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ETHNOBOTANIC ASSESSMENT OