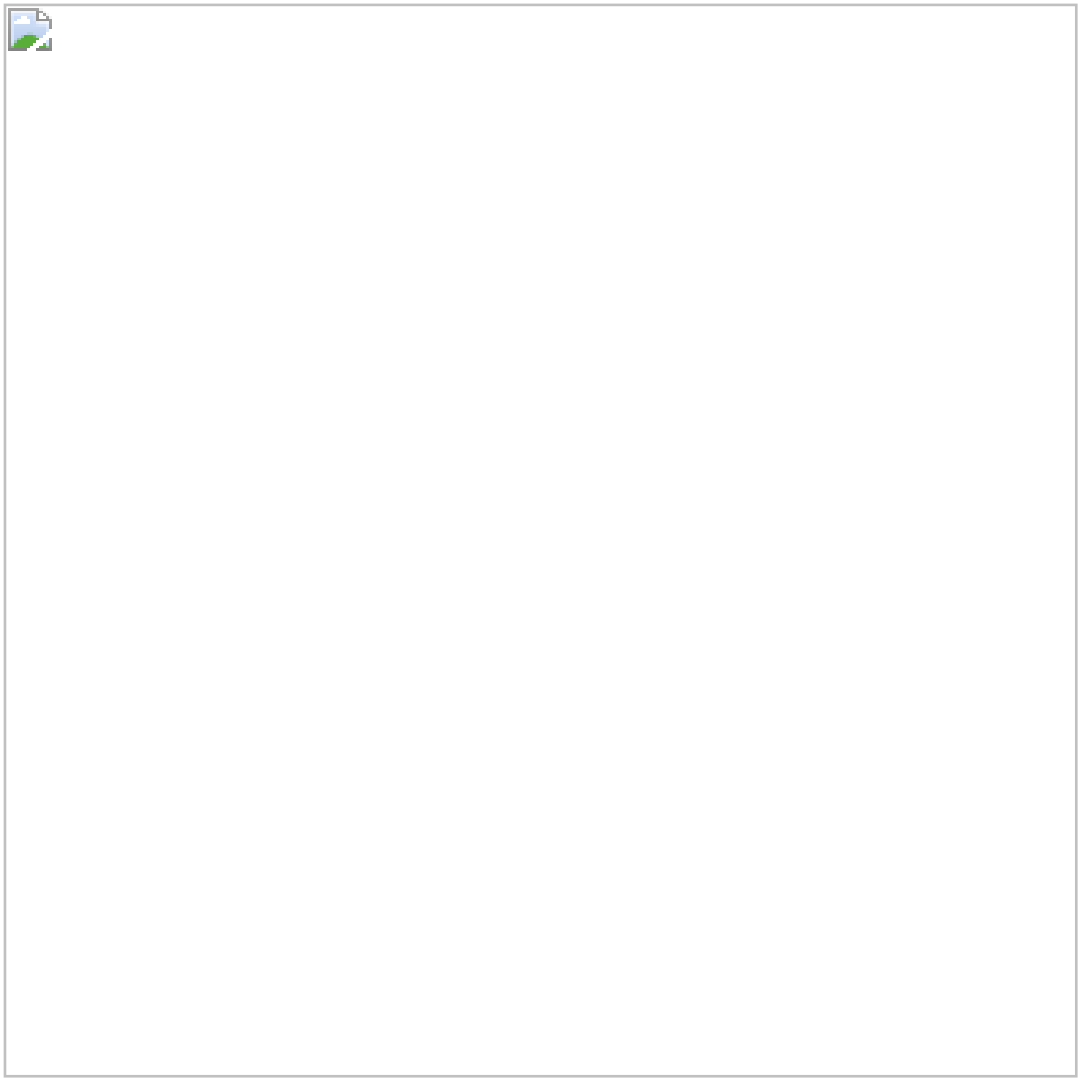

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Knowledge, Local Uses, and Vulnerability of the African Ebony Tree (*Diospyros crassiflora* Hiern, Ebenaceae) Among Communities Around the Campo-Ma'an National Park (Southern Cameroon)

Komo Mbarga Yves[1,2], Froumsia Moksia[1], Aaron Manga Mongombe[1], Malan Djah François[3], Ngotta Biyon Bruno Jacques[4], and Bakwo Fils Éric-Moïse[2]

Abstract

Background: The African ebony tree is a multipurpose tree native to the Guinea-Congolese forest. Its long-term viability and sustainability are threatened by the conversion of primary forest to agricultural land. To conserve the species, it is necessary to evaluate the local community's understanding of its usage and conservation strategies to identify the factors that could potentially influence the species' long-term viability in the study area.

Methods: Data was collected between June and August 2022. The random sampling method was used to administer structured and semi-structured interview questionnaires to 301 villages living within three to nine kilometers of the Campo-Ma'an National Park's boundaries.

Results: Several parts of the plant are used by the locals, notably the wood and bark, with a citation frequency of 49% and 20.4%, respectively. Cutting is the most important collection method, with a relative frequency of citation of 49.1%. These parts are valued in six categories of uses; timber was the most cited (UV = 38.9%), followed by traditional medicine (UV = 36.9%). Wood was the only part of the plant that generated considerable annual income for the local communities (52.537 USD). The vulnerability index showed that the ebony tree is highly vulnerable (IV = 2.5) in the study area.

Conclusion: The results obtained show strong pressure from local populations on *D. crassiflora*, leading to a decrease in the tree population.

Conservation Implications: Given the ongoing threat to *D. crassiflora* in the study area, this research will assist in valorising the species usage in traditional medicine and as a commercial wood. In addition, we have proposed conservation strategies like assisted regeneration and community-led planting projects to promote long-term plantation-based *D. crassiflora* production to mitigate the effects of deforestation.

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Keywords
Ethnobotany, vulnerability index, campo-Ma'an National Park, sustainable conservation strategies

Introduction

Tropical forests offer many benefits, which are grouped under the term "ecosystem services." These forests constitute a vast supply network for human needs. Indeed, humans have been exploiting forest environments for many millennia, either locally for purposes like hunting, non-timber forest products, and fuelwood, or industrially and semi-industrially for purposes like agroforestry and timber exploitation (Pomel and Salomon, 1998; Ernst et al., 2013). These forests also provide cultural services, which form the basis of the cultural, religious, and spiritual identities of the communities living in the forests and the surrounding villages. Furthermore, several authors have reported how some West African communities employ forest products from woody species to meet their everyday needs (Lykke et al., 2004; Sop et al., 2012; Zizka et al., 2015), with almost all tree parts used in ethnomedicine (Fandohan et al., 2008). Beyond their economic and cultural importance, tropical forests play a key role in maintaining the balance of the biosphere through the storage of atmospheric CO_2 in the form of carbon. Indeed, an estimated proportion of 40–50% of terrestrial carbon is stored in tropical forests (Jopaul Loubota et al., 2016). In addition, the tropical forest plays a key role in rainfall patterns in the regulation of local temperatures, as well as in the protection of soils against erosion and the loss of nutrients. (Lhoest et al., 2019).

Sacred forest sites and agroforestry systems have historically protected some tree species, which have long-held cultural and social significance for some African communities (Savadogo et al., 2018). Some of these trees are known to be grown in agricultural farming systems, primarily to supply food demands (Yaméogo et al., 2005). Currently, however, these trees are frequently planted interspersed among field crops to meet the population's needs for fuel, pharmaceuticals, feed, and building materials (Ouôba et al., 2018a). In addition to these uses, agroforestry systems also retain trees to preserve soil fertility (Biaou et al., 2016). Indeed, agroforestry has been demonstrated in numerous studies to be beneficial in preserving and enhancing soil fertility (Yélémou et al., 2013; Ouôba et al., 2018a). Agroforestry does help combat wind and water erosion as well as reduce the need for mineral and organic fertilizers (Yaméogo et al., 2005). Additionally, trees support the preservation of plant diversification and the enhancement of the soil's carbon pool (Yaméogo et al., 2013; Ouôba et al., 2018a).

The African ebony tree is a multipurpose tree that has great socio-economic importance to local communities. It is native to the African evergreen Guineo-Congolian forest, which extends from southern Nigeria through Cameroon to southern Gabon and the Democratic Republic of the Congo (Deblauwe, 2021). The species occupies evergreen forests and islands of evergreen forests inside dry semi-evergreen forests below 1,000 m of altitude (Letouzey, 1985). The African ebony is intensively used in food, medicine, construction wood, and cultural practices (Daanon et al., 2021). The timber produced by this black or streaked wood is used to create a variety of items, including walking sticks, pool cues, doorknobs, tool handles, gun grips, organ stops, piano black keys, guitar fingerboards and bridges, chess pieces, tailpieces, and tuning pegs for all orchestral stringed instruments, including violins, violas, cellos, and double basses. Additionally, the species, leaves, bark, and seeds have been used for a variety of traditional medicinal purposes throughout its range, including the treatment of ovarian problems, healing of wounds, purulent ophthalmia, treatment of abscesses, treatment of labor pain, treatment of stomach aches, as an enema, an aphrodisiac, and the treatment of yaws (Deblauwe, 2021). Furthermore, the antifungal and antibacterial activities of stem bark extracts have been demonstrated (Tangmouo et al., 2006; Dzoyem et al., 2007). However, despite the revealed importance of the species for local communities, knowledge remains low on its different possible uses (variability of uses depending on socio-demographic characteristics, organs harvested, and interactions between the different uses) (Avocèvou-Ayisso et al., 2012).

Cameroon is the largest exporter of African ebony trees, with 1,200 trees harvested each year (IUCN 2019). According to Tangmouo et al. (2006) and Dzoyem et al. (2007), this tree is vulnerable because of the conversion of primary forests into agro-industrial areas, with an estimated population decline of more than 16% over the last 120 years (IUCN 2019). A total population reduction of more than 30% is predicted for the next century (IUCN 2019). Therefore, concerns regarding the long-term viability of harvesting and the preservation of the species have arisen. Indeed, deforestation in the vicinity of the study area is exacerbated by ongoing industrial projects such as the Kribi deep water port project, the Memve'elé hydropower plant project, and various mining exploration projects. In addition, several agro-industries companies are also involved in agro-land conversions. These activities can trigger the progressive disappearance of large mammals such as the forest elephant (*Loxodonta cyclotis*) and the lowland gorilla (*Gorilla gorilla diehli*) that constitute potential seed dispersers of *D. crassiflora* in the study area (Masi et al., 2015). These anthropogenic pressures have caused the loss of 100,000 to 200,000 ha of forest per year, or an annual deforestation rate of 0.3% to 1% in Cameroon (Bikié et al., 2000). These losses pose a problem for the sustainable management and conservation of these species. This is the case of the African ebony tree, also known as *Diospyros crassiflora* Hiern (Ebenaceae), which is classified on the IUCN Red List as a vulnerable species (IUCN, 2019), The aim of this study was five folds to i) identify the parts of the plant used and the collection methods; ii) determine the categories of

use; iii) characterize the recipes of the plant used in the treatment of diseases; iv) determine the annual income from marketed timber; v) assessing the degree of vulnerability of the African ebony tree in the study area. This information will bridge the knowledge gap and help include *D. crassiflora* on the list of priority species for conservation in the study area.

Materials and Methods

Study Area

The Campo-Ma'an National Park is located in the South Region of Cameroon. It covers an area of 264,064 ha. However, with its peripheral zone inclusive it covers an area of 771,668 ha, or 16.33% of the area of the Region, and spans the Ocean division including the Subdivisions of Campo, Niété, and Akom II, the Ntem Valley division including the subdivisions of Ma'an and the Mvila. It is located between latitude 2°10' and 2°45' North and longitude 9°50' and 10°48' East. The climate of the Campo-Ma'an National Park and its peripheral zone is of the coastal equatorial type with four unequal seasons including two dry seasons and two rainy seasons. The vegetation in the area is typical of the equatorial forest, but tertiary, secondary, and primary forests may be found depending on the distance from human habitations.

Sampling Procedure Data Collection

The ethnobotanical surveys were conducted in eight villages located at the periphery of the Campo-Ma'an Park, namely Assok I, Bifa, Minko, Mabiogo, Aloum II, Mvini, Ebianemeyong, and Aloum I (Figure 1). These villages were chosen based on criteria such as the proximity of the park (up to three to nine kilometers), accessibility, the diversity of ethnic groups present, and their activities inside the park. A preliminary study was initially carried out on a random sample of 90 people across all localities. This survey enabled us to determine the proportion of people who know the ethnobotanical uses of Diospyros crassiflora. The sample size of the survey sample was determined according to the formula of Dagnelie (1998):

$$n = \frac{U_1^2 \alpha/2 \times \mathrm{P}(1-p)}{d^2}$$

Where n, is the total number of respondents in this study.

$U_1\text{-}\alpha/2$, is the value of the normal random variable for a probability value $\alpha = 0{,}05$, $U_1\text{-}\alpha/2 = 4$; p: is the proportion of people who know the ethnobotanical uses of *D. crassiflora* (survey results gave p = 95). d is the allowed margin of error. For this study, we took d = 5%. The calculation of our sample size gave n = 304 people. A margin of error of 5% was accepted concerning the 304 individuals surveyed.

