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Population structure and traditional management patterns of two threatened medicinal tree species (*Garcinia lucida* and *Pausinystalia johimbe*) in the southern humid forest of Cameroon

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Abstract

Garcinia lucida and *Pausinystalia johimbe* are two medicinal tree species well-known in southern Cameroon as they provide non-timber forest products. Particularly, their barks and sometimes fruits, seeds and leaves of *G. ludica* are used to cure many ailments in local communities. Unfortunately, natural stands of both species are seriously threatened in Cameroon. The objectives of the study were to document use of the targeted species, their management patterns and assess their populations' structure to establish better plans for the sustainable management and conservation. Ethnobotanical and quantitative ecological methods were used. The results showed that both species provided several products and services. The most mentioned services were the conservation of foodstuffs and medicine. Community responses indicated that the species became rare and there were no strategies developed to preserve them. The quantitative inventories supported this community's view. Indeed, both species showed weak size classes' distribution and low densities respectively 14.52 individuals/ha for *G. lucida* and 58.63 for *P. johimbe*. In addition, both species appeared to be threatened because of poverty and increasing demography, illegal logging, shifting cultivation, overexploitation and poor attitude to their conservation. Furthermore, because of the high value of these species of local, national and international levels, respondents claimed that they were interested in domesticating and conserving them but they lacked appropriate propagation techniques, materials and skills. Thus, the sensitization and the domestication of the species should urgently be considered in the farmer environment with strong sound of policy.

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Introduction

Nowadays, non-timber forest products (NTFPs) play an anchor role in fostering livelihood of local communities, thereby reducing dependency on major forest resources. Indeed, the situation of major forest resources preservation and poverty alleviation is a big concern all over the world. It is more critical in developing countries because of poverty and rapidly increasing populations leading to a decreasing availability of livelihood support (Nji, 2004). Furthermore, it may be unethical to harness natural resources in a manner by which existence of all living things is threatened (Maundu and Eyog-Matig, 2006). In addition, tropical rain forests of West and Central Africa endowed with abundant high value indigenous fruit and medicinal tree species (Jamnadass *et al*., 2011; Sunderland, 2011; Tieguhong *et al*., 2012). In this regard, local communities in Africa depend undoubtedly on forests for their daily needs including goods and services (Termote *et al*., 2011; Venter and Witkowski, 2011; Yobo and Ito, 2015). Moreover, some of these products, particularly medicinal plants are trade internationally, and contribut significantly to the economy of the countries of the region (Mahonge *et al*., 2006).

Today, herbal or traditional medicine has been brought into focus for meeting the goals of a wider coverage of primary health care delivery, not only in Africa but also, to various extents, in all countries of the world (Subedi, 2010; Uprety *et al*., 2011). Indeed, traditional medicine plays an important role, as the "modern equivalents" of health care are poorly accessible. It is the first-choice healthcare treatment for at least 80% of Africans who suffer from common ailments (Elujoba *et al*., 2005; Jiofack *et al*., 2010). With this alignment, the African Heads of States have since declared the years (2001-2010) as a period for Traditional Medicine development in Africa and this has been tagged as the "Decade of Traditional Medicine in Africa" (Elujoba *et al*., 2005). According to Sofowora *et al*. (2013), "a medicinal plant is any plant which, in one or more of its organs, contains substances that can be used for therapeutic purposes or which are precursors for the synthesis of useful drugs". This description makes it possible to distinguish between medicinal plants whose therapeutic properties and constituents have been established scientifically, and plants that are regarded as medicinal but which have not yet been subjected to a thorough scientific study. In developing countries such as Nepal, the importance of NTFPs for rural communities has been overlooked and available government legislations have contributed to poorly regulate resources extraction, use, trade and marketing (Kumar *et al*., 2011; Hasan *et al*., 2013).

Similarly in Cameroon, although NTFPs including medicinal plants are important source of income for local people livelihood, there is scarcity of studies assessing their extraction, use, management, trade and marketing (Leakey *et al*., 2005; Jiofack *et al*., 2010). Thus, *Garcinia lucida* Vesque and *Pausinystalia johimbe* (K. Schum.) Pierre ex Beille are two medicinal tree species well-known in southern Cameroon, respectively as "Essok" (Boulou) and "Adjeck/Atyek" (Ewondo). These species are listed among the threatened species although valorized in various domains by local communities (Oldfield *et al*., 1998; IUCN Red List, 2012). *G. lucida* is listed as 'vulnerable' while *P. johimbe* is listed as 'endangered'. Although they represent an important economic potential for local populations, nowadays, the overexploitation and the habitat loss led the species to be rare.

Likewise, to identify a plant species for protection priority, it is desirable to have baseline information on its density, stem size and reproduction status (Tuxill and Nabhan, 2001). This is because classification of plants in classes based on their stem diameters, showing size-class distribution tell us about plant population structure that indicates the chances of plants in one size class to survive into next size class. This classification is used to establish plant population dynamics especially for trees, and therefore the status of the population (Cunningham, 2001). Furthermore, Cunningham (2001) argued that

"information on how a plant population is regenerating provides a valuable data for resource management purpose and is widely used in planning for sustainable management of uneven-aged, mixed species forest". Thus, it is imperative to think about the magnitude of threats that the species is facing (Tuxill and Nabhan, 2001).

Furthermore, during the last decades, some studies were conducted on threatened species through the world (Abd El-Ghani and Abdou, 2007; Hamawa *et al.*, 2012; Baig *et al.*, 2014). Indeed, factors leading to forest habitat modifications include activities such as tree cutting and selective removal of timber trees. Hence, putting selective pressure on individual tree species threatens many species. In the case of southern Cameroon, little works were achieved in this domain (Guedje *et al.*, 2003; Ngo Mpeck *et al.*, 2003). This survey coupled to botanical inventories were undertaken to fill the gap related to threats to the targeted species, through their population structure and farmers' exploitation patterns. Thus, the aims of the paper were threefold: (i) record the main domestic uses of the species; (ii) develop and understand their traditional management patterns and (iii) assess their population dynamics to establish better plans for the sustainable management and conservation.

Materials and methods

Study areas

The study was conducted at the southern region of Cameroon, especially in Akom II Sub-Division for *G. lucida,* then Nyete Sub-Division's boundaries for *P. johimbe*, both in the Ocean Division (Fig. 1).

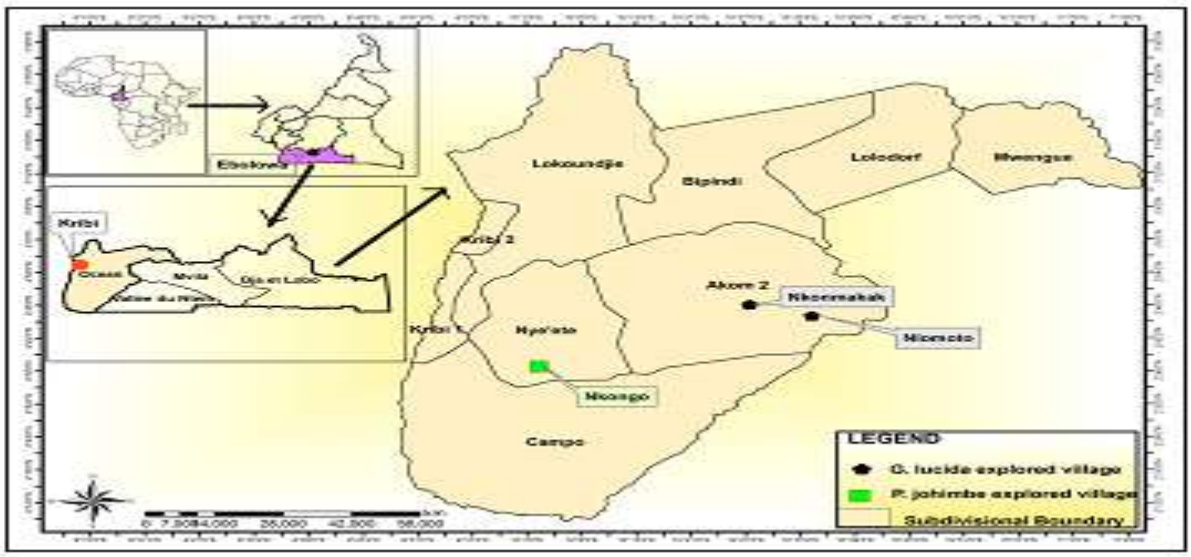

Fig. 1. Study location.

On the whole, three villages were retained in the rate of two for *G. lucida* and one for *P. johimbe*. Thus, in Akom II for *G. lucida,* the explored villages were Nkonmakak (latitude 2°06.71'N, longitude 11°49.23'E and 497 m asl), and Nlomoto (latitude 2°06.79'N, longitude 11°49.98'E and 400 m asl). Dikonhop (latitude 3°23.64'N, longitude 10°52.12'E and 368 m asl) in the Nyong Ekelle Division which was also explored for this species was finally left out because of the non-consistency of the raw data. Village Nkongo around Nyete (latitude 2°06.16'N, longitude 10°28.29'E and 55 m asl) was the only explored village for *P. johimbe* because of the scarcity of the species. Indeed, because of high exploitation pressure and its scarcity, untouched stands of *P. johimbe* were rarely found in the studied site.

In the study area, the climate is humid tropical with two rainy and two drier seasons, with a yearly rainfall of 2000 mm, and with an average annual

temperature of 25.8˚C (Olivry, 1986). Beside annual and perennial crops (cereals, legumes, root crops), indigenous and exotic fruit tree crops, cocoa (*Theobroma cacao* L.) and oil palm (*Elaeis guineensis* Jacq.) farms are very present in Akom II landscape while Nyete landscape is mostly occupied by rubber (*Hevea brasilensis* (Willd. ex A.Juss.) Müll.Arg.) plantations with the Company HEVECAM (Hévéa du Cameroun). The Akom II landscape consists of mountains and abrupt hills. The studied plots are located at approximately 500 m asl. The soils have been classified by van Gemerden and Hazeu (1999) as well drained, deep to very deep soils, moderately well drained soils and poorly to very poorly drained soils.

According to Letouzey (1985), the vegetation can be characterized as mid altitude evergreen forest rich in Caesalpiniaceae. Biodiversity in this part of Cameroon ranks among the highest in Africa. The forest cover is still largely intact, but due to human influence, it is alternated with a mosaic of fields, fallow lands, secondary forest, and logged over forest. Human beingpopulation density is low (5-10 inhabitants km^{-2}). Approximately 90% of the population are Bantus, belonging to the Boulou, Fang, Bassa and Ngumba tribes while approximately five percent of the population are Bakola (or Bagyeli) pygmies (van Gemerden and Hazeu, 1999). These later are mainly forest dwelling hunters and gatherers, although some of them as well as most in the other tribes seem to be in the process of sedentarization by practicing shifting cultivation.

Studied species

G. lucida (Clusiaceae) is a small evergreen dioecious tree, reaching 25-30 cm of diameter and 12-45 m height. It naturally occurs in West Africa tropics and most specimens of this species are found in Gabon, Cameroon and Equatorial Guinea. It grows high-density in hilly moist forests (Vivien et Faure, 1985) and is reproductively gregarious (Guedje and Nkongmeneck, 2001). Its seeds and bark are the most commonly used parts in traditional medicine and food. Indeed, bark and seeds are exploited and commercialized for medicinal purposes and palm wine processing in Cameroon (South), Equatorial Guinea and Gabon (Guedje *et al.*, 2003; 2007). Eitherdried or fresh parts are widely used for treatment of gastric and gynecological infections, diarrheas, and as antidote against poison as well as to cure snake-bite (Guedje and Fankap, 2001; Lacmata *et al.*, 2012). Fresh bark and sometime seeds are used as an additive to palm wine production and distilling fermented palm wine to produce liquor (traditional alcohol locally called “odontol”).

As far as *P. johimbe* (Rubiaceae) is concerned, it is described as an evergreen tree, which can become a medium sized tree, up to 30-35 m tall and 30-60 cm diameter; the bole is straight, cylindrical with a monopodial growth habit (Thirakul, 1985). This tree is native to the coastal forests of West and Central Africa and restricted to the lower Guinea domain, where it is distributed from southern Nigeria to the Congolese Mayombe (Stoffelen *et al.*, 1996; Vivien et Faure, 1985), through Equatorial Guinea, Cameroon, Gabon, Congo-Brazzaville and the Democratic Republic of Congo. The species occurs mainly in closed-canopy forest, although not widespread throughout its range (Sunderland *et al.*, 1997). In closed-canopy forest, it displays a healthy recruitment and is reproductively gregarious (Stoffelen *et al.*, 1996). The bark of *P. johimbe* is the only part used by local communities.

Yohimbine is the principal indole alkaloid derived from its bark. This bark contains up to 6% indole alkaloids, 10-15% of which are yohimbine (Zanolari *et al.*, 2003; Yakubu *et al.*, 2003; Chen *et al.*, 2008), used both clinically and traditionally to treat male organic impotence (Adeniyi *et al.*, 2007), cardio-vascular diseases and increasingly to enhance athlete's performance (Sunderland *et al.*, 1997). Indeed, Yohimbe is believed to be effective in dealing with male organic impotence, mainly due to its ability to stimulate blood flow by dilating blood vessels. The increase in the flow of blood to the penis helps in

bringing about erections. Another manner in which Yohimbe relates to impotence is that it increases the body's production of norepinephrone; which is essential in the formation of erections. Studies have shown that this herb can restore potency even to diabetic and heart patients that were suffering from impotency due mainly to their diseases. Because of its many uses, its value on international market (Ingram and Shure, 2010) and the destructive methods used to harvest the bark (Sunderland *et al.*, 2000), to date yohimbe's bark has been taken entirely from trees in natural stands and there has been little effort made to develop strategies of sustainable exploitation of the wild resource (Ngo Mpeck, 2004).

Research method

The fieldwork took place from June to November 2014 using both some enthobotanical and ecological studies. Focus groups discussion were held within each community before interviews. This was to discuss research plans and request group permission to undertake work in the area and record traditional knowledge and know-how of local communities on the use and management of *G. lucida and P. johimbe*. The ethnobotanical investigations entailed structured interviews that were conducted using questionnaires. These were administrated face to face. The household was the sampling unit and its head was the target respondent often assisted by any other adult in the household. Surveyed households were selected randomly from village registries or lists of existing households. A household was considered in the Cameroonian context and comprised people living under the same compound, using the same kitchen and sharing meals, cultivating the same land and recognizing the authority of one person, the head of the household. Because of low population density, a total of 60 households head were living in the localities above. Respondents were mainly constituted by those who had a good knowledge of local plant species. Indeed, the questions asked concerned the habitat of the species, the patterns of harvest and sale, different uses of the species and the attitude of the local community towards their domestication and/or conservation. Hence, information was obtained by interviewing key informants about the studied plant species (collection, purpose, trade and income, management patterns, etc.).

For the ecological part, in each explored village, the species niche was identified and geo-referenced (altitude, longitude and latitude). For this study, as both species are gregarious (Guedje and Nkongmeneck, 2001; Stoffelen *et al.,* 1996), the same methodology was used for inventories. This methodology was adapted from Hall and Bawa (1993) and has been previously used by Guedje *et al.*, (2003) for a study on *G. lucida* and Tasse (2007) for *Prunus africana*. In each village, a reconnaissance survey was undertaken in collection sites with Bantou or Baka guides offered by the community village. Once these collection sites usually frequented by farmers in each village were covered, a transect grouping them was installed. The width of each transect was 20 m, but the length was not fixed in advance. It was equivalent to the distance measured from the first to the last collection site identified by the guides. Enumeration and surveying was undertaken as follows:

(i) transect along the rods for adults having diameter ranging between 5-10 cm;

(ii) within the plots of 100 m^2, distant from each other by 100 m, clumps and single stems were counted;

(iii) the installed transects for juvenile rods having a size of at least 1 m and a diameter less than 5 cm DBH;

(iv) to facilitate the numbering, the under-quadrats (or within sub-plots) of 4 m^2 contained in the plots mentioned above were settled for the assessment of the seedlings less than one meter height

In whole, 4.20 ha were inventoried for *G. lucida* while 2.20 ha were inventoried for *P. johimbe*. The parameters as the height of the individuals, and the

diameter at breast height (DBH) were assessed.

Conceptual framework

One of the essential pieces of information for developing sustainable management strategies and actions for a species is the description of its current management including diverse local knowledge and uses associated to it (Assogbadjo *et al.*, 2009; Feyssa *et al.*, 2012). Indeed, by incorporating local knowledge and practices in the process of scientific research (Fig. 2), new hypotheses can be developed for research experiments relevant to management (Chia, 2004; Dawson *et al.*, 2009; Hamawa *et al.*, 2012).

Data analysis

The Statistical Package for Social Sciences (SPSS) version 17.0.0 (Aug 23, 2008) was used to process and analyse data collected from different sources. Data from households' questionnaire survey were put into Microsoft Excel spreadsheet for the preliminary analysis. Furthermore, cross tabulation of descriptive statistics and graphics were used to present the results from data analysis. From the quantitative inventory, species' density were calculated.

A size class frequency distribution plot (SCD) was drawn by plotting the number against size class. The SCD slope summarizes in a single number, the shape of the SCD as previously pointed out by Tabuti and Mugula (2007). It is worth noting that if a population has a strong negative slope; it is interpreted like a stable and naturally able to replace itself whereas the weak negative slopes or flat slopes show a poor restoration and declining population (Hall and Bawa, 1993).

Results and discussion

Characteristics of surveyed respondents

The results (Table 1) indicated that majority of respondents were male (63.2%). Women involved in the survey were only 36.8%. Farming was the major activity of the respondents and employed 85%. This is an indication that this sector must be improved. Like in most of African countries, households were large with an average of 73.3% people living upon tiny pieces of land. Large households constitute a risk factor for poverty and heavily tax natural resources. This is true especially in rural areas where there are limited viable alternatives to farming.

Different uses of the studied species

Seventy three percent of the respondents indicated that leaves, seeds and stem bark of *G. lucida* harvested by local populations are used in different categories. They are used as ferment for palm or *raphia* wine, for the treatment of gastro-intestinal and gynecological disorders, diarrhea and colic (Table 2). These results indicate that stem bark and seeds of *G. lucida* may content many phytochemical substances useful for human healthcare. Indeed, the genus *Garcinia* is known to be rich in xanthones with several biological activities, such as antimicrobial and antibacterial such as *Escherichia coli* (T. Esch.), *Pseudomonas areruginosa* ((Schro.) and *Candida albicans* (Benk.) (Sunit *et al.*, 2002; Momo *et al.*, 2011; Policegoudra *et al.*, 2012); antifungal (Gopalakrishnan *et al.*, 1997), cytotoxic and anti-HIV (Vichai *et al.*, 2006; Magalula and Tewtrakul, 2010). These previous studies carried on phytochemical substances contained in *Garcinia* genus in general and *G. lucida* in particular indicated the usefulness of the species for human healthcare.

In addition, *G. lucida* is believed to possess some aphrodisiac properties (van Dijk, 1999; Guedje and Nkongmeneck, 2001). It has been also reported to have anti-leishmanial and anti-trypanosomal properties (Fotie *et al.*, 2007; Kuete and Efferth 2010; Lacmata *et al.* 2012; Dzoyem *et al.*, 2013). Studies showed that phytochemical substances such as flavonoids, anthocyanins, saponins, carbohydrates, triterpenes and derivatives of cycloartane were isolated in seeds and stem bark of *G. lucida* (Nyemba *et al.*, 1990; Gangoue-Pieboji 2007; and Momo *et al.*, (2011). Thus, they play very significant roles in human medicine. For instance, flavonoids have been shown to protect gastrointestinal tract, having

antispasmodic, anti-diarrhea, antibacterial, anti-secretory and antiulcer properties as well as strong antioxidant capacities. Moreover, seeds and stem bark of *G. lucida* are also used as antidote for poison and to cure snake-bites (Soares *et al.*, 2005). Some respondents stated that its leaves are used to repel insects (Table 2). These results are in line with those reported by Guedje and Fankap (2001). These results can explain the wide use of stem bark, leaves and seeds of this species by local communities. These potential health enhancing properties of flavonoids inherent in *G. lucida* stem bark and seeds would be contributing immensely to the health of local population.

Table 1. Snapshot of survey respondents (N= 60).

Demographics and assets	Nkonmakak	Nlomoto	Nkongo	Total
Individual variables				
Number of household heads	20	20	20	60
Sex				
Male	15	17	12	44
Female	5	3	8	16
Age groups (years)				
<18	1	2	0	3
20-50	13	13	15	41
>60	6	5	5	16
Education				
No formal education	1	0	2	3
Primary	4	7	6	17
Secondary	15	12	10	37
University Degree	0	1	2	3
Marital status				
Married	15	9	5	29
Single and never married	3	3	10	16
Separated	0	4	0	4
Divorced	0	1	0	1
Widow	2	3	5	10
Professional status				
Peasant	8	13	14	35
Civil servant	7	2	0	9
Retired	4	2	0	6
Others (trader, pastor, hunter, traditional healer, etc.)	1	3	6	10

Source: Authors' calculations from study finding.

Key informants indicated that exploitation of *G. lucida* does not involve many actors. In fact, very few respondents considered as wholesalers (15%), indicated that they harvest these products for sale. They usually harvest them for their household consumption. At local level, clients for *G. lucida* stem bark in the studied area were from Abang-Minko'o, Ebolowa, Yaoundé and Douala. The buyers come to the harvesters' house to by the products and they will further sale them in their towns market as retailers. A fruit (berry Fig. 3) costs 50 FCFA (see Abbreviation) while a basket of fruits costs about 5000 FCFA. Prices of a bag of stem bark equal to 25 kg vary from 15000 to 20000 CFA. The money earned from the sale of *G. lucida* products can be used to cover various households' needs such as buying food and utensils or paying children's school fees.

At national, regional and international level, data on the quantity of *G. lucida* stem bark produced, commercialized and exported to Gabon and Equatorial Guinea are very scarce. Nonetheless, between 1995 and 1996, a great quantity of its stem bark was commercialized within the region (Table 3). Since then, to our knowledge, few or almost no other study has been conducted on production and trade channels of this species; Table 3 really indicated the scarcity of available data on *G. lucida* products.

Indeed, as the production and trade channels are not well organized, a great amount of its products is not quantified. As pointed out by Shackleton *et al.* (2011), difficulties in adequately quantifying NTFP value, however, include the multiplicity of products, informal trade and bartering that occur in unmonitored local markets, direct household provisioning without products entering markets at all, and the fact that wild-harvested resources have been excluded from many large-scale rural household surveys. Therefore, further studies should be conducted to fill the gap, with more emphasis on market surveys recording quantities and prices of products, and trade channels.

Table 2. Uses and types of *G. lucida* and *P. johimbe* organs traditionally used in Cameroon.

Species	*CS (IUCN)	Category of use	Type of use	Part used	Mode of preparation
G. lucida	Vu	Food	Ferment or adjuvant of natural sap	Bark, seed	Crushed
		Traditional medicine	Gastrointestinal disorders (diarrhea, abdominal colic, bloating, indigestion)	Twig rod, bark, seed, leave	Decoction infusion, maceration
			Gynecologic disorders, Sexual transmissible diseases, gastric ulcers, cough		
			Excitant or stimulant (aphrodisiac), speed lactation, flatulence, sleeping sickness	Seed, bark	Crushed
			Antidote against poison	Seed, bark	Crushed
			Against snake bites	Seed, bark	Decoction, crushed and used as a paste
		Others	Against evil spirits	Leave	Trituration
			Insectifuge	Leave	
P. johimbe	En	Medicine (traditional and modern)	Sexual weakness (erectile dysfunction or early ejaculation), stimulant, nervousness, sleeplessness, anxiety, constipation, headache	Stem bark	Decoction for fresh part or infusion for dried powder

**CS: Conservation status; En: Endangered; Vu: Vulnerable.*

As far as *P. johimbe* is concerned, the stem bark is the only part used in the traditional medicine of the local communities interviewed. It can be used dried (powder took as a tea) or fresh (decoction or boiled). Eighty-four percent of respondents indicated that it is used to prevent and cure sexual weakness. A few (8%) indicated that it also treat nervousness, sleeplessness, anxiety, constipation and headache. These results from local communities are consistent with the literature from the international market of yohimbe (Sunderland *et al*, 1997). With regard to treatment of sexual disorders, these results are consistent with those of Bhawani *et al.* (2013) who pointed out that the extract of the stem bark of another threatened medical plant namely *Allanblackia floribunda* Oliv., is also used to treat sexual disorders, hypertension, nervousness, sleeplessness and anxiety.

Table 3. Value of *G. lucida* stem bark produced, commercialized in Cameroon and exported to neighboring countries. ND = non determined.

Year	Production unit	Value unit (FCFA)	Export unit (tons)	Author (s)
1995	41 kg	10.360.000.000	ND	Lehoux and Chakib (2012)
	ND	10. 360. 000	ND	Awono *et al.* (2002)
1996	27 kg	9.870.000.000	3 t	Lehoux and Chakib (2012)
	ND	9.867.000	ND	Awono *et al.* (2002)

In addition to its local widespread use as an aphrodisiac and as part of traditional healthcare system where it is used for a wide range of vascular-related ailments, the species has been long exported to Europe for Western medicine (Sunderland *et al.*, 2000). From Cameroon, the main sole supplier of *P.*

johimbe bark to Europe is PLANTECAM (Plantes du Cameroun), which is a pharmaceutical company, involved in sales of raw, semi-processed and processed medicinal plants products. This company is supposed to buy only bark supplied by local contractors, who are registered local business with licences to exploit medicinal plants, unfortunately that is not always the case. The licence issued by the Ministry of Environment, Protection of Nature and Sustainable Development, clearly mention the species, the plant part exploited, the quantities and the localities where the contractor can undertake his activities (Ngo-Mpeck, 2004). Respondents indicated that yohimbe bark exploitation is a process made of different steps and involving a team of many people (Fig. 4): (i) prospectors involved in identifying individual trees of the species, are most of the times local Bantu young men and pygmies (Bakola) living in the nearby settlements; (ii) local harvesters are involved in felling trees and stripping the bark, then carried it to the roadside where it will be sold to (iii) contractors holding licences.

