured individual surveys were conducted among FCHS residents. In addition, inventories through rectangular area surveys (500 m x 10 m) crossing different agro-ecological environments were carried out to report on the availability of NTFP source species within the FCHS. Surveys revealed that 136 source species of NTFPs are commonly used by FCHS riparian populations. These species are divided into 119 genera, arranged in 55 families, the most represented in number of species being the Euphorbiaceae. They are mainly used in six fields, namely pharmacopoeia, food, crafts, construction, packaging and culture. They are mainly used in six fields, namely pharmacopoeia, food, crafts, construction, packaging and culture. However, the plants used in the pharmacopoeia are the most important. However, the plants used in the pharmacopoeia are the most important. These plants are sought after for their bark (52.52%), leaves (28.78%), stem (21.58%), sap (14.38%), almonds (2.16%) and fruit pulp (0.72%) depending on the domain. According to usage values, among the top 20 source species of NTFPs identified, *Elaeis guineensis* (Vu = 2.96) is the best-known and most sought-after species. In total, 45 source species of NTFPs, or 32.37% of the plant species used by the FCHS riparian population, are vulnerable. Of these species, five (5) are threatened with extinction. These are *Irvingia gabonensis*, *Neuropeltis acuminata*, *Laccosperma secundiflorum*, *Entandrophragma utile* et *Entandrophragma angolense*.

Keywords: Upper Sassandra classified forest, Non-timber forest products, Anthropisation, Vulnerability, Côte d'Ivoire

1. Introduction

Forests play a key role in terms of ecosystem services (conservation of biological diversity, regulation of water regimes, soil maintenance, carbon storage, etc.) and economic development (Jesel, 2005; Tchatat and Ndoye, 1999) [25, 49]. In addition to timber, tropical rainforests provide a variety of alternative products that generate income and employment. The latter, considered as resources of biological origin, other than wood, derived from forests or other wooded land, are known as non-timber forest products (FAO, 1999) [18]. Through their importance in various fields (traditional medicine, culture, construction, food, etc.), they provide people with income and are also key subsistence products (Priso *et al*., 2011) [46]. To this end, in many tropical countries, the exploitation of source species of non-timber forest products (NTFPs) is an increasingly attractive activity for many people. These products have attracted considerable interest around the world in recent years as their contribution to household economies and food security as well as to environmental objectives such as the conservation of plant biodiversity has been increasingly recognized (Apema *et al*., 2010) [7]. In Côte d'Ivoire, several studies have been carried out on NTFPs, but they have focused either on the ethnobotanical and ecological aspects of medicinal and food plants (Aké Assi, 1984; Tra bi, 1997; Ambé, 2001; N'Guessan *et al*., 2009; Soro *et al*., 2014) [4, 51, 5, 39, 48]., or on the valuation and conservation strategies of certain source species of NTFPs (Schreckenberg *et al*., 2006; Kouamé *et al*., 2008; N'Dri *et al*., 2012; Djaha *et al*., 2014; Ouattara *et al*., 2016) [53, 27, 12, 41 43], or on socio-cultural value (Malan, 2009). However, the vegetation cover and heritage of source species of NTFPs are gradually deteriorating, due in particular to their non-rational use (Mbayngone and Thiombiano, 2011) [36]. In the face of the population explosion and increasing pressure on these natural resources, some species that could have been of great use have disappeared or become very rare (Traoré *et al*., 2012) [52]. These pressures do not spare classified forests and other protected State areas in Côte d'Ivoire. For example, the Haut-Sassandra classified forest (FCHS) located in and around central-western Côte d'Ivoire is now occupied by farms. The analysis of the dynamics of the different types of land use shows a considerable decline in the forest in favour of crops and fallows in the FCHS area (Kouakou *et al*., 2015; Kouakou *et al*., 2017) [31, 32]. This situation, which worsened during the decade of crises in Côte d'Ivoire from 2002 to 2011, resulted in the loss of more than 70% of forest cover in the area. (Barima *et al*., 2016; Assalé *et al*., 2016) [1, 9]. The result of this situation is undoubtedly the depletion or even disappearance of several plant species, including the source species of NTFPs on which these populations depend. (Kouakou *et al*., 2018) [31]. In this context, knowledge of vulnerable species is more than necessary to integrate the needs of populations into decision-making aimed at the preservation, rehabilitation (or restoration) and sustainable management of protected areas. This study aims to contribute to the sustainable management of source species of non-timber forest products of plant origin used by the populations living along the banks of the Haut-Sassandra classified forest. It is based on the assumption that due to human activities and/or their uncontrolled harvesting around and/or within FCHS, several plant species that are sources of non-timber forest products have become vulnerable. Specifically, it will be:

- Determine the different uses of NTFP source species used by FCHS residents;
- Assess the vulnerability of NTFP source species used by FCHS residents.

2. Material and Methods

2.1 Study site

This study was carried out in the FCHS area, in the Centre-West of Côte d'Ivoire, about 60 km from the town of Daloa. FCHS is located between 6º50' and 7º22' North latitude and 6º58' and 7º22' West longitude (Figure 1) precisely in the Haut-Sassandra region between the departments of Vavoua and Daloa in Côte d'Ivoire. It covers an area of 102.400 hectares and is directly influenced by the Sassandra River and its tributaries. The population bordering the FCHS is composed of indigenous people, namely the Niaboua settled in the South, the Niédéboua and Gouro in the North and North-East of the forest, non-natives is dominated by the Baoulé from the centre of the country and non-natives represented mainly by the Burkinabès. Unlike the natives, non-natives are generally settled in camps around the FCHS. In addition to food crops (yam, rice, maize, groundnuts, etc.) for food, cash crops (cocoa, coffee and in recent years rubber and cashew nuts) are the main occupations of the population (Kouakou *et al*., 2015) [30]. The FCHS was covered by a dense semi-deciduous humid forest with *Celtis* spp. and *Triplochiton scleroxylon* (Guillaumet and Adjanohoun, 1971) [21]. Today, this forest has almost disappeared, giving way to other types of vegetation such as degraded forests, fallows and fields of food and perennial crops.

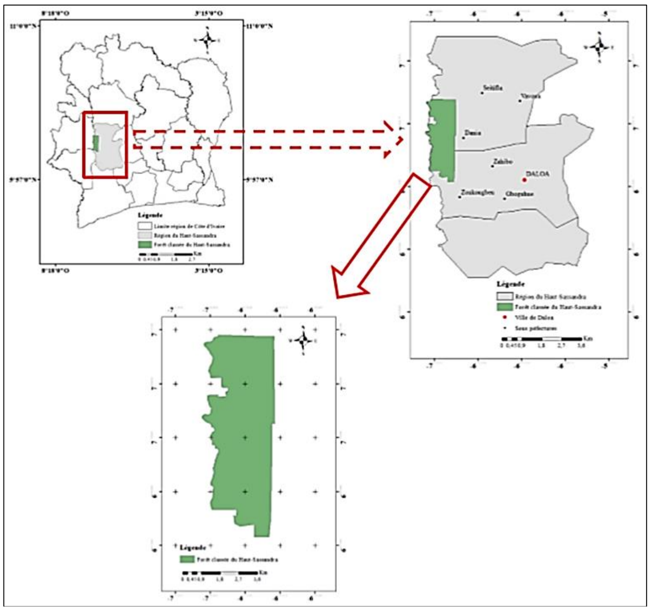

Fig 1: Location of the Haut-Sassandra region and the Haut-Sassandra Classified Forest in Côte d'Ivoire

2.2. Data collection

Individual semi-structured surveys, using an open and closed questionnaire, were conducted in 36 villages and camps adjacent to the FCHS. The choice of persons to be surveyed in each village was made randomly and took into account any person aged 30 years or older, without distinction of sex and permanent residents in the targeted villages. These individuals should have a good knowledge of the source species of NTFPs. The questionnaire covered the different uses of source species of NTFPs related to areas of use, different parts used and sampling methods. Similarly, according to their perception, the persons surveyed are invited in the questionnaire to give their apprehension about the current availability of the species.

To assess the availability of NTFP source species used by FCHS residents, 18 rectangular plots (500 m x 10 m or 5000m²) were installed in different agro-ecological environments within FCHS. Within these plots, all the plant species encountered have been inventoried.

2.3 Data processing

Samples of NTFP source species collected by the populations surveyed in the survey were directly identified using the identification key proposed by Hawthorne (1996) [22]. The nomenclature of plant species according to Cronquist (1981) [11] is the one that has been adopted. In addition, the scientific names of locally named species were determined on the basis of samples taken. The plant species that are sources of NTFPs and the families and genera that make up them have been listed. On the basis of the list drawn up, surveys and field observations, the floristic richness of the NTFP source species, their different uses and their use value were determined. Similarly, the availability of source species of NTFPs and their vulnerability were studied.

2.4 Data analysis
2.4.1 Determination of the Use Value of a species
To determine the Use Value (Vu) of a NTFP source species, the Frequency of Use (Fu) was used. This citation-based frequency corresponds to the ratio between the numbers of persons surveyed who cited the species and the total number (N) of persons surveyed. This approach is based on the principle that the most commonly used source species of NTFPs are those that are cited several times by the population that makes up the survey sample (Djègo *et al*., 2011; Dossou *et al*., 2012) [14, 16].

$$Fu = \frac{S}{N} x\, 100 \quad (1)$$

The frequency of use (Fu) is associated with the value of use (Vu), which is an index that allows each species to be given an approximate value according to its social and economic importance (Hoffman and Gallaher, 2007) [24]. Use value was used to classify NTFP source species according to areas of use (pharmacopoeia, crafts, food, etc.). For a species (i), the use value within a given use category is represented by its average use score within that category. This importance score, which is assigned to each species by the interviewee, changes from 0 (lower value) to 3 (higher value). The Use Value (Vu) of the species corresponds to the ratio between the use score assigned to this species (Si) and the number of respondents for the given use category (n) according to the mathematical formula:

$$Vu\ (i) = \frac{\sum_i^n Si}{n} \quad (2)$$

According to Piba *et al*. (2015) [45], the more a species is sought by populations, the greater its use value.

2.4.2 Determination of the significance value of a species
The value of importance (VI) of a given species (i) represents the ratio between the number of different uses (Naked) for that species and the total number of uses of all listed species (∑N):

$$VI\ (i) = \frac{Nu}{\sum N} \quad (3)$$

The species with a high number of uses is the most important by population. The calculation of the value of importance makes it possible to know the most important species for a community (Albuquerque *et al*., 2006) [6].

2.4.3 Abundance or rarity of a plant species
To measure the abundance or rarity of a plant species, the rarefaction index (Ri) or species rarity-weight richness has been used, as have several studies (Kokou *et al*., 2005; Dro *et al*., 2013; Vroh *et al*., 2014; Piba *et al*., 2015) [26, 17, 54,45]. The rarity index (Ri) of a species is determined from the formula of Géhu & Géhu (1980) whose mathematical expression is:

$$Ri = (1- \frac{ni}{Nt})\ x\ 100 \quad (4)$$

Ri: rarefaction index of species i
ni: number of plots in which the presence of species i has been reported
Nt: total number of plots laid.
According to the work of Kokou *et al*. (2005) [26] and Adomou *et al*., 2012 [2],
Ri < 50%: the species is very abundant in the environment
50% ≤ Ri < 80%: the species is frequent and abundant in the environment
Ri ≥ 80%: the species is rare in the environment
Ri = 100%: the species is very rare and has not been observed in the environment
From this index and the floristic list obtained from the inventories, it was possible to assess the availability of source species of NTFPs.

2.4.4 Determination of the vulnerability of source species of NTFPs
To determine the vulnerability of source species of NTFPs, a three-level vulnerability scale of 1 to 3, proposed by Traoré *et al*. (2011) [52], was used and adapted for this study. Thus, a value of 1 indicates a species with low vulnerability for the chosen parameters, a value of 2 represents an average vulnerability and a value of 3 characterizes a highly vulnerable species. For this purpose, a vulnerability index (Table I) is calculated based on the parameters of the frequency of use of the species (N1), the types of use of the species (N2), the plant parts used (N3), the harvesting method (N4), the use value (N5), the current availability of the species (N6), and the commercial value (N7). When several parts of a plant are used in a use, only the part with the highest value from the vulnerability scale is taken into account in the calculation of the indices (Badjaré *et al*., 2018) [8]. Species considered vulnerable are those that are most commonly used, have slow growth, are under great pressure from populations and have high commercial value. Herbaceous plants were not taken into account in determining the vulnerability of species because of their much faster reproduction mode than tree species. The calculation of the vulnerability index for species i (Iv) was determined by the following formula:

$$Iv = \frac{\sum Ni}{\text{Number of parameters}}$$

With Ni (N1+N2+N3+N3+N4+N4+N5+N5+N6+N7+N8), the value assigned to parameter i according to its specific level of vulnerability.
Iv < 2, the plant is said to be weakly vulnerable;
2 ≤ Iv < 2.5, the plant is said to be moderately vulnerable;
Iv ≥ 2.5, the plant is said to be very vulnerable.
The calculation of the vulnerability index highlighted the list of source species of NTFPs that are likely to be vulnerable in the study area.

Table 2: Parameters taken into account for the calculation of the vulnerability index (Traoré *et al*., 2011 modified) [52].

N°	Parameters	Vulnerability index		
		Low (scale = 1)	**Average (scale = 2)**	**Strong (scale = 3)**
1	Frequency of use	(Fu <50%)	20% ≤Fu <50%	Fu ≥ 50%
2	Number of uses	Nu < 2	2 ≤ Nu ≤ 4	Nu ≥ 5
3	Plant parts or organs used	sheet	Fruit, almond, branch	bark, stem, trunk, root, pulp
4	Method of sampling	picking	fruit cutting, picking up	debarking, trunk and root cutting

5	Use value	0,01 ≤ Vu ≤ 0,09	1≤ Vu ≤ 2	Vu ≥ 2
6	Current availability	plentiful	less abundant	uncommon
7	Commercial value	no one	weak	intense

Fu: Frequency of use; Nu: Number of uses; Vu: Use value

3. Results
3.1 Qualitative diversity of source species of non-timber forest products
3.1.1 Floral composition
The sample of people surveyed consisted of 499 people. The analysis of the questionnaires identified 136 source species of NTFPs. These species are divided into 119 genera, classified into 55 families, the most represented in number of species being Euphorbiaceae with ten (10) species or 7%, followed by Asteraceae, Caesalpiniaceae and Moraceae with 8 species each or 5%. The families Apocynaceae and Sterculiaceae with seven (7) species each represented 5%, while Arecaceae and Meliaceae with six (6) species each occupied 4% (Figure 2). The other least abundant families specifically represent 60% of the taxa. The chorological spectrum of NTFP source species showed a dominance of taxa common to the Guineo-Congolese (GC) region with 60% (Figure 3). Transition taxa (GC-SZ) accounted for 35% (Figure 4).

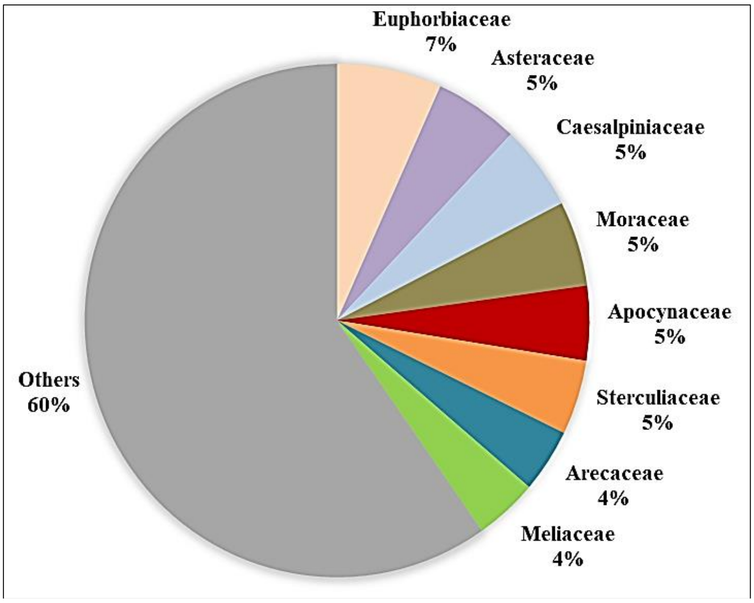

Fig 2: Families of dominant non-timber forest products used by riparians of the Upper Sassandra classified forest

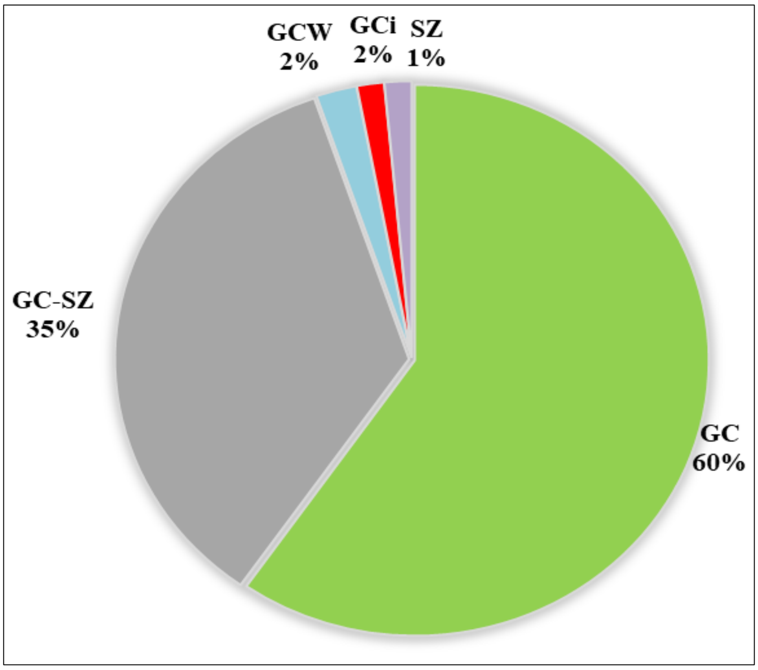

Fig 3: Distribution of NTFP source species by chorological affinity

GC : Taxon of the Guinea-Congolese region; GC-SZ : Taxon of the transition zone between the Guinea-Congolese region and the Sudanese region; GCW : Endemic taxon of the forest block in western Togo, including Ghana, Côte d'Ivoire, Liberia, Sierra Leone, Guinea Bissau, Gambia and Senegal; GCi : Taxon endémique du bloc forestier à la Côte d'Ivoire

3.2 Uses of source species of non-timber forest products

The parts of NTFP source plants (Figure 4) exploited by the population are bark (52.52%), leaves (28.78%), stem (21.58%), sap (14.38%), fruit kernels (2.16%), fruit pulp (0.72%). The sampling methods (Figure 5) such as bark sampling (45.55%) and stem cutting (37.78%) are generally carried out with a machete or axe. While leaf pulling (8.89%), fruit picking (3.89%), sap extraction (1.67%), fruit picking (1.11%) are generally done by hand.

The 136 source species of NTFPs are solicited in six areas of use: pharmacopoeia, food, crafts, construction and packaging, and cultural (Figure 6). The plants used primarily in the field of pharmacopoeia are 109 species or 78.42% of all NTFP source species cited by the population. These include, among others *Alchornea cordifolia*, *Alstonia boonei*, *Carapa procera*, *Entandrophragma angolense*. Food plants are 11 species or 7.91% of all NTFP source species and are represented primarily by *Elaeis guineensis*, *Irvingia gabonensis*, *Myrianthus arboreus*, *Ricinodendron heudelotii*, etc. There are ten (10) species of plants commonly used as construction equipment, representing 7.19% of the source species of NTFPs. They are represented by *Antiaris toxicaria*, *Baissea leonensis*, *Bambusa vulgaris*, *Calamus deërratus*. The species involved in handicrafts are five (5) or 3.59% of the total represented by *Baphia nitida*, *Laccosperma secundiflorum*, *Eremospatha hookeri*. In the cultural field, there are three (3) species, or 2.15% represented by *Erythrophleum ivorense*, *Parquetina nigrescens* used for certain traditional ceremonies and *Milicia excelsa* for sacred rites. A species is used for packaging objects. It is *Thaumatococcus daniellii*.

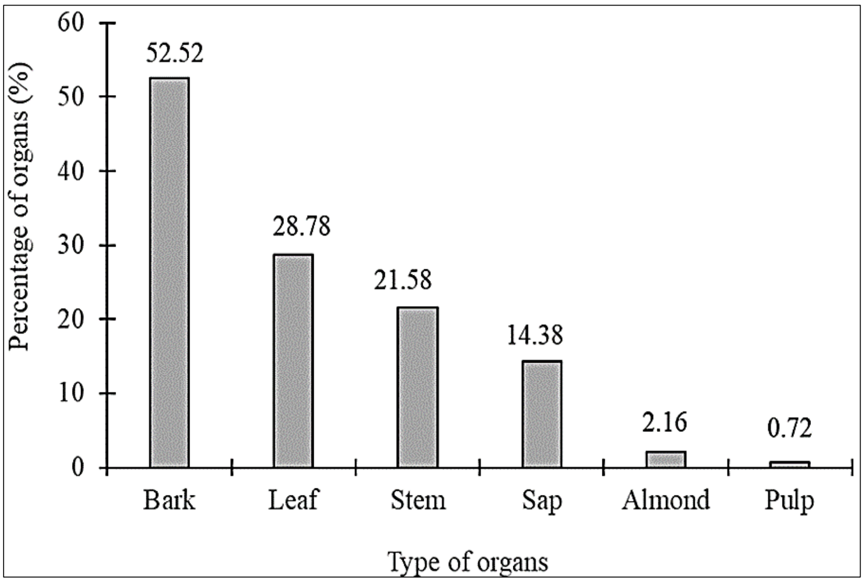

Fig 4: Proportion of plant organs removed by riparians in the classified forest of the Upper Sassandra