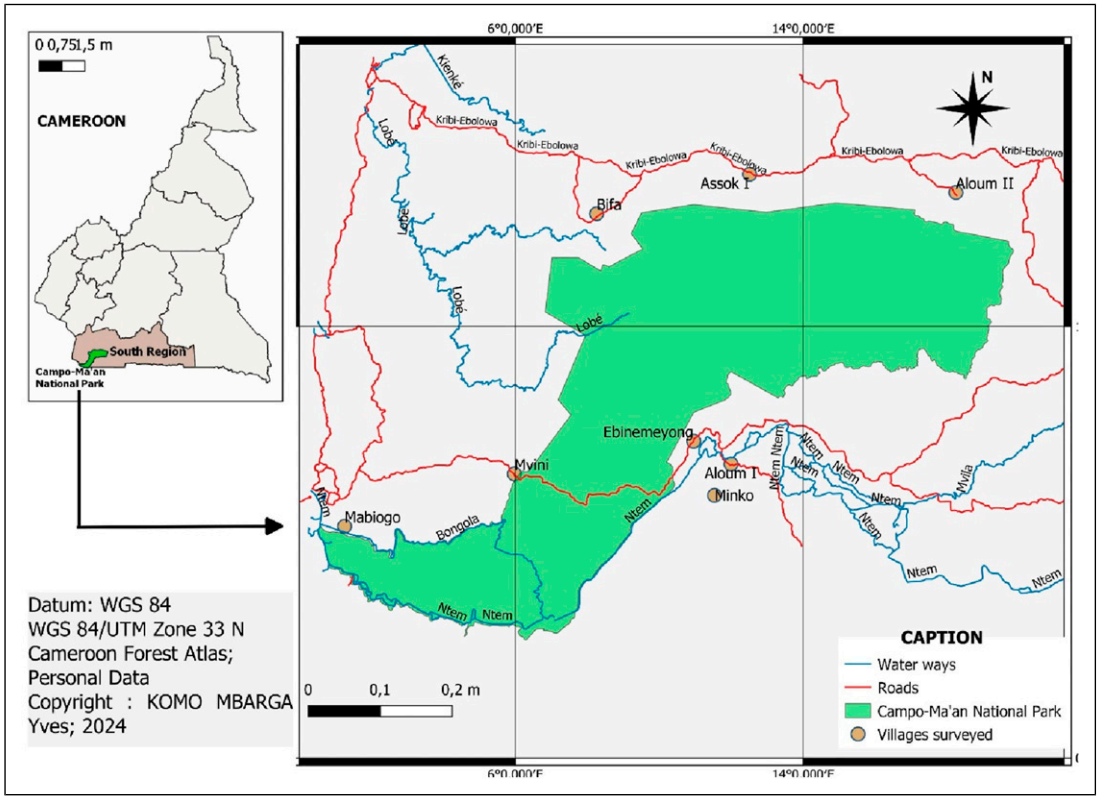

Figure 1. The map of Campo-Ma'an National Park showing the location of surveyed villages.

The data was collected between June and August 2022 using a structured and semi-structured questionnaire that gathered quantitative and qualitative information from 301 interviewees in the villages A local guide translated the questions and answers from French to the local Bulu language. Main data gathered included: (i) age, gender, and sociocultural group; (ii) knowledge of the use categories (energy, pharmacopeia, animal feed, handicrafts, timber, and religious ritual); (iii) organs used and collection techniques; (iv) diseases treated and preparation techniques; and (v) income generated from the sale of the ebony tree.

To determine the socio-economic value of the ebony tree, the following questions were addressed to local populations using a survey sheet:

a) Do you sell ebony wood?
b) Can you quantify the amount of ebony wood traded? If yes, give the quantity in kg of wood sold (male tree, female tree) per month and year;
c) How much does a kg of wood sold cost?
d) How much income do you have per month, per year, from the sale of the ebony wood?

The ebony wood is sold in kg in the village of Campo-Ma'an Park. A kilogram costs 300 FCFA, or approximately 0.49 USD. The quantity of wood marketed and the income generated were determined both within each community studied and internationally.

Data Analysis

The quantitative ethnobotanical data was analyzed using the following indices to determine the degree of vulnerability of the African ebony tree in the study area: Relative frequency of citation (RFC); Importance of the organ use (Fki); Use value (UV); and the Vulnerability Index (VI).

The relative frequency of citations (RFC) was used to show the local importance of the African ebony tree as cited by respondents using the formula Dossou et al. (2012):

$$\mathrm{RFC} = \frac{S}{N} x\, 100,$$

Where S is the number of respondents that reported using the African ebony tree; N is the total number of respondents involved in the surveys.

The response rate (Fki) was used to determine organ importance. It represents the most commonly used organ of the African ebony tree (Todou et al., 2019):

$$\mathrm{Fki} = \frac{Oki}{N} x\, 100$$

Where, Oki: number of respondents who gave a positive answer (YES) for the use of the organ concerned; N: total number of respondents.

The ethnobotanical Use Value (UV) was used to measure the relative relevance of the African ebony tree based on its usage by respondents. The importance of each use category was also calculated (Philips and Gentiz, 1993):

$$\mathrm{UVx} = \frac{\mathrm{Ui}}{\mathrm{N}} x\, 100$$

Where UVx is the use value of African ebony tree in the village X Ui is the number of respondents who mentioned the use of African ebony tree and N is the total number of respondents interviewed in the village. The total use value of the species was obtained by the formula (Todou et al., 2019):

$$\sum \mathrm{UVx}$$

The Vulnerability Index (VI) was calculated from the parameters reported by Betti (2001) and Traoré et al. (2011). For this study, six parameters were considered (Table 1): N1 = frequency of use, N2 = plant organ used, N3 = stage of development, N4 = mode of collection, N5 = morphological type, and N6 = pharmaceutical form.

$$\mathbf{VI} = \frac{\mathbf{N_1} + \mathbf{N_2} + \mathbf{N_3} + \mathbf{N_4} + \mathbf{N_5} + \mathbf{N_6}}{\mathbf{6}}$$

The frequency of use (N1) was obtained with the formula (REF):

Table 1. Codified and quantified parameters to assess vulnerability.

	Quantitative scales		
Parameters	1	2	3
Frequency of use	Weak F.U < 20%	Average 20% ≤ F.U < 60%	High F.U ≥ 60%
Plant organ used	Leaf ; latex	Fruit, branch	Wood, seed, bark, root, flower
Development stage	Old	Adult	Young
Collection method	Pickup	-	Picking, cutting
Morphological type			Tree
Pharmaceutical form	Ash, powder	-	Macerated, decocted, crushed

$$N_1 = \frac{npij}{ntpe} * 100$$

Where npij = the number of people who mentioned the species in a village i in use j and ntpe = a total number of people. The species is said to be weakly vulnerable if VI < 2, it is said to be moderately vulnerable if 2 ≤ VI < 2.5, and very vulnerable if VI ≥ 2.5.

Results

Respondents Traits

The respondents interviewed were divided into 190 men (63.1%) and 111 women (36.9%). The majority of responders (29.6%) were between the ages of 31 and 41. The village Mvini recorded the highest proportion of informants with 49 respondents (16.3%). It was followed by Mabiogo with 45 respondents (14.9 %), and Aloum II with 41 respondents (13.62 %). Of the respondents surveyed, 134 (44.5%) were college students, and just 8 (2.6%), had completed higher education. Additionally, 189 (62.8) of the respondents were married (Table 2).

Parts of the Plant Used

A total of five organs have been cited by the respondents: wood, bark, leaves, fruits, seeds, and roots. The RFC of the different organs ranges from 49% to 1.5%. The highest RFC was observed for wood (49%), followed by roots (14.3%), and the lowest RFC was recorded for fruits (1.5%), followed by leaves (4.5). Wood is the most commonly used organ in the village of Aloum 1, with an RFC of 64.3%; bark is the most commonly used organ in Bifi, with an RFC of 30.8%; leaves are the most commonly used organ in Aloum 1, with an RFC of 17.8%; fruits in Mvini, with an RFC of 6.7%; and seeds and roots in Minko and Mabiongo, with RFCs of 22.2% and 23.1%, respectively (Table 3). Mvini and Assok I villages represent the only localities where all the organs mentioned by the respondents are used. Also, Mvini village represents the locality where the species is most used with a relative frequency of mention (RFC = 16.9 %).

Table 2. Socio-demographic characteristics of survey participants in villages in the vicinity of the Campo-Ma'an National Park (Southern Cameroon).

	Categories	Total number of participants	Percentage (%)
Gender	M	190	63.1
	F	111	36.9
Age	20-30	68	22.6
	31-41	89	29.6
	42-52	78	25.9
	53-63	52	17.3
	64-75	14	4.6
Marital status	Single	106	35.2
	Married	189	62.8
	Divorced	6	1.9
Education	Primary	89	29.6
	College	134	44.5
	High school	70	23.2
	University	8	2.6
Locality	Assok I	33	10.9
	Aloum I	32	10.63
	Aloum II	41	13.62
	Bifa	30	9.9
	Ebinemeyong	40	13.3
	Mabiogo	45	14.9
	Minko	31	10.3
	Mvini	49	16.3

Organ Collection Techniques of Diospyros Crassiflora

There are six organ harvesting techniques used by the local populations of the Campo Ma'an National Park notably cutting, digging, picking, debarking, and collecting. Our findings also revealed that the techniques of cutting and debarking were the most used, with a relative frequency of citation of FRC = 49.1% and FRC = 20.4%, respectively (Figure 2).