Table 4. Farmers' perception on the management patterns of *G. lucida* and *P. johimbe* in southern Cameroon.

Variables	Opinions of farmers (%)	
Pattern of harvest	*G. lucida* (N=40)	*P. johimbe* (N=20)
No definite schedule	100	100
Time of return to places of gathering for the product		
One year	22.5	34
Two years	20	46
Three years	40	10
More than five years	17.5	10
Conservation/domestication willingness		
Wish	05	15
Don't know or don't need	05	17
Free exploitation of the resource	61	48
Controlled exploitation of the resource	29	20

At local level, the first element of the commercialization chain is the harvester, who is generally a Bantu (native of the local tribe) or a pygmy and in all the cases men. Women are not involved in bark harvesting activities, because the task is physical; their main role is to carry the harvested bark from the forest to roadsides. Harvesters are working in a close relationship with collectors who are commissioned by contractors. Harvesters received from collectors a price varying between 100 and 150 CFA francs per kilo. The lowest price (100 CFA francs) is paid to pygmy harvesters who sell the bark on the Nyete-Kribi-Campo road. As mentioned above for *G. lucida* products, money earned from yohimbe's bark activities can be used to cover various households' needs such as purchasing food, utensils, and paying children's school fees.

At international level, as mentioned above for *G. lucida*, market data recorded for Yohimbe bark are very sparse. Indeed, between 1984 and 1998, the exported quantity of this product varied from 286 to 715 t (Lehoux and Chakib, 2012). In 2007, this quantity produced was estimated at 29.029 t. Together with their high stem bark market value estimated at 171.175$ and 847.182$, respectively for *G. lucida* and *P. johimbe* (Ingram and Shure, 2010), these species are of choice among local communities.

Farmers' perception on sustainable management of the studied species

The management and the conservation *of G. lucida* and *P. johimbe* in the survey areas remained a preoccupying subject in peasant environment. Indeed, respectively for *G. lucida* and *P. johimbe*, 61%

and 48% of respondents stated that these species constitute "a gift of God" and the resource is abundant and will always be available. Hence, their exploitation must remain free of control. Nevertheless, others become aware that with the overexploitation coupled to high shifting cultivation and artisanal logging (Lescuyer *et al.*, 2012), the resource becomes more and more depleted and the communities ignored what strategies to adopt for solve this problem. Indeed, harvesting techniques go from the cut to the selective deduction of the parts (bark, seed and leaves) of the resource. For instance, ring-barking (100% of trunk circumference debarked) and felling trees were predominant techniques used for bark extraction for both species. For *G. lucida* trees which were entirely cut, we observed that some coppiced new trunks and generated new individuals over time. Unfortunately, those multiple new trunks, generally small in size, do not produce good quality bark. *P. johimbe* trees did not show the same trend. For sustainable management of the resources, farmers could be advice to cut *G. lucida* individuals at 1 m height and then harvest the bark (coppice management). Similar recommendation was already proposed by Vermeulen (2006) as a bark harvesting technique for *Ocotea bullata* (Burch.) E. Meyer (Lauraceae).

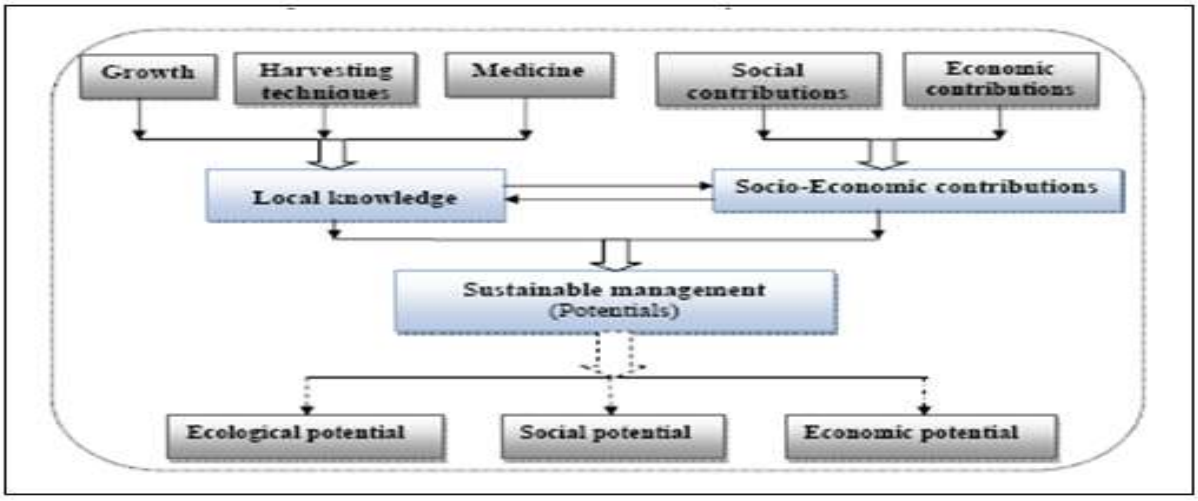

Fig. 2. Conceptual framework illustrating local communities' interventions on the sustainable management of environmental resources (Adapted from Lawas, 1997; Yakeu, 2012).

A great number of informants attested that *G. lucida* and *P. johimbe* are communal properties, people collect them and use from the wild. Indeed, for *G. lucida*, the study site belongs to a Community Forest established within the village boundaries in 2002. They also stated that they were going long distances to fetch these medicinal plants. As the pattern of harvest of the plant's parts, the number of deduction per year is variable. The periodicity of the harvest depends on the individuals and the size of the problems met (Table 4).