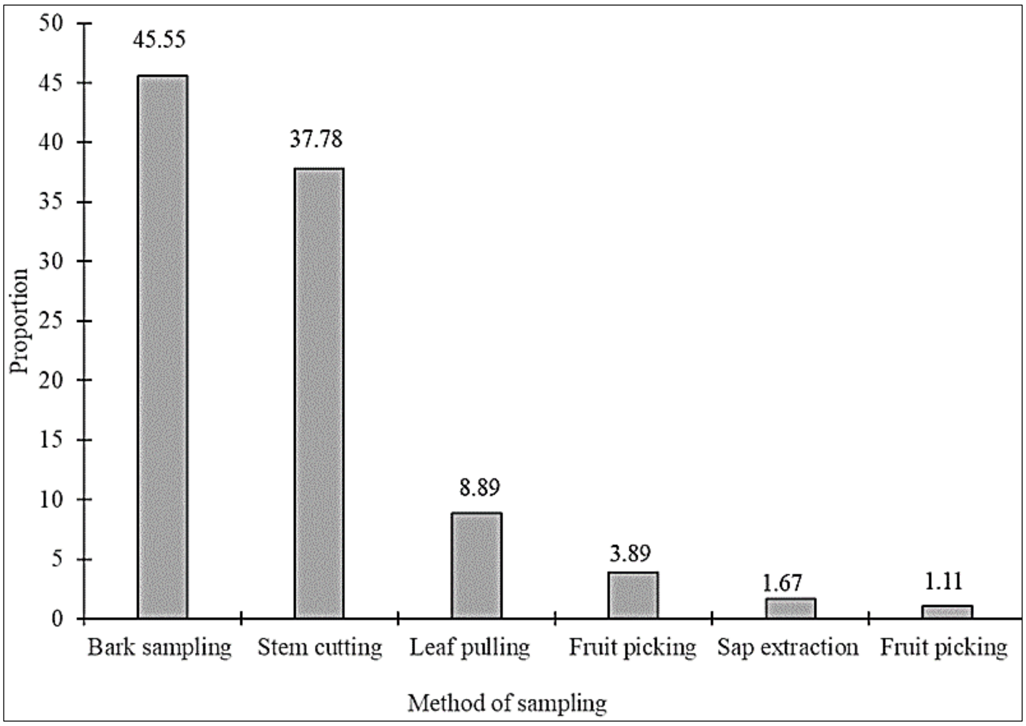

Fig 5: Proportion of the different ways in which NTFP source species are exploited by the riparian population of the classified forest of the Haut-Sassandra

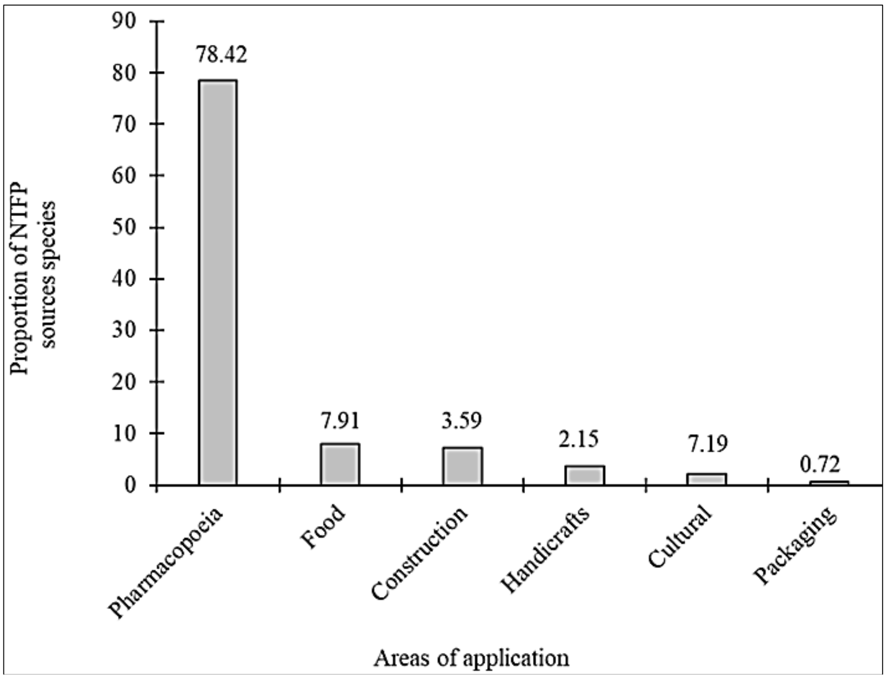

Fig 6: Proportion of NTFP source species by use domain

3.3 Use and significance values of species that are sources of non-timber forest products

According to use values (Table 2), of the first 20 source species of NTFPs identified, *Elaeis guineensis* (Vu = 2.96) is the species whose use is best known or the species most solicited by populations living on the periphery of the FCHS. Other species, namely *Ricinodendron heudelotii* (Vu = 2.88), *Irvingia gabonensis* (Vu = 2.41), *Entandrophragma angolense* (Vu = 2.00), *Milicia excelsa* (Vu = 1.96), *Thaumatococcus daniellii* (Vu = 1.95), *Eremospatha hookeri* (Vu = 1.93), *Neuropeltis acuminata* (Vu = 1.92), etc. are among the useful species identified in the study area. With regard to species importance values, Elaeis guineensis with an importance value of 0.83, which corresponds to five (5) uses out of the six (6) types recorded by the population. It is followed by *Milicia excelsa* with a significance value of 0.67, or four (4) uses, then *Ricinodendron heudelotii*, *Entandrophragma angolense*, *Ceiba pentandra*, *Bambusa vulgaris* which obtained a significance value of 0.5 each.

Table 2: Priority non-timber forest product source species for riparian populations in the classified Upper Sassandra forest

N°	Species	Use value	Value of importance	Number of uses
1	*Elaeis guineensis*	2,96	0,83	med, con, foo, han, cult
2	*Ricinodendron heudelotii*	2,88	0,5	med, foo, con
3	*Irvingia gabonensis*	2,41	0,33	med, foo
4	*Entandrophragma angolense*	2,00	0,50	med, con, han
5	*Milicia excelsa*	1,96	0,67	med, con, han, cult
6	*Thaumatococcus daniellii*	1,95	0,17	pack
7	*Eremospatha hookeri*	1,93	0,33	con, han
8	*Neuropeltis acuminata*	1,92	0,33	con, han
9	*Entandrophragma utile*	1,9	0,33	con, han
10	*Entandrophragma cylindricum*	1,8	0,33	con, han
11	*Calamus deërratus*	1,6	0,33	con, han
12	*Laccosperma secundiflorum*	1,6	0,33	con, han
13	*Alstonia boonei*	1,59	0,33	med, con
14	*Ceiba pentandra*	1,58	0,50	med, con, hand
15	*Bambusa vulgaris*	1,56	0,50	med, con, hand
16	*Olyra latifolia*	1,51	0,33	con, han
17	*Detarium senegalense*	1,48	0,33	con, han
18	*Celtis zenkeri*	1,36	0,33	con, han
19	*Cola nitida*	1,32	0,17	foo
20	*Alchornea cordifolia*	1,21	0,17	med

foo : food, med : medicinal : con : construction ; hand : handmade; pack : packaging ; cult ; cultural

3.4 Availability of NTFP source species

In general, according to interviewees, a decline in forest resources in general, and in phancular in NTFP source species of plant origin, has been observed in recent decades. Indeed, 80.16% of respondents consider that NTFP source species are declining. On the other hand, the opinion is more optimistic among 19.84% of respondents who believe that non-timber resources are still abundant in the study area. However, according to the interviewees, some species such as *Irvingia gabonensis*, *Neuropeltis acuminata*, *Entandrophragma cylindricum*, *Laccosperma secundiflorum*, *Annickia polycarpa*, *Mansonia altissima*,

Garcinia afzelii, *Entandrophragma candoleii* etc. have become rare in their immediate environment due to deforestation (94.12%) and FCHS degradation (3.62%).
Considering the rarity index (Annex), 73 or 53.67% of the NTFP source species cited by the population have a rarity index of more than 80%. Of the latter species, 46 or 33.82 were not observed in FCHS (RI = 100%). These include *Afraegle paniculata*, *Bambusa vulgaris*, *Detarium senegalense*, *Diospyros mespiliformis*, *Garcinia kola*, *Irvingia gabonensis*, *Garcinia afzelii*, *Millettia takou*, *Zanthoxylum Zanthoxyloides*. In addition, 34% or 25% of NTFP source species are common in the FCHS (50% ≤ RI < 80%). Finally, 29 or 21.32% of all NTFP source species are very frequent or very abundant in the FCHS (RI < 50%). Of these, four (4) were counted in all survey plots. There are *Baphia bancoensis*, *Ceiba pentandra*, *Nesogordonia papaverifera*, *Griffonia simplicifolia*.