Use Categories of Diospyros crassiflora

Six use categories were mentioned by the population namely animal feed, handicraft, timber, energy, religious ritual, and traditional medicine. The UV ranged between 6.8% and 34.3%. *D. crassiflora* was most frequently used as timber in the study area according to its high UV (34.3%), followed by traditional medicine (31%). The least UVs were reported for animal feed (6.4%), followed by ritual (6.8%). Also, the species was used for timber, handicrafts, energy, and traditional medicine in all villages surveyed. Mvini and Mabiongo had the highest use reports of *D. crassiflora*, as demonstrated by their highest total UV (Table 4).

Table 3. Relative frequency of citation of *Diospyros crassiflora* organs used by villages.

		Organs					
Villages	Wood	Bark	Leaves	Fruits	Seeds	Roots	Total
Assok I	41.4	20.7	6.9	3.4	17.2	10.3	10.9
Bifa	38.5	30.8	11.5	-	-	19.2	9.8
Aloum I	64.3	-	17.8	-	17.8	-	10.6
Mabiogo	51.3	25.6	-	-	-	23.1	14.7
Aloum II	41.7	27.8	-	-	16.7	13.9	13.6
Mvini	40	22.2	4.4	6.7	11.1	15.5	16.9
Ebinemeyong	57.1	28.6	-	-	-	14.3	13.2
Minko	62.9	-	-	-	22.2	14.8	10.2
TOTAL	49	20.4	4.5	1.5	10.2	14.3	100

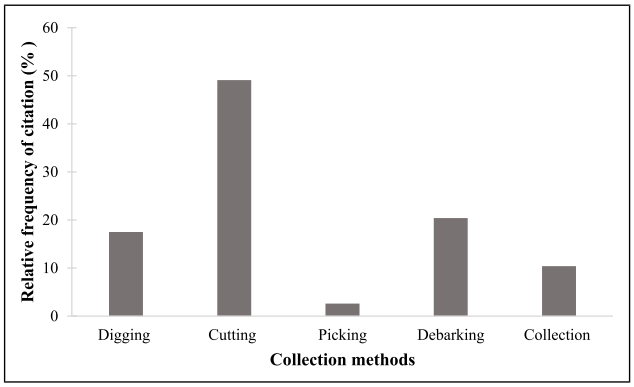

Figure 2. Proportion of organ collection methods.

Table 4. Ethnobotanical use and the value of each use category of *Diospyros crassiflora* by village in the vicinity Campo-Ma'an National Park (Southern Cameroon).

	Use category					
Villages	Af	Cr Ti	En	Tm	Ri	TUV
Assok I	20.7	7.9 34.5	6.9	30	-	10.9
Bifa	-	4.6 30	3.8	30.8	30.8	9.8
Aloum I	-	5 42.8	21.4	30.7	-	10.6
Mabiogo	-	18.7 38.5	12.8	30	-	14.7
Aloum II	16.7	3.3 25	16.7	30	8.3	13.6
Mvini	11.1	15 25	4.4	37.8	6.7	16.9
Ebinemeyog	-	20 328	14.3	32.8	-	13.2
Minko	-	10 45.5	7.4	22.2	14.8	10.2
Total	6.4	10.6 34.3	10.9	31	6.8	100

Af = Animal feed; Cr = Handicrafts; Ti = Timber; En = Energy; Tm = Traditional medicine; Ri = Ritual; TUV= Total use value.

Socio-Economic Importance of Exploited Products

Wood was the only traded organ. In Cameroon, logging companies are granted a special permit by the Ministry of Forests and Wildlife annually to extract ebony trees. Ebony wood is sold in kilograms, and the primary beneficiaries are sculptors and forestry corporations (Figure 3). Each year, 105,600 kg (105.6 tons) of ebony is sold from the Campo Ma'an National Park's periphery (Table 5). According to the statistics gathered for this study (Table 5), the ebony wood business generates an average of 52,537 USD each year. The tree is most heavily exploited in the community of Aloum I, where 11,852 USD is earned annually from an estimated 27,157 kg of the tree. The survey's findings showed that *D. crassiflora* trees with smaller diameters are the most valued in the market. The ebony plant is dioecious, and the wood of the female tree is the most valuable. Female plants account for 85.5 tonnes of the 105.6 tons of wood extracted, or 80.96% (Table 6).

Medicinal Importance of Diospyros Crassiflora

According to our findings, four organs, namely the bark, leaves, seed, and root, as well as four preparation methods, including decoction, maceration, powder, and trituration, were used to cure seven distinct diseases. (Table 7). Local inhabitants identified gastric pain and ophthalmia as the most common diseases treated by ebony tree remedies, with a frequency of mention of 36.7% and 18.4%, respectively (Figure 4). The bark decoction and seed powder are used to relieve stomach pain. While the trituration of the leaves is used to treat ophthalmia. The bark represents the most used part in the treatment of diseases, with a frequency of citation of 55.1%, followed by the root with a 22.4% frequency of citation. The leaf represents the least used organ in the treatment of diseases with a frequency of mention of 10.2% (Figure 5). Decoction and powder are the main techniques of medicine preparation stated by the local population, with citation frequencies of 40.8% and 28.6%, respectively (Figure 6). With a frequency of mention of 10.2%, trituration is the least frequent method of remedy preparation.

Vulnerability of Diospyros Crassiflora

The vulnerability index (IV) indicated that *D. crassiflora* was both extremely vulnerable (IV > 2.5) and moderately vulnerable (2 < IV < 2.5) in the study area. In the villages of Assok I, Bifa, Ebinemeyong, and Mvini, the vulnerability index was (IV = 2.5) (Table 8). With an index of IV = 2, the Aloum I village has the lowest pressure on ebony trees from the inhabitants surrounding the protected area. The vulnerability index for the research area as a whole was high (IV = 2.5).

Discussion

Socio-demographic Profile of Survey Participants

The vast majority of survey respondents in this study (62.5%) were men. This finding supports the findings of (Nga et al., 2016) on the usage of medicinal herbs in Ndom, Ngambé, and Pouma (Cameroon), where men made up the majority of survey participants. This observation may be attributed to women's incapacity to get to the forest to harvest plant organs. On the other hand, the study differs from that of Ladoh-Yemeda et al. (2016) on medicinal plant use in Douala (Cameroon), where women made up 68.5% of the surveyed participants. This disparity could be attributed to the fact that Ladoh-Yemeda et al. (2016) conducted their surveys in markets where women make up the majority of the petite traders. Furthermore, the sale and use of herbal medicinal plants by mostly women could be attributed to illiteracy (Dansou et al., 2014; Agbankpé, 2015).