In addition, efforts are necessary to domesticate a large number of tree species producing agroforestry tree products (AFTPs) collected in the wild. It is a matter of avoiding serious erosion of genetic diversity, extinction and overuse of indigenous plants, on the one hand, while ensuring their availability and quality assurance on the other (Emshwiller, 2006; Duminil *et al.*, 2009; van Tassel *et al.,* 2010). The process of "domestication" which has been applied so successfully to agricultural and horticultural crops (Tchoundjeu *et al.,* 1999; Appiah, 2003) is a result of management, selection and cultivation of useful forest species by indigenous people for subsistence purposes and it is as old as that of human kind's use of forest ecosystems.With regard to this, and as far as *G. lucida* is concerned, 5% of respondents indicated that they

wish to domesticate the species, but the major constraint is the fact that it grows naturally only on the slopes of the hills and along or near a stream. For farmers, as the species does not grow near farmlands, they were not aware that it can be domesticated. Moreover, those hills where the product can be found are very far from the village, at about 8 to 12 km and famers do not use a mean of transport to gather the products. Like the exploitation of these species is done at the wild state, some opinions are different on its conservation. For *G. lucida*, 61% percent of the interviewed people thought that the exploitation of these species must stay free whereas 29% of them agree the controlled exploitation of the resource. Those who wished a sustainable exploitation represented 29% of the whole interviewed population as far as *G. lucida* is concerned while 5% agrees to domesticate the species.

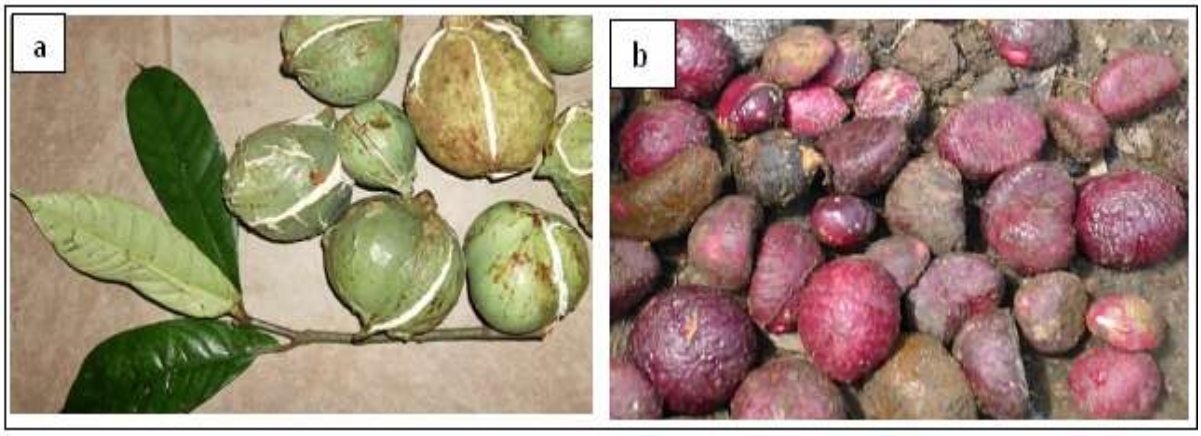

Fig. 3. (a) Leaves and berries of G *lucida;* (b) Seeds of G *lucida*.

In the same line, for *P johimbe*, 48% of the interviewed people thought that the exploitation of these species must stay free whereas 20% of them agree the controlled exploitation of the resource. For this purpose, the main constraint is the lack of knowledge on propagation methods and the availability of quality planting materials. Trees are felled using a chainsaw; generally, only the bark of the main stem is stripped, with the branches and the remainder of the crown remaining untouched. Prior to the bark removal, trees are crosscut into uniform sections of 1.5-2 m long; the wood being used later as fuel by nearby local populations. Bark is removed from the cut logs and carried by young women and men to the roadside, where large amounts of bark will be gathered.

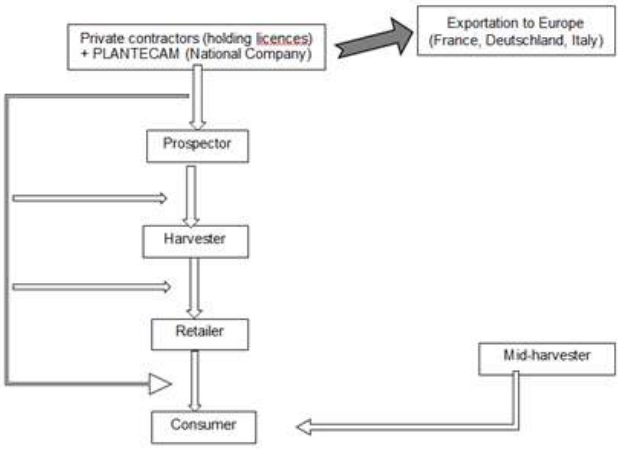

Fig. 4. *P. johimbe* bark harvest channels in Cameroun.

As far as *P. johimbe* management is concerned, the present study showed that some crosscut stem barks were left in the forest by harvesters because "the contractor did not paid money for the task". This situation constitutes a real wastage of the resource (Fig. 5). As the species has a restricted distribution (endemic to Lower Guinea Domain of the Guineo-Congolian region of tropical Africa), the remaining populations of *P. johimbe* are under threat of genetic erosion and in the worst case threatened of extinction. From a management point of view, it is not the limited harvesting by traditional healers that represents the problem, but the non-sustainable, commercial harvesting to supply an international demand for Yohimbe bark. This result is consistent with the findings of Sakala (2002) on *Pterocarpus angolensis* (DC.) in Tanzania. The impact of current harvesting practices is mostly influenced by the fact that *P. johimbe* is a slow growing species with a limited distribution.

Fig. 5. A typical picture of yohimbe resource wastage at Nkongo in Cameroon: (a) a stem of yohimbe tree cut and abandoned without stripping the bark; (b) yohimbe bark gathered and abandoned in the forest.

Density and distribution of the studied species

Species frequency and density are efficient ways to reveal the distribution and strength of any species in a landscape (Alhamad, 2006). In the study sites, a total of 190 individuals were recorded in the rate of 61 for *G. lucida* and 129 for *P. johimbe*. Determination of density distribution reflected the occurrence of 14.52 individuals/ha for *G. lucida* and 58.63 for *P. johimbe*. Thus, these results suggest that local populations of *G. lucida* and *P. johimbe* appeared threatened.

Population structure of G. lucida

It was noted that the diameter of the population varied from 2.5 to less than 28 cm. Individuals belonging to the class diameter of 13-25cm were the most abundant. On the whole, mean diameter at breast height (DHB) was 15.25 cm and the highest DBH was 12.5 cm. In general, the graphical appearance of a species distribution varies with logs size. Thus some species having a "bell-shaped distribution curve" in small logs can be "inverted J-shaped" when the size of the log enlarges. For *G. lucida*, inventories showed "bell-shaped curve" diameter class distribution with disrupted points which may indicate the threat to the species (Fig. 6). It is well known that "bell-shaped distribution curves" are usually the prerogative of light species that grow in dense forest, gaps, windthrows and degraded areas. This statement is in line with the result obtained from the present study as *G. lucida* naturally grows on the slopes of the hills. In the case where it grows along or near a stream, the obtained "bell-shaped distribution" may be due to logs' size as mentioned above. Hence, ecology restricted distribution of the species can threaten it.