3.5 Vulnerability of non-timber forest products of plant origin
The calculation of vulnerability parameters identified 45 source species of vulnerable NTFPs (Figure 7). These species constitute 32.37% of all NTFPs used by the FCHS riparian population. Of these species, five (5) have a vulnerability index greater than or equal to 2.5. The latter are therefore the most vulnerable. These are *Irvingia gabonensis*, *Neuropeltis acuminata*, *Laccosperma secundiflorum*, *Entandrophragma utile* and *Entandrophragma angolense*. Ten (10) others with a vulnerability index between 2 and 2.5 are moderately vulnerable. These include *Milicia excelsa*, *Eremospatha hookeri*, *Entandrophragma cylindricum*, *cola nitida*, *Garcinia afzelii* and *Zanthoxylum zanthoxyloides*. Finally, twenty (20) others with a vulnerability index of less than two (2) are low (or low) vulnerable. These are *Mansonia altissima*, *Terminalia ivorensis*, *Christiana africana*, *Diospyros mespiIiformis*, *Nauclea latifolia*, *Piptadeniastrum africanum*, etc.

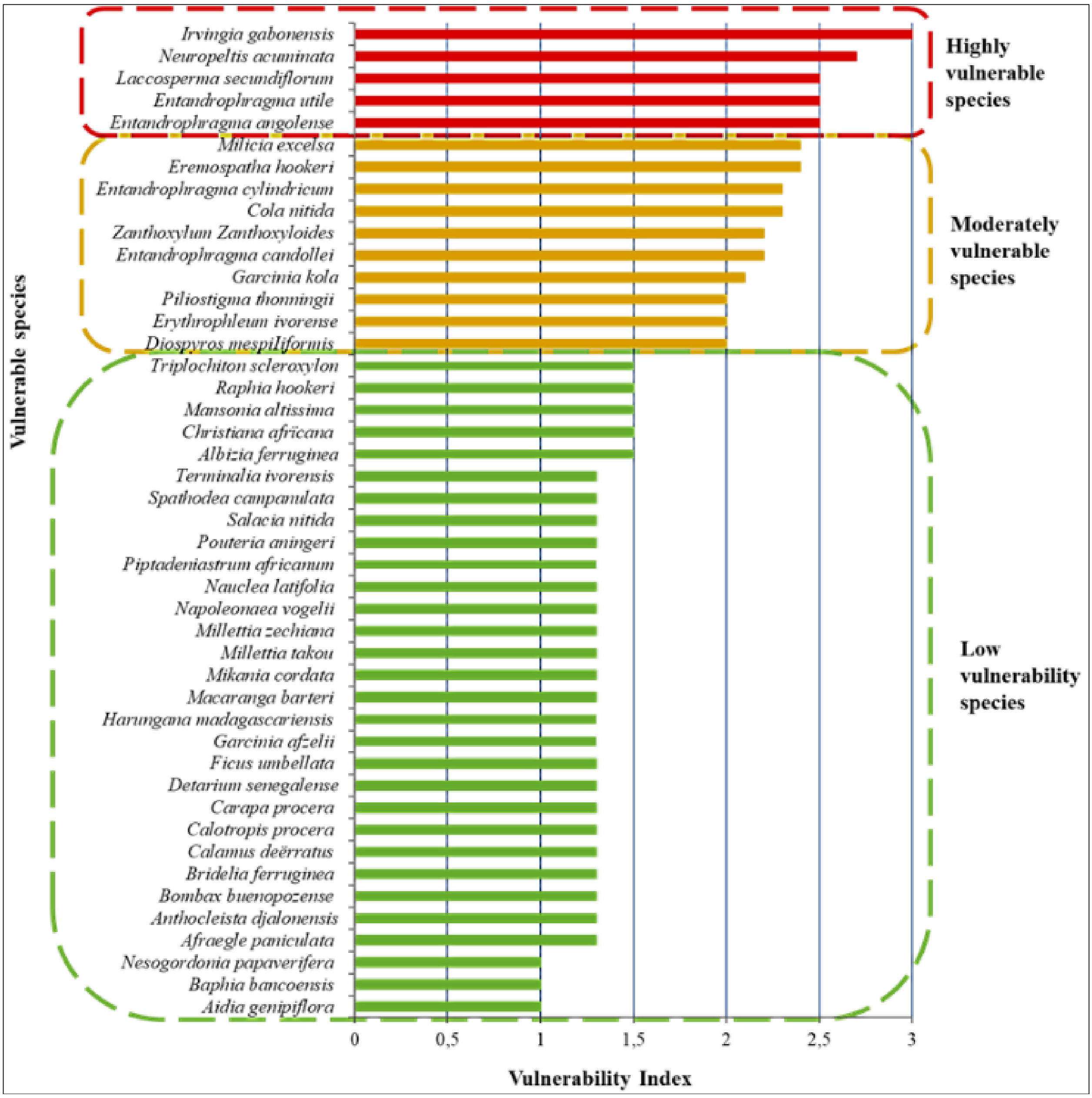

Fig 7: Vulnerability spectrum of species that are sources of non-timber forest products identified in the area of the classified forest of Haut-Sassandra

4. Discussion

4.1Wealth of NTFP source species exploited by FCHS riparian populations

Surveys of 499 people living on the periphery of the FCHS identified 136 source species of NTFPs. En outre, ce travail a permis de recenser plusieurs domaines d'utilisation d'espèces sources de PFNL. These are food, construction, pharmacopoeia, crafts, culture and packaging. These various uses demonstrate the importance of NTFP source species in the daily lives of FCHS riparian populations. Studies, including those of Zirihi (1991) [56]; N'Guessan *et al*., (2009) [38] and Piba *et al*. (2015) [45], conducted on plant species used by rural populations in other localities in Côte d'Ivoire, have reported similar forms of use. However, medicinal species are the most widely used. Depending on the local population, all plants can be used for care. Indeed, medicinal plants are a valuable resource for the majority of rural populations in Africa. According to OMS (2002) [42], more than 80% of people in developing countries, particularly those in tropical forest areas, use medicinal plants for their health. (FAO, 1999; Tchatat and N'Doye, 2006; N'Guessan *et al*., 2009) [42, 50, 38]. This observation is attested by numerous studies in Côte d'Ivoire, including those of N'Guessan *et al*. (2010, 2011) [37, 39], Djah and Danho (2011) [13], Aké-Assi (2012) [3], Piba *et al*. (2015) [45], Dro *et al*. (2013) [17], which have made it possible to inventory over 1500 species of medicinal plants used by the Ivorian population. The preponderance of medicinal plant use can be explained by the distance from health centres or even by the high cost of modern health services. For the rural population, first aid can be provided free of charge with plants in their environment. Indeed, rural populations only use health centres as a last resort, when health conditions do not improve (Goussanou *et al*., 2010) [20]. In contrast, in Cameroon and Equatorial Guinea, the main use of NTFP source species is for food. These food plants are the most exploited and marketed (N'Doye *et al*., 1997; Lescuyer, 2010) [40, 33] in this country. Plant species are exploited preferentially for their bark, stems and leaves. The most sought-after organ of the plant is the bark and the method of sampling is barking. This is due to the fact that most of the species sought by the local population are woody. Indeed, Mpondo *et al*. (2017) [35], woody species are often solicited for their bark or roots. The preference given to woody people is due to their easy access. According to the interviewees, woody people are effective in the treatment of several diseases. The part or organ of the harvested plant varies according to the field of use. Thus, vines, stems, and trunks are generally used for handicrafts and in habitat construction. This finding corroborates the work of Soro e*t al*. (2014) [48], which reported that 80% of plant organs regularly used in crafts and construction are stems or trunks. Fruits, seeds, sap and leaves are mainly used as food. This is evidenced by the work of Doamba (2012) [15] and Soro *et al*. (2014) [48]. These authors have shown that 40% and 75% of the edible plant organs exploited by the residents of Arly Park in Burkina Faso and the classified forest of Port Gauthier in Côte d'Ivoire are fruits, respectively. The exploitation of multiple plant species organs is further evidence of the important role that NTFPs play in the lives of rural African populations. This importance of NTFPs has been highlighted in several studies including Biloso and Lejoly (2006) [10] in the Democratic Republic of Congo, Tchatat and N'Doye (2006) [40] in Cameroon, Priso *et al*. (2011) [46] in Cameroon, Ouédraogo *et al*. (2013) [44] in Burkina Faso, Ambé (2001) [5], Séguéna *et al*. (2013) [47], Piba *et al*. (2015) [45] in Côte d'Ivoire, etc. Crafts and the construction of traditional habitats followed by pharmacopoeia are considered by the local population as the main causes of the decline of source species of NTFPs. Indeed, for these three categories of use, populations fell trees and shrubs to remove leaves, branches, stems and trunks or by mutilation. This finding is confirmed by the work of Soro *et al*. (2014) [48].