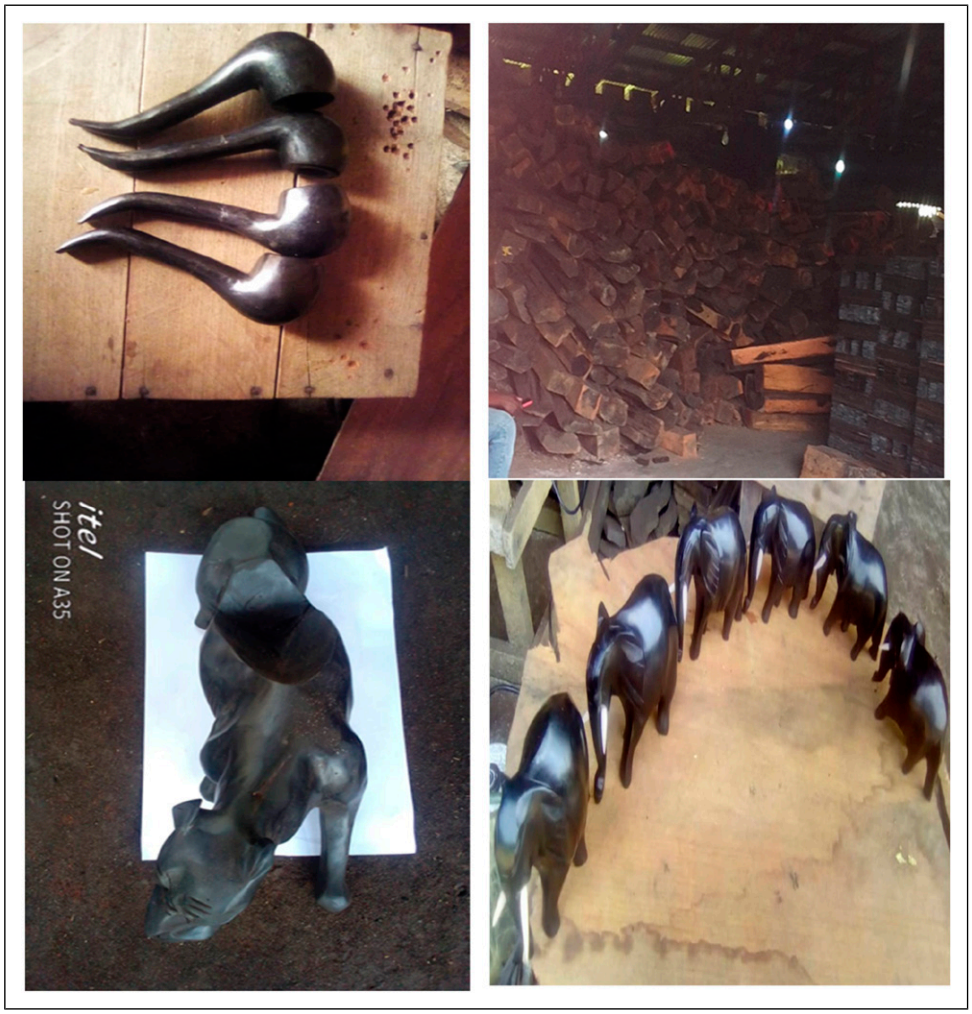

Figure 3. Photographs of various wooden sculptures made of ebony.

Table 5. Annual income generated from timber marketing of *Diospyros crassiflora* in villages in the vicinity of the Campo-Ma'an National Park (Southern Cameroon).

Villages	Unit of measure	Unit price (F CFA)	Quantity harvested	Annual income (F FCA)
Assok I	Kg	300	16, 800 Kg (16.8 t)	5, 040, 000
Aloum I	Kg	300	27, 157 Kg (27.157 t)	8, 147, 100
Aloum II	Kg	300	14, 567 Kg (14.567 t)	4, 370, 100
Bifa	Kg	300	10, 765 Kg (10.765 t)	3, 229, 500
Ebinemeyong	Kg	300	12, 868 Kg (12.868 t)	3, 860, 400
Maabiogo	Kg	300	4, 632 Kg (4.632 t)	1, 389, 600
Minko	Kg	300	7, 325 Kg (7.325 t)	2, 197, 500
Mvini	Kg	300	11, 486 Kg (11.486 t)	3, 445, 800
Total	-	-	105, 600 Kg (105.6 t)	31, 680, 000

Importance of Ebony Tree Products

Ebony tree exploitation by communities in the peripheral zone of Campo-Ma'an National Park is a significant source of income for the community. Similar findings were supported by Mapongmetsem et al. (2012), who indicated that the products of plant origin are exploited to provide a considerable source of revenue to ensure the well-being of rural communities. Our research revealed that the ebony tree was exploited for its wood, leaves, fruits, seeds, and roots. Our

Table 6. Quantity of ebony wood marketed in the peripheral areas of Campo-Ma'an national park.

Villages	Aloum I	Aloum II	Assok I	Bifa	Ebinemeyong	Mabiogo	Minko	Mvini	Total
Male feet	6,5 t	2,4 t	2,7 t	1,3 t	3,1 t	0,8 t	1,1 t	2.2 t	20.1 t
Female feet	20.6 t	12,2 t	14,1 t	9,5 t	9,8 t	3,8 t	6, 2 t	9.3 t	85.5 t
Total	27.1 t	14.6 t	16.8 t	10.8 t	12.9 t	4.6 t	7.3 t	11.5 t	105. 6 t

Table 7. Use of *Diospyros crassiflora* in the treatment of diseases in villages at the periphery of the Campo-Ma'an National Park (Southern Cameroon).

Diseases	Organ used	Modes of preparation	Methods of administration, dosage, duration of treatment
Gastric pain	Bark and seed	Maceration in 1 L of water for 2 hours	Drink 1/2 glass morning and evening per day until the maceration is finished
Ophthalmia	Leaf	Crush the leaves in ¼ L of water then filter	3 drops in the injured eye until healed
Cough	Bark	Dry in the shade, then crush	Take 2 pinches morning and evening per day until healing
Wound	Bark and leaf	Dry in the shade, then crush, crush the leaves in ¼ L of water then filter	Apply 2 pinches morning and evening on the diseased part, pour 6 drops on the diseased part until healed
Ovarian problems	Bark	Decoction in 2 L of water for 1 hour	Drink 1 glass morning and evening per day until the decoction is finished.
Syphilis	Bark and root	Decoction in 2 L of water for 1 hour	Drink 1/2 glass morning, noon and evening per day until the decoction is finished.
Tuberculosis	Bark	Decoction in 1 L of water for 1 hour	Drink 1 glass morning and evening per day until the decoction is finished.

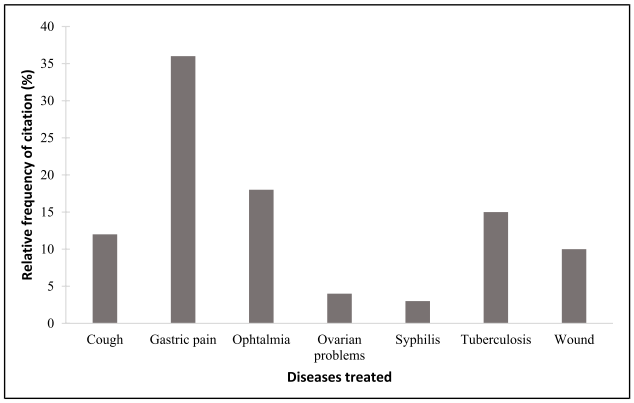

Figure 4. Proportion of diseases treated by *Diospyros crassiflora*.