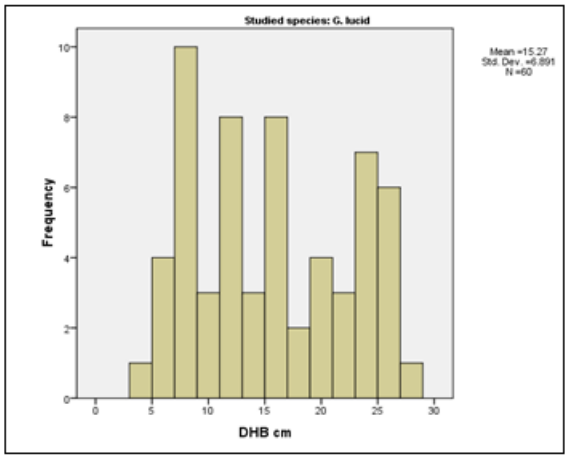

Fig. 6. Diameter classes' distribution of *G. lucida* in southern humid forest of Cameroon.

Population structure of P. johimbe

As far as *P. johimbe* is a concerned, individuals belonging to the class diameter of 4-25cm were the most abundant. The analysis of SCD indicated that the species have a weak population structure. It exhibited and inverted J-shaped slope (Figure 7). This structure characterizes species that are shade tolerant as *P. johimbe*. In general, inverted J-shaped curve shows that the number of stems of a diameter class is half that of the previous class as pointed out by Adou Yao *et al.* (2007). It also shows that all species combined, younger trees with smaller diameters are more than those of large diameters. The results from this study are similar. The perception of the local communities was confirmed by the analysis of the population distribution. This result is consistent with the findings of Tabuti and Mugula (2007) who reported that species with weak slopes generally have a poor regeneration potential and may be declining. For many species, sustainable management is constrained by lack of ecological knowledge. Indeed, baseline ecological data on many non-timber forest products is limited (density, distribution, growth rate, regeneration niche and production/yield). Further studies should put emphasis on sustainable management of important priority indigenous tree species for farmers' livelihoods guarantee.

The SCD plots showed a higher number of young individuals. For a population to maintain itself, it needs to have abundant juveniles which will recruit into adult size class. This result is in line with that reported by Bationo *et al.* (2001) on *Afzelia africana*. Similarly, the absence of adults in population (individuals belonging to the class diameter of 150-200cm), affects recruitment into the population because of lack of seeds. Indeed, *P. johimbe* has very small seeds only dispersed by wind. Similar result has been outlined by Mapongmetsem *et al.* (2011) on *Vitellaria paradoxa* Gaerten. F. (Sapotaceae). Our findings also highlighted the low availability i.e population size and habitat of these species in the wild. This has important conservation applications as the species with specific habitat requirements are at great risk than the species with broad habitat range. This is consistent with the study of Samant *et al.* (1996). Besides a minimum population size is required for the long term viability of rare and endangered species. According to the respondents, the adult individuals of the two species were scarce and declining in abundance. The quantitative inventory supported the respondents view.

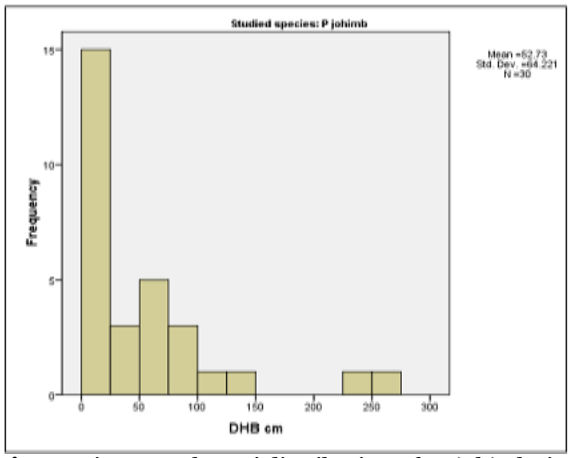

Fig. 7. Diameter classes' distribution of *P. johimbe* in Southern humid forest of Cameroon.

With regard to their distribution and percentage of debarking according to class diameter sizes, it was found that for DBH ≤ 10 cm, 29.5% of *G. lucida* trees were concerned, whereas 70.49% fall into DBH comprise between 10 and 30 cm. By contrast, independently to class diameter sizes, the degree of debarking was very high, with respectively 72.22% of trees with entire circumference debarked for DBH ≤

10 cm and, 51.16% of trees with entire circumference debarked for 10 cm ≤ DBH ≤ 30 cm. The percentage of dead exploited trees (>20 cm DBH) was more than 40%. Indeed, the bark is often removed over almost the entire circumference of the stem, leading to high mortality rates. A similar trend was registered for *P. johimbe*.

Perception of local people on current status of G. lucida and P. johimbe

Within the study sites, field inventories of *G. lucida* and *P. johimbe* clearly showed that *G. lucida* was found only around stony hill sides of mountains of Nkonmakak and Nlomoto, at about 8 to 12 km from the village while *P. johimbe* was found very far from pygmy camps at about 12 km away. Key informants responded that the elderly people were telling them the species were abundant in the past. Because of this rarity, respondents said that they were not aware of what has happened. Nonetheless, the perception of local people on current status of these species strongly pointed out the decline in status of the species.

Major factors threatening G. lucida and P. johimbe in the study areas

About 63% of respondents asserted that in the early times, both species were abundant in the local vegetation, roadsides and easily accessible to collect bark and/or seeds. Nowadays, they are obliged to work for more than 12 km to find a single population, as the species are gregarious. Hence, the rarity of these species can be attributed largely to past and current anthropogenic factors and exacerbated by climate change (seasonality changes, unpredicted rainfall) in this area. As pointed out by Dale *et al.* (2001), climate change can have an impact on forests structure and composition on one hand while it influences also the severity and magnitude of forest disturbances through rainfall shift on the other hand. Indeed, the vegetation in this area has been over destroyed for the plantation of the most cultivated cash crops such as oil palm, rubber and cocoa.

From this study, key informants revealed some drivers that threatening these species such as: (i) poverty and increasing demography; (ii) illegal logging (uncontrolled harvesting) as early stated by Lescuyer *et al.* (2012); indeed, the domestic timber market in Cameroon is estimated at about 2 M cm^3 of timber per year, almost equal to the official national industry timber production (Ceruti *et al.*, 2010). Moreover, small scale logging is becoming one of the most important off-farm sources of income for a growing number of people in rural areas (Lesuyer *et al.*, 2009; Marieke *et al.*, 2012); (ii) shifting cultivation coupled with expansion of 'slash and burn' agriculture to marginal lands; (iii) over-harvesting or unsustainable harvesting (no norms of harvesting) and somehow climate change at a lesser extent. Indeed, pressures being led by the above mentioned drivers have resulted in rarity of these species due to their habitat destruction. Similar results were found by Ickowitz (2011) and Robiglio *et al.* (2012).