4.2 Forest degradation, the main cause of NTFP vulnerability

The perception of the FCHS riparian populations on the state of non-timber resources is consistent with the observations made in the field following the inventory inside the plots. Indeed, more than 50% of the species reported as having become rare by the population are also rare in the FCHS. The source species of NTFPs common in the FCHS have also been reported as abundant by local populations. The abundance of some NTFP source species in FCHS can be explained by the fact that FCHS illegals leave some trees or shrubs for the protection of young plants (cocoa, coffee, etc.) and solar radiation (kouakou *et al*. 2015) [28]. However, many species, including *Abrus precatorius*, *Aerva lanata*, *Ficus umbelatta*, *vernonia amygdalina*, *Spondias mombin*, *Sterculia oblonga*, *Manniophyton fulvum*, etc. have not been mentioned as rare species by the population, although they are very rare in FCHS. This result reflects the interest that local populations can give to a plant species. This observation was made by Hahn-Hadjali and Thiombiano (2000) [23] who reported that populations only refer to or notice species that are useful to them. Species that are not used go unnoticed and may even disappear without their knowledge.

The population is aware of the decline in NTFP source species. The main cause mentioned is deforestation for agricultural activities. In the rural sector, for example, the practice of shifting cultivation on abattis-brûlis has led to the use of large areas and caused land and ecosystem degradation. Indeed, every year, farmers destroy large areas of forest for cocoa cultivation, mainly. During clearing, utilitarian species, whether food, artisanal, fodder, energy or medicinal, are not spared (Traoré *et al*., 2011; Zanh *et al*., 2016; Kouakou *et al*., 2018) [52, 55, 31]. Within the FCHS, the rarity of NTFP source species is due to the various anthropogenic disturbances observed in recent decades. This forest has been infiltrated mainly for cocoa cultivation, thus affecting the availability of source species of NTFPs. These human activities have caused the loss of 40% of plant species in the FCHS, including source species of NTFPs (Zanh *et al*., 2016; Kouakou *et al*., 2017) [55, 32]. This increases the risk of vulnerability of NTFP source species in the study area. Fortunately, in response to the vulnerability of source species of NTFPs, riparian populations have adopted a strategy of substitution of NTFPs through the use of manufactured products. Indeed, the use of products of industrial origin such as baskets, glues, basketry, cooking broths, etc. instead of products directly from forests is becoming more and more frequent in households. However, this change in the habits of riverside populations could lead to a lack of knowledge of the source species of NTFPs by future generations in an urbanized lifestyle.

Table 4: Annex: Exhaustive list of NTFP source species cited by FCHS residents and their use values

N°	Scientific name	Families	Biological types	Chorology	Frequency of use	Use value	Rarity index	Vulnerability Index
1	*Abrus precatorius* Linn.	Fabaceae	Lmp	GC-SZ	10.02	0.6	100	
2	*Adenia lobata* (Jacq.) Engl.	Passifloraceae	Lmp	GC	6.01	0.6	33.33	
3	*Aerva lanata* (Linn.) Juss. ex Schult.	Amaranthaceae	Ch	GC	8.5	0.4	100	
4	*Afraegle paniculata* (Schumach. & Thonn.) Engl.	Rutaceae	mp	GC-SZ	8.02	0.5	100	1.3
5	*Aframomum alboviolaceum* (Ridley) K. Schum.	Zingiberaceae	Gr	SZ	12.02	0.68	100	
6	*Aframomum exscapum* (Sims) Hepper	Zingiberaceae	np	GC	14.03	0.8	100	
7	*Aframomum melegueta* K. Schum.	Zingiberaceae	np	GC	16.03	0.3	100	
8	Ageratum conyzoides Linn.	Asteraceae	Th	GC-SZ	40.08	1.1	33.33	
9	*Aidia genipiflora* (DC.) Dandy	Rubiaceae	mp	GC	2	0.2	27.78	1
10	*Albizia adianthifolia* (Schumach.) W.F. Wright	Mimosaceae	mP	GC	30.06	1	44.44	
11	*Albizia ferruginea* (Guill. & Perr.) Benth.	Mimosaceae	mP	GC-SZ	33.27	1.12	77.78	1.5
12	*Alchornea cordifolia* (Schum. & Thonn.) Müll.Arg.	Euphorbiaceae	Lmp	GC-SZ	41.28	1.2	44.44	
13	*Alstonia boonei* De Wild.	Apocynaceae	MP	GC	48.08	1.59	50	
14	*Anchomanes difformis* (Blume) Engl	Araceae	G	GC	7.01	0.3	94.44	
15	*Anthocleista djalonensis* A. Chev.	Loganiaceae	mp	GC-SZ	4.21	0.33	94.44	1.3
16	*Antiaris toxicaria* var. africana (Engl.) C.C. Berg	Moraceae	mP	GC-SZ	11.22	0.3	27.78	
17	*Aspilia africana* var. ambigua C.D. Adams	Asteraceae	np	GC-SZ	4.61	0.44	100	
18	*Baissea leonensis* Benth.	Apocynaceae	LmP	GC	11.22	0.9	88.89	
19	*Bambusa vulgaris* Schrad. ex J. C. Wendel.	Poaceae	Gr	GC-SZ	43.06	1.56	100	
20	*Baphia bancoensis* Aubrév.	Fabaceae	mp	GCi	9.02	0.7	-	1
21	*Baphia nitida* Lodd.	Fabaceae	mp	GC	7.01	0.46	72.22	
22	*Boerhavia diffusa* Linn.	Nyctaginaceae	Ch	GC-SZ	4.61	0.4	100	
23	*Bombax buenopozense* P. Beauv.	Bombacaceae	MP	GC	9.02	0.9	72.22	1.3
24	*Bridelia ferruginea* Benth.	Euphorbiaceae	mp	GC-SZ	6.81	0.67	100	1.3
25	*Bryophyllum pinnatum* (Lam) Oké	Crassulaceae	np	GC	4.61	0.64	100	
26	*Caesalpinia bonduc* (Linn.) Roxb.	Caesalpiniaceae	Lmp	GC	13.03	0.69	100	
27	*Calamus deërratus* L.	Arecaceae	LmP	GC-SZ	46.24	1.6	100	1.3
28	*Calotropis procera* (Ait.) Ait.f.	Asclepiadaceae	mp	GC-SZ	6.41	0.87	100	1.3
29	*Carapa procera* DC. De Wilde	Meliaceae	mp	GC-SZ	39.48	0.2	94.44	1.3
30	*Cassia occidentalis* Linn.	Caesalpiniaceae	np	GC-SZ	17.43	1	100	
31	*Ceiba pentandra* (Linn.) Gaerth.	Bombacaceae	MP	GC-SZ	45.24	1.58	-	
32	*Celtis zenkeri* EngI.	Ulmaceae	mP	GC	34.21	1.36	11.11	
33	*Christiana afrïcana* DC.	Tiliaceae	mp	GC-SZ	10.82	1.09	61.11	1.5
34	*Chrysophyllum albidum* G.Don	Sapotaceae	mp	GC-SZ	8.62	0.69	100	
35	*Cola nitida* (Vent.) Schott & Endl.	Sterculiaceae	mP	GC	49.7	1.32	94.44	2.3
36	*Combretum molle* R. Br. ex G. Don	Combretaceae	mp	SZ	13.03	0.71	100	
37	*Cordia platythyrsa* Bak.	Boraginaceae	mP	GC	19.64	0.66	83.33	
38	*Cynometra megalophylla* Harms	Caesalpiniaceae	mP	GC	8.62	0.86	88.89	
39	*Deinbollia pinnata* (Poir.) Schumach. & Thonn.	Sapindaceae	np	GC	17.84	0.94	55.56	
40	*Detarium senegalense* J.F. Gmel.	Caesalpiniaceae	mP	GC-SZ	35.07	1.48	100	1.3
41	*Dichapetalum madagascariense* Poir.var.	Dichapetalaceae	mp	GC	32.62	1.21	77.78	
42	*Diospyros mespiIiformis* Hochst. ex A. DC.	Ebenaceae	mp	GC-SZ	25.42	0.82	100	2
43	*Diospyros vignei* F. White	Ebenaceae	np	GCW	39.62	0.97	55.56	
44	*Distemonanthus benthamianus* Baill	Caesalpiniaceae	mP	GC	11.22	0.71	66.67	
45	*Drypetes gilgiana* (Pax) Pax & K. Hoffm.	Euphorbiaceae	mp	GC	17.43	0.91	27.78	