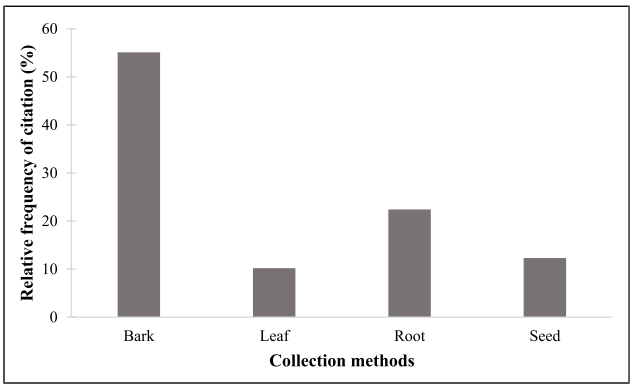

Figure 5. Relative Frequency of citation of organs used in the treatment of diseases.

findings concur with those of Ali et al. (2021) on *Diospyros mespiliformis* in Niger, which demonstrated that wood, leaves, flowers, fruits, seeds, and roots were the major organs exploited by the community. Our results also revealed that the wood and the bark were the organs mostly exploited by the population. Similar results were obtained by Lougbegnon et al. (2011) in the Sitatunga Valley swamp forest reserve in Zinvié, Benin. The extraction of wood can impede sustainable ebony tree management because the harvesting of the wood, as well as the roots and barks, can affect the plant species more than the harvesting of the leaves (Zheng and Xing, 2009; Koudouvo et al., 2011). National Park is a significant source of income for the community.

Methods of Harvesting Ebony Tree Parts

Cutting and debarking are the techniques mostly used by the local populations for harvesting ebony tree products. The use of these techniques can be a hindrance to the sustainable management of ebony trees because the harvesting of wood and debarking can lead to the cutting down of individual trees. It is therefore important to sensitize the populations to sustainable techniques of harvesting the organs of the plant

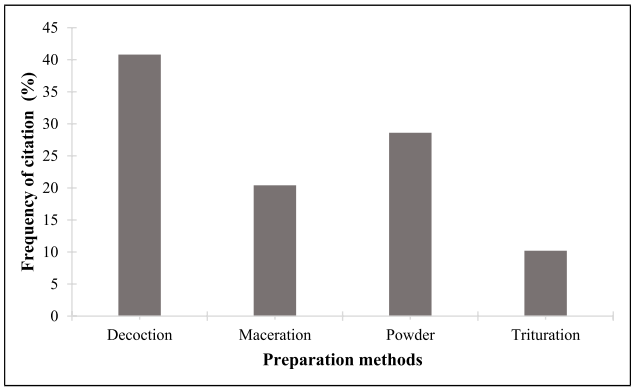

Figure 6. Proportion of preparation methods used in the treatment of diseases.

Table 8. Vulnerability status of *D. crassiflora* in each village situated at the periphery of the Campo-Ma'an National Park (Southern Cameroon).

	Settings							
Villages	A	B	C	D	E	F	IV	Status
Assok I	I	3	2	3	3	3	2.5	Highly vulnerable
Bifa	I	3	2	3	3	3	2.5	Highly vulnerable
Aloum I	I	3	I	3	3	I	2	Moderately vulnerable
Mabiogo	I	3	I	3	3	3	2.3	Moderately vulnerable
Aloum II	I	3	I	3	3	3	2.3	Moderately vulnerable
Mvini	I	3	2	3	3	3	2.5	Highly vulnerable
Ebinemeyong	I	3	2	3	3	3	2.5	Highly vulnerable
Minko	I	3	I	3	3	3	2.3	Moderately vulnerable
Total	I	3	2	3	3	3	2.5	Highly vulnerable

A= Frequency of use; B= Plant organ used; C= Stage of development; D= Mode of the collection; E= Morphological type; F= Pharmaceutical form; IV= Index of Vulnerability.

and to apply the forest policy, whose aim is to ensure the sustainable exploitation of the ebony tree. A technique for harvesting the bark, such as small areas of the bark of irregular size, taken from different places along and around the stem, or the tree can also be partially debarked on one side only, as described by Guedje (2002), should be recommended to local inhabitants. The ebony tree's products are utilized in a variety of applications, including animal feed, lumber, and traditional medicine, demonstrating the species' importance to local populations and, as a result, explaining the species' high demand. Timber and traditional medicine were the most important use categories in the study area. This result is similar to that obtained in Benin by Daanon et al. (2021), which showed that *Diospyros mespiliformis* is mostly used in traditional medicine by local populations. The use of the species in various categories of uses and the use of several parts of the plants can strongly contribute to the overexploitation and vulnerability of this species. The villages Mvini, Aloum II, Bifa, Minko, and Assok I represent the localities where the species is overexploited because almost all of its organs are used in four to five categories of use by the local populations living there. The establishment of sustainable management strategies is essential for the survival of this species in these localities. The vulnerability index of ebony is (Iv = 2.3) in the study area similar to the results obtained by (Todou et al., 2023) on *D. crassiflora* (IV = 2) in Nyé'été forest, South Region of Cameroon.

Use Categories and Vulnerability of D. crassiflora

Diospyros crassiflora products are grouped into several use categories namely animal feed, timber, handicraft, energy, ritual, and ethno-medicine. This illustrates how important the species is locally and helps to explain why it is under so much pressure. The importance given to a species does not depend on its availability, but on its ability to meet the needs of populations in the different use categories (Camou-Guerrero et al., 2008; Dossou et al., 2012). Timber (UV = 38.9%) and traditional medicine (UV = 36.9%) are the most important use categories in the study area. This result is similar to that obtained in Niger by Ali et al. (2021), which showed that *Diospyros mespiliformis* is mostly used in traditional medicine by local populations. Wood is the only organ that generates important revenue for the community. Lumbering is done throughout the year with low intensity during the rainy seasons (September-November and April-May) due to poor road conditions. This study also found that pistillate plants, or female *D. crassiflora* trees with a smaller diameter, are more in demand in the market due to their superior black color (darker color) than staminate plants, or male trees. This situation could jeopardize the species' natural regeneration because, as a dioecious plant pollination requires the assistance of both a male and female tree. In addition, we estimate that 105,600 kg (105.6 t) of ebony wood is extracted annually. These findings differ from those of other forest products, such as *Gnetum spp*. Leaf exploitation in the forested zone of southern Cameroon, was estimated to be 488.57 tons by Mbolo et al. (2002), and Souare et al. (2020), who quantified 172.96 tons of products from the exploitation of *Xylopia aethiopica* in the peripheral areas of Mbam and Djerem National Park. The income from using wood is 52,537 USD. The commercialization of wood allows poor peasants to have at least one product that can increase their annual income. According to Jiofack et al. (2010) and Mvondo et al. (2012), 80% of the African population uses medicinal plants as the first step in healthcare due to the abundance of plant resources, low standard of living, and high cost of conventional drugs. People use ebony to treat a variety of disorders, including stomach ailments, ophthalmia, coughs, wounds, ovarian problems, syphilis, and tuberculosis. Obtained similar results on the fruit of *D. mespiliformis*, demonstrating that the fruit oil would help reduce dysfunction of the cardiovascular, renal, reproductive, gastrointestinal, and immunological systems.