State of community-based enterprise development

With regard to the existence of the community-based enterprise development or other technology available for processing and market facilities, Nkonmakak and Nlomoto villages showed typical examples. In Nkonmakak, there was a Common Initiative Group called "ADEVIN" (Association pour le Développement du Village Nkonmakak) created in 2007. Its main goal is the education of women and young girls. Its members work for the sustainable management of their Community Forest and also protect their medicinal plants, including *G. lucida*. As far as Nlomoto village is concerned, there was also a Common Initiative Group named "LADYNTO" (La Dynamique de Nlomoto) initiated in 2010, with similar goal as "ADEVIN". Group members are more involved in crops cultivation such as cocoa, palm oil, rubber, cassava (*Manihot esculenta* Crantz), cocoyam (*Xanthosoma* spp.), plantain (*Musa paradisiaca* L), maize (*Zea maize* L) and groundnut (*Arachis hypogea* L). Generally, income earned from the sale of different products in the group is distributed to group members. It may help to purchase the machine

for cassava processing, kitchen materials and pay children' school fees. To reduce poverty in the rural milieu, this approach should be developed in Nkongo village for *P. johimbe*. These results are consistent with the findings of Debraux (1998); Doucet and Kouadio (2007), and Makueti *et al.*, (2015) for *Baillonella toxisperma* in eastern Cameroon. Similar results were also outlined by Seixas (2010) and Tieguhong *et al.*, (2012) on other NTFPs.

Implications for conservation

The accumulated traditional knowledge of local and indigenous communities on forest and tree-based systems contribution needs to be acknowledged and incorporated into management practices and policy. Indeed, their implication in the management of the species is a key of arch of its conservation. Therefore, adequate recognition from the policy level, something which has been lacking in the past decades, is extremely important for further studies on the importance of NTFPs (Foundjem-Tita *et al.*, 2012). Furthermore, drivers that might contribute to undermine successful implementation of governmental forest policies include mostly: (i) the contradicting nature of the forest policies with regards to forest and land tenure; (ii) the non-recognition of legal traditional rights of collectors over harvest of the forest products and, (iii) the lack of effective involvement of local people in forest resources management and policy elaboration process.

In addition, efforts demonstrated by the local people through traditional management patterns should be honored and supported. For instance, domestication can be supported by: (i) encouraging community-based home gardens; (ii) establishing field genebanks (seed/seedlings) and nurseries serving research and conservation efforts. This is the case of Rural Resources Centres' concept well-developed within ICRAF's framework in Cameroon by Degrande *et al.* (2013) and Takoutsing *et al.*, 2013; 2014). This concept focuses on farmer innovation and emphasizes access to knowledge, interactive learning and networking. Furthermore, emphasis should be directed on supporting local people with appropriate extension services and technology to properly use the species. Hence, a farmer-to-farmer extension approach which has also been founded by users as effective (Tsafack *et al.* 2015) can be promoted to strengthen such initiatives. Furthermore, this system should be made profitable to local people through linkage to market opportunities and transformation of their produce to value added fruit products under sound policy environment. With regard to this, *G. lucida* seeds were collected and sown for further integration in framers' nurseries. Furthermore, in the fulfilment of cultivars development for high quality planting material, these farmers later will be trained on propagation techniques such as grafting, leafy stem cutting and air-layering, especially for *P. johimbe* which has very small seeds only dispersed by wind.

Some of the solutions to overcome the issues of resources decline have been suggested by the respondents themselves, including: (i) sustainable use of resources through implementation of domestication initiatives; (ii) deforestation reduction and better climate management. Another valuable solution to lower local people's dependence and pressure on the wild forest products may also include provision of alternative income sources to local people through proper incentives as early stated by Alemagi *et al.* (2014).

The present study highlighted interesting relationship between the conservation of biodiversity and human health. Indeed in Africa, the reality that traditional management practices exist implies that efforts should be taken to strengthen famers on genetic resources conservation (Muchugi *et al.*, 2008). Thus, it is arguable that knowledge and the practice resulting from traditional management systems by local communities conform well to the philosophy of co-management, which advocates for involving all stakeholders, sharing power, responsibilities, rights, and duties between the state and the local resources

users (Dkamela, 2001; Kalaba *et al*., 2010; Larson *et al.* (2011); Nduwamugu and Munyanziza, 2012). In line with this argument, it is imperative for natural resources management and heath sectors to collaborate in research works that will generate sufficient information to improve the application of traditional practices in enhancing conservation of medicinal plants. Similar trend was found in Ethiopia by Yirga (2010) and in Uganda by Kamatenesi and Remigius (2002).

To optimize the use and sustainability of these genetic resources, it is necessary to: (i) assess the resources available in the rural populations' environment; (ii) promote the establishment of nurseries with high quality seeds/seedlings; (iii) promote the planting or maintenance of multipurpose species during forest clearance for shifting cultivation even though land tenure remains a major issue; (iv) strengthening and backstopping the organizational capacity of farmers; (v) vulgarizing simple techniques; (vi) support rural communities by helping them obtain the necessary little equipment for processing, packaging, storage and marketing of their products; (vii) encourage cultivation of medicinal plants and development sense of ownership of communities over the resources; and (viii) emphasize on development and implementation of appropriate management options and guidelines for sustainable harvesting of medicinal plants.

Conclusion

The survey highlighted population structure and traditional management patterns of *G. lucida* and *P. johimbe* among which the conservation of the foodstuffs and medicine were the most cited. The conservation of the species still timid, or in the worst of the cases non-existent among the local communities, because of lack of knowledge of appropriate techniques to be used. It was therefore necessary and urgent to develop a programme of participatory domestication of these threatened medicinal plants in the interest of the present and future generations. Thus, the resident communities have need to be sensitized on the true value of the multifunctional local genetic resources. Our findings may help to formulate a conservation strategy for the threatened vital plants of the southern humid forest of Cameroon. However, while the low and localized distribution of both suited species deserves effective conservation strategies; the scope of such measures should be explored in a way to address the reliance of local communities on these plants. Moreover, further studies on policy guidelines should be developed for sharing indigenous knowledge.

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Abbreviation

FCFA: CFA francs, where CFA stands for Communauté Financière Africaine (African Financial Community); 656 FCFA≈1€ and 500 FCFA≈1 USD.

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