46	*Eclipta prostrata* (Linn.) Linn.	Asteraceae	Th	GC-SZ	13.63	0.78	94.44	
47	*Elaeis guineensis* Jacq.	Arecaceae	mP	GC	94.18	2.96	44.44	
48	*Elytraria marginata* Vahl	Acanthaceae	Ch	GC	10.82	0.2	100	
49	*Entandrophragma angolense* (Welw.) C. DC.	Meliaceae	MP	GC	67.13	2	77.78	2.5
50	*Entandrophragma candollei* Harms	Meliaceae	MP	GC	25.01	0.9	83.33	2.2
51	*Entandrophragma cylindricum* (Sprague)	Meliaceae	MP	GC	50.72	1.8	100	2.3
52	*Entandrophragma utile* (Dawe & Sprague)	Meliaceae	MP	GC	50.13	1.9	11.11	2.5
53	*Eremospatha hookeri* (G. Mann & H. Wendl.)	Arecaceae	Lmp	GC	53.12	1.92	44.44	2.4
54	*Erythrophleum ivorense* A. Chev.	Caesalpiniaceae	mP	GC	21.64	0.2	94.44	2
55	*Euadenia eminens* Hook. f	Capparidaceae	np	GCW	33.22	0.8	100	
56	*Ficus exasperata* Vahl	Moraceae	mp	GC-SZ	13.03	0.07	27.78	
57	*Ficus sur* Forsk.	Moraceae	mp	GC-SZ	11.02	0.1	55.56	
58	*Ficus umbellata* Vahl	Moraceae	mp	GC	17.43	0.15	100	1.3
59	*Funtumia africana* (Benth.) Stapf	Apocynaceae	mP	GC	37.88	0.22	27.78	
60	*Garcinia afzelii* Engl.	Clusiaceae	mp	GC-SZ	39.68	0.79	100	1.3
61	*Garcinia kola* Heckel	Clusiaceae	mP	GC	39.28	0.9	100	2.1
62	*Glyphaea brevis* (Spreng.) Monachino	Tiliaceae	mp	GC	19.84	0.11	66.67	
63	*Griffonia simplicifolia* (Vahl ex DC.) Baill.	Caesalpiniaceae	Lmp	GC	41.08	0.4	-	
64	*Harungana madagascariensis* Lam. ex Poir.	Hypericaceae	mp	GC	37.88	0.62	88.89	1.3
65	*Heliotropium indicum* Linn.	Boraginaceae	Th	GC-SZ	15.23	0.13	94.44	
66	*Holarrhena floribunda* (G. Don) Dur. & S.	Apocynaceae	mP	GC-SZ	17.03	0.22	66.67	
67	*Hoslundia opposita* Vahl	Lamiaceae	np	GC-SZ	13.43	0.11	94.44	
68	*Irvingia gabonensis* (Aubry-Lecomte ex O'Rorke)	Irvingiaceae	MP	GC	58.12	2.41	100	3
69	*Jatropha curcas* Linn.	Euphorbiaceae	np	GC-SZ	39.48	0.09	100	
70	*Kalanchoë crenata* (Andrews) Haw	Crassulaceae	np		11.22	0.04	100	
71	*Kigelia africana* (Lam.) Benth.	Bignoniaceae	mp	GC-SZ	15.03	0.05	94.44	
72	*Laccosperma secundiflorum* (P. Beauv.)	Arecaceae	Lmp	GC	53.11	1.6	83.33	2.5
73	*Lecaniodiscus cupanioides* Planch.	Sapindaceae	mp	GC	11.22	0.06	66.67	
74	*Leea guineensis* G. Don	Leeaceae	mp	GC-SZ	18.04	0.05	94.44	
75	*Macaranga barteri* Müll. Arg.	Euphorbiaceae	mp	GC	17.84	0.07	94.44	1.3
76	*Manniophyton fulvum* Müll. Arg.	Euphorbiaceae	Lmp	GC	31.86	0.62	72.22	
77	*Mansonia altissima* (A. Chev.) A. Chev.	Sterculiaceae	mP	GC	42.88	1.04	16.67	1.5
78	*Marantochloa leucantha* (K. Schum.) M.	Marantaceae	np	GC	7.82	0.04	44.44	
79	*Mareya micrantha* (Benth.) Müll. Arg.	Euphorbiaceae	mp	GC	13.63	0.03	100	
80	*Microglossa pyrifolia* (Lam.) Kuntze	Asteraceae	np	GC	19.44	0.02	100	
81	*Mikania cordata* (Burm.f.) B.L. Robinson	Asteraceae	Lmp	GC	15.63	0.07	100	1.3
82	*Milicia excelsa* (Welw.) Benth.	Moraceae	MP	GC	59.28	1.96	27.78	2.4
83	*Millettia takou* Lorougnon	Fabaceae	mp	GCi	17.89	0.02	100	1.3
84	*Millettia zechiana* Harms	Fabaceae	mp	GC	17.84	0.02	77.78	1.3
85	*Mitragyna ledermannii* (K. Krause) Ridsdale	Rubiaceae	MP	GC	7.5	0.06	100	
86	*Momordica charantia* L.	Cucurbitaceae			11.82	0.05	61.11	
87	*Morinda lucida* Benth.	Rubiaceae	mp	GC-SZ	35.67	0.6	77.78	
88	*Morus mesozygia* Stapf ex A. Chev.	Moraceae	mp	GC	20.64	0.07	72.22	
89	*Motandra guineensis* A. DC.	Apocynaceae	Lmp	GC-SZ	10.2	0.8	11.11	
90	*Myrianthus arboreus* P. Beauv.	Cecropiaceae	mp	GC	13.03	0.09	72.22	
91	*Napoleonaea vogelii* (Hook.f.) Planch.	Napoleonaeaceae	mp	GC	19.64	0.05	50	1.3
92	*Nauclea latifolia* Sm.	Rubiaceae	Lmp (mp)	GC-SZ	34.61	0.76	94.44	1.3
93	*Nesogordonia papaverifera* (A. Chev.) R.	Sterculiaceae	MP	GC	20.24	0.82	-	1