Conservation Implications and Recommendations

The development of both in-situ and ex-situ conservation strategies and management plans for a plant species depends on knowledge about its economic and local uses. This is particularly true for species like *D. crassiflora*, which are threatened by the conversion of primary forests to agricultural and urban areas and the deliberate elimination of traditional seed dispersal agents as a result of the bushmeat trade. Data collection on local communities' knowledge of a tree species is also particularly significant since it can help identify the true socio-economic value of the species, leading to more reasonable and informed decisions by both the local communities and authorities in charge of wildlife conservation about the species' sustainable exploitation. For example, the multipurpose socio-economic value of the ebony tree can be the driving force behind its ex-situ and in-situ conservation. The setting up of nurseries by villagers can help in community-driven planting initiatives to promote sustainable plantation-based production of *D. crassiflora*, which is currently absent in the study area. This can promote a large-scale restoration effort for the species in areas where it is threatened by deforestation. It can help alleviate the existing harvest pressures on the wild populations of this plant species. Our findings offer insights into the local economic and cultural use of this species in the villages of Assok I, Bifa, Minko, Mabiogo, Aloum II, Mvini, Ebinemeyong, and Aloum I located in the vicinity of Campo Maan National Park, one of the species strongholds in the Congo Basin forest, to raise awareness of the species vulnerability to potential local extinction and to further valorize and protect it.

The current study, conducted in the villages around Campo-Ma'an Park, has allowed us to contribute to the long-term management of *D. crassiflora*. The results demonstrate that all parts of the species are used in a variety of applications. Wood is the most sought-after plant component among the locals, and cutting is the most popular collection method among the local community. *D. crassiflora* was most frequently exploited for its timber. Wood was the plant component that delivered the highest economic earnings. The survival of this species requires the appreciation of ethnobotanical information about this plant, education of the local population about the sustainable use of the species, and the development of policies for community-based management and protection of this species in particular and the tropical forests in general. Indeed, we recommend that the current forest exploitation law in Cameroon be strictly enforced. Furthermore, villagers and forest exploiters in the research region should be offered additional training on sustainable harvesting techniques, which should be rigorously supervised by local authorities in charge of wildlife protection to ensure their implementation. This training can be delivered through seminar workshops conducted by the Cameroon Ministry of Forestry and Wildlife, which will include all stakeholders involved in the forestry sector. This will help to eliminate illegal harvesting and unsustainable harvesting practices.

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Authors' Contributions

Komo Mbarga Yves, Froumsia Moksia, and Bakwo Fils Eric Moise collected the data, performed the experimental work, and wrote the first draft while Aaron Manga Mongombe, Malan Djah François and Ngotta Biyon Bruno Jacques read and corrected the manuscript.

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References

Agbankpé, A. J., Bankolé, S. H., Assogba, F., Dougnon T. V., Yèhouénou, B., Gbénou, J., and Baba-Moussa L. (2015). Phytochemical Screening and Cytotoxic Analysis of Three Local Vegetables Used in the Treatment of Bacterial Diarrhoea in Southern Benin (West Africa): A Comparative Study. *BBJ*, *9(4):* 1–13.

Ali, A., Manirou, O., Soumaila, M., Ali, M., Mahamane, S. (2021). Perception paysanne de l'utilisation de *Diospyros mespiliformis* Hochst. ex A. Rich Au Niger. *Journal of Applied Biosciences*, 16460–16474.

Avocèvou, A.C., Avohou, T.H., Oumorou, M., Dossou, G., & Sinsin, B. (2012). Ethnobotany of Pentadesma butyracea in Benin: A quantitative approach. *Ethnobotany Research and Applications*, *10*:151-166.

Betti, J.L. (2001). *Usages traditionnels et vulnérabilité des plantes médicinales dans la réesrve du Dja et dans les marchés de Yaoundé, Cameroun*. Thèse de Doctorat, Université Libre de Bruxelles, Bruxelles, 229 p.

Biaou, S.S.H., Natta, A.K., Dicko, A., & Kouagou, M. (2016). Typologie des systèmes agroforestiers et leurs impacts sur la satisfaction des besoins des populations. *Bulletin de la recherché agronomique du Bénin* 43-56.

Bikié, H., Ndoye, O., et Sunderlin, W.D. (2000). L'impact de la crise économique sur les systèmes agricoles et le changement du

couvert forestier dans la zone forestière humide du Cameroun. Yaoundé : *Center for international Forestry Research*, 1–40.

Camou-Guerrero, A., Reyes-García, V., Martínez-Ramos, M., & et Casas, A. (2008). Knowledge and use value of plant species in a Rarámuri community: a gender perspective for conservation. *Hum Ecol*. *36*: pp259-272.

Daanon, A., Padonou, E.A., Akakpo, B.A., & Houinato, M. (2021). Variabilité des utilisations de Diospyros mespiliformis Hochst suivant les facteurs sociodémographiques au Nord-Benin. *Bois et Forêts des Tropiques*, *347*: 29-40.

Dagnelie, P. (1998). Interférence statistique à une et à deux dimensions, *Statistique théorique et appliquée*. Volume, *2*, De Boeck, 664 p.

Danssou, H.G., Ogni, C.A., Yédomonhan, H., Adomou, A.C., Tossou, M., Dougnon, J.T., & Akoègninou, A. (2014). Diversité, usages vétérinaires et vulnérabilité des plantes médicinales au Nord-Bénin. *Int. J. Biol. Chem. Sci*, *8*(1): 189-210.

Deblauwe, V. (2021). "Life history, uses, trade and management of Diospyros crassiflora Hiern, the ebony tree of the Central African forests: A state of knowledge". *Forest Ecology and Management*. *481*: 118655. https://doi.org/10.1016/j.foreco.2020.118655

Dossou, M.E., Houessou, G.L., Lougbégnon, O.T., Tenté, A.H.B., & Codjia, J.T.C. (2012). Etude ethnobotanique des ressources forestières ligneuses de la forêt marécageuse d'Agonvè et terroirs connexes au Bénin. *TROPICULTURA*, *30*(1), 41–48.

Dossou, M.E., Houessou, G.L., Lougbégnon, O.T., Tenté, A.H.B., & Codjia, J.T.C. (2012). Étude ethnobotanique des ressources forestières ligneuses de la forêt marécageuse d'Agonvè et terroirs connexes au Bénin, *Tropicultura*, *30* (1) :41-48.

Dzoyem, J.P., Tangmouo, J.G., Lontsi, D., Etoa, F.X., & Lohoue, P.J. (2007). In Vitro antifungal activity of extract and plumbagin from the stem bark of *Diospyros crassiflora* Hiern (Ebenaceae). *Phytother. Res 21*, 671–674.

Ernst, C., Mayaux, P., Verhegghen, A., Bodart, C., Christophe, M., & et Defourny, P. (2013). National forest cover change in Congo Basin: deforestation, reforestation, degradation and regeneration for the years 1990, 2000 et 2005. *Global Change Biology*, *19*(4), pp.1173-1187.

Fandohan, B., Kakai, R.G., Sinsin, B., & Pelz, D. (2008). Caractérisation dendrométrique et spatiale de trois essences ligneuses médicinales dans la forêt classée de Wari-maro au Benin, *Rev. Ivoir. Sci. Technol 12*. pp 173 – 186.

Guedje, N.M. (2002). *La gestion des populations d'arbres comme outil pour une exploitation durable des Produits Forestiers Non Ligneux : L'exemple de Garcinia lucida (Sud Cameroun)*. Thèse de doctorat PhD, Université Libre de Bruxelles, Bruxelles, p. 266.

Jiofack, T., Fokunang, C., Guedje, N., Kemeuz, V., Fongnzossie, E., Nkongmeneck, B.A., Mapongmetsem, P.M., & et Tsabang, N. (2010). Ethnobotanical uses of medicinals plants of two ethnoecological regions of Cameroon, *International Journal of Medicine and Medical Sciences*. *2* (3), pp. 60-79.

Jopaul, L.G., Doucet, J., Loumeto, J., & et Biwole, A. (2016). Biomasse et stocks de carbone des forêts tropicales africaines (synthèse bibliographique*). Biotechnol. Agron. Soc. Environ*, *20*(4), pp.508-522.

IUCN. (2019). Red List of Threatened Species: Diospyros crassiflora – published in 2019. https://doi.org/10.2305/IUCN.UK.2019-1.RLTS.T33048A2831968.en

Koudouvo, K., Karou, D.S., Kokou, K., Essien, K., Aklikokou, K., Glitho, I.A., Simpore, J.R., Sanogo, R.C., De, Souza., & Gbeassor, M. (2011). An ethnobotanical study of antimalarial plants in Togo Maritime Region, *Journal of Ethnopharmacology.134*, pp. 183- 190.

Ladoh, Y., Vandi, D., Dibong, S.D., Mpondo, M.E., Wansi, J., & Betti, J.L. (2016). Étude des plantes médicinales commercialisées dans les marches de la ville de Douala, Cameroun. *Journal of Applied Biosciences*, *99*: 9450-9466.

Letouzey, R. (1985). Notice de la carte phytogéographique du Cameroun au 1: 500 000. *Institut de la carte Internationale de la Végétation, Toulouse.*, *5 Vols*.

Lhoest, S., Dufrêne, M., Vermeulen, C., Oszwald, J., Doucet, J.L., & Fayolle, A. (2019). Perceptions of ecosystem services provided by tropical forests to local populations in Cameroon. *Ecosyst. Serv 38*, 100956.

Lougbegnon, T.O., Tenté, B.A.H., Amontcha, M., & Codjia, J.T.C. (2011). Importance culturelle et valeur d'usage des ressources végétales de la réserve forestière marécageuse de la vallée de Sitatunga et zones connexes. *Bulletin de la Recherche Agronomique du Bénin 70*:35-46.

Lykke, A.M., Kristensen, M.K., & Ganaba, S. (2004). Valuation of local use and dynamics of 56 woody species in the Sahel. *Biodivers Conserv.*; *13*:1961–1990.

Mapongmetsem, P.M., Kapchie, V.N., & Tefemba, B.H. (2012). Diversity of local fruit trees and their contribution to sustaining the livelihood in northern Cameroon. *Ethiopian Journal of Environmental Studies and Management*, *5*(1): 32-46.

Masi, G., Muratori, P., Manfredi, A., Pisano, S., & Milone, A. (2015). Child behaviour checklist emotional dysregulation profiles in youth with disruptive behavior disorders: Clinical correlates and treatment implications. *ScienceDirect*. Volume *225*, Issues 1-2, pages 191-196.

Mbolo, M., Walter, S., Lejeune. (2002). La collecte et l'analyse des données statistiques sur les produits forestiers non ligneux. Une étude pilote au Cameroun. *FOPW/02/.2. Rome*.

Mvondo, J.P., Boukong, A., Beyegue, D.H., Abou, A.A., Mvondo, Z.D.E., Passale, S.M., & Lawane. (2012). Production de biomasse de *Brachiaria ruziziensis* (Germain et Evrard) en vue de la mise en place de systèmes de culture sous couvertures végétales dans la zone cotonnière du Cameroun. *Cameroon Journal of Experimental Biology*. Vol.*8*, N° 1, 1-7.

Nga, N.E., Kidik, P.C., Boumsong, N.C.P., Dibong, D.S., & Mpondo, M.E. (2016). Inventaire et caractérisation des plantes médicinales utilisées en thérapeutique dans le département de la Sanaga Maritime : Ndom, Ngambe et Pouma, *Journal of Applied Biosciences 106* :10333 –10352.

Ouôba, P., Yaméogo, J.T., Ouédraogo, A., & Kouaman, S. (2018a). Potentialités agroforestières de *Maranthes polyandra* (Benth) Prance au Sud-Ouest du Burkina Faso. *Journal of Applied Biosciences*. *128*:12920-12931.

Phillips, O., & Gentry, A.H. (1993). The useful plants of Tambopata, Peru: Additional hypothesis testing in quantitative ethnobotany. *Economy Botany 47*:33-43.

Pomel, S., & Salomon, J.N. (1998). *La déforestation dans le monde tropical*. Bordeaux: Presses de l'Université de Bordeaux.160 p.

Savadogo, S., Traoré, L., & Thiombiano, A. (2018). Groupes ethniques et espèces végétales à hautes valeurs socio-culturelles au Burkina. *Geo-Eco-Trop 42*(1):207-226.

Sop, T.K., Oldeland, J.S., Bognounou, F., Schmiedel, U., & Thiombiano, A. (2012). Ethnobotanical knowledge and valuation of woody plants species: a comparative analysis of three ethnic groups from the sub-Sahel of BurkinaFaso. *Environ Dev Sustain*.*8*.

Souare, K., Fotso, R.C., Froumsia, M., Todou, G., Ibrahima, A., & Mapongmetsem, P.M. (2020). Social and economic values chain assessment of key non-timber forest products around Mbam and Djerem National Park's ecoregion of Cameroon: Case of *Xylopia aethiopica, Beilschmiedia anacardioides* and *Beilschmiedia jacques-felixii*, *Journal of Development and Agricultural Economics* Vol. *12*(3), pp. 143-153.

Tangmouo, J.G., Meli, A.L., Komguem, J., Kuete, V., Ngounou, F.N., Lontsi, D., Beng, V.P., Choudhary, M.I., & Sondengam, B.L. (2006). Crassi°orone, a new naphthoquinone from Diospyros crassi°ora (Hien). *Tetrahedron Lett 47*, 3067–3070.

Todou, G., Nnanga, J.F., Bayé-Niwah, C., Kamlaba, P., Froumsia, M., & Ibrahim, A. (2019). Ethnobotanical study of indigenous woody plants in traditional agroforestry of the Sudano-Sahelian zone of Cameroon: Case of Mandara MountainsSSRG *International Journal of Agriculture & Environmental Science 6*: 1-8.

Todou, G., Komo, M.Y., Tchobsala, & Ibrahima, A. (2023). Quantitative ethnobotany and vulnerability of woody plant species in Nyé'été forest, South Region of Cameroon, *Ethnobotany Research and Applications 26*:28.

Traore, L., Ouedraogo, I., Ouedraogo, A., & Thiombiano, A. (2011). Perceptions, usages et vulnérabilité des ressources végétales ligneuses dans le Sud-Ouest du Burkina Faso. *International Journal of Biological and Chemical. Sciences 5*(1):258-278.

Yaméogo, G., Yélémou, B., Boussim, J., & Traoré, D. (2005). Pratique et perception paysanne dans la création de parc agroforestier dans le terroir de Vipalogo (Burkina Faso). *Biotechnol. Agron. Soc. Environ 9*(4):241-248.

Yélémou, B., Yaméogo, G., Barro, A., Taonda, S.J., & Hien, V. (2013). La production de sorgho dans un parc à Piliostigma reticulatum en zone nord soudanienne du Burkina Faso, *Tropicultura 31*(3): 154-162.

Zheng, X., & Xing, F. (2009). Ethnobotanical study on medicinal plants around Mt. Yinggeling, Hainan Island, China *Journal of Ethnopharmacology 124*: 197-210.

Zizka, A., Thiombiano, A., Dressler, S., Nacoulma, B.M.I., Ouédraogo, A., & Ouédraogo, I. (2015). Traditional plant use in Burkina Faso (West Africa): a national-scale analysis with focus on traditional medicine. *J Ethnobiol Ethnomed 11*:9.