94	*Neuropeltis acuminata* (P. Beauv.) Benth.	Convolvulaceae	LMP	GC	50.9	1.92	50	2.7
95	*Newbouldia laevis* (P. Beauv.) Seemann ex.	Bignoniaceae	mp	GC	37.47	0.8	50	
96	*Ocimum gratissimum* Linn.	Lamiaceae	np	GC	21.24	0.72	100	
97	*Olax subscorpioidea* Oliv.	Olacaceae	mp	GC-SZ	11.02	0.08	100	
98	*Olyra latifolia* Linn.	Poaceae	np	GC	40.68	1.51	55.56	
99	*Palisota hirsuta* (Thunb.) Schum. ex Engl.	Commelinaceae	np	GC	4.21	0.02	77.78	
100	*Parquetina nigrescens* (Afzel.) Bullock	Periplocaceae	Lmp	GC	15.63	0.04	77.78	
101	*Paullinia pinnata* L.	Sapindaceae	Lmp	GC-SZ	21.64	0.31	61.11	
102	*Phoenix reclinata* Jacq.	Arecaceae	mp	GC-SZ	20.54	0.31	100	
103	*Phyllanthus amarus* Schum. & Thonn.	Euphorbiaceae	np	GC	19.64	0.2	100	
104	*Phyllanthus muellerianus* (O. Ktze.) Exell	Euphorbiaceae	Lmp	GC-SZ	15.23	0.2	27.78	
105	*Picralima nitida* (Stapf) T. Durand & H.	Apocynaceae	mp	GC	15.63	0.04	88.89	
106	*Piliostigma thonningii* (Schum.) M.	Caesalpiniaceae	mp	GC-SZ	30.25	0.71	100	2
107	*Piper guineense* Schum. & Thonn.	Piperaceae	Lmp	GC	34.25	0.81	94.44	
108	*Piptadeniastrum africanum* (Hook.f.) B.	Mimosaceae	MP	GC	17.43	0.06	77.78	1.3
109	*Pothomorphe umbellata* (L.) Miq.	Piperaceae	np	GC	17.84	0.02	66.67	
110	*Pouteria aningeri* Baehni	Sapotaceae	MP	GC	19.84	0.09	38.89	1.3
111	*Pycnanthus angolensis* (Welw.) Warb	Myristicaceae	mP	GC	51.64	1.18	55.56	
112	*Raphia hookeri* G. Mann & H. Wendl.	Arecaceae	mp	GC	4.01	0.4	88.89	1.5
113	*Rauvolfia vomitoria* Afzel.	Apocynaceae	mp	GC-SZ	24.25	0.58	38.89	
114	*Ricinodendron heudelotii* (Baill.) Pierre.	Euphorbiaceae	mP	GC	90.77	2.88	22.22	
115	*Salacia nitida* (Benth.) N. E. Br.	Hippocrateaceae	Lmp	GC	8.82	0.05	100	1.3
116	*Salacia owabiensis* Hoyle	Hippocrateaceae	Lmp	GC	11.22	0.04	88.89	
117	*Solanum nigrum* Linn.	Solanaceae	np	GC-SZ	11.02	0.06	100	
118	*Spathodea campanulata* P. Beauv.	Bignoniaceae	mP	GC	6.41	0.44	72.22	1.3
119	*Spondias mombin* Linn.	Anacardiaceae	mp	GC-SZ	26.45	0.61	94.44	
120	*Sterculia oblonga* Mast.	Sterculiaceae	MP	GC	25.05	0.09	94.44	
121	*Sterculia rhinopetala* K. Schum.	Sterculiaceae	MP	GC	2	0.2	44.44	
122	*Sterculia tragacantha* Lindl.	Sterculiaceae	mP	GC-SZ	25.65	0.05	55.56	
123	*Streblus usambarensis* EngI.	Moraceae	np	GC	9.02	0.03	44.44	
124	*Terminalia ivorensis* A. Chev.	Combretaceae	MP	GC	25.85	0.8	88.89	1.3
125	*Terminalia superba* EngI. & Diels	Combretaceae	MP	GC	40.05	0.74	33.33	
126	*Thaumatococcus daniellii* (Benn.) Benth.	Marantaceae	Gr	GC	51.7	1.95	55.56	
127	*Tiliacora dinklagei* Engl.	Mennispermaceae	Lmp	GCW	7.5	0.06	100	
128	*Treculia africana* Decne. subsp. africana var.	Moraceae	mP	GC	4.5	0.06	94.44	
129	Trema guineensis (Schum. & Thonn.) Ficalho	Ulmaceae	mp	GC-SZ	17.84	0.04	11.11	
130	*Triplochiton scleroxylon* K. Schum.	Sterculiaceae	MP	GC	48.7	1.19	50	1.5
131	*Turraea heterophylla* Sm.	Meliaceae	np	GC	39.68	0.8	88.89	
132	*Vernonia amygdalina* Delile	Asteraceae	mp	GC-SZ	20.64	0.03	100	
133	*Vernonia colorata* (Willd.) Drake	Asteraceae	mp	GC-SZ	22.04	0.03	100	
134	*Vernonia conferta* Benth.	Asteraceae	mp	GC	23.05	0.03	100	
135	*Xylopia aethiopica* (Dunal) A. Rich.	Annonaceae	mP	GC-SZ	32.5	1.1	100	
136	*Zanthoxylum Zanthoxyloides* (Lam.) Zepern.	Rutaceae	mp	GC-SZ	37.47	0.78	100	2.2

GC : Taxon of the Guinea-Congolese region; GC-SZ : Taxon of the transition zone between the Guinea-Congolese region and the Sudanese region; GCW : Endemic taxon of the forest block in western Togo, including Ghana, Côte d'Ivoire, Liberia, Sierra Leone, Guinea Bissau, Gambia and Senegal; GCi : Taxon endémique du bloc forestier à la Côte d'Ivoire; mi : microphanerophyte ; na : nanophanerophyte ; me : Mesophanerophyte ; mg : Megaphanerophyte; Lmi : microphanerophyte liana; Lme: Mesophanerophyte liana; th : Therophyte ; Ch : Chamephyte ; geo : Geophyte ; Lm : Megaphanerophyte lian

5. Conclusion

Non-timber forest products (NTFPs) are one of the main sources of food and medicines for people living along the banks of the Haut-Sassandra classified forest (FCHS). Surveys show that FCHS residents regularly use 136 source species of NTFPs in six (6) areas of use. These species are divided into 119 genera, classified into 55 families, the most represented in terms of number of species are Euphorbiaceae with ten (10) species, Asteraceae, Caesalpiniaceae and Moraceae with 8 species each. Medicinal species are the most sought-after and represent 78.42% of all NTFP source species followed by food species and then those used as construction equipment. The source species of NTFPs collected by populations vary from one species to another and according to the use that populations make of them. However, the bark is used more by the local population. According to the perception of local populations, the expansion of agricultural activities has led to a significant reduction in the number of NTFP source species. Thus, 32.37% of the source species of NTFPs cited by the population became vulnerable in the study area. Of these species, five (5) have been reported as highly vulnerable. These are *Irvingia gabonensis*, *Neuropeltis acuminata*, *Laccosperma secundiflorum*, *Entandrophragma angolense*, *Entandrophragma utile*.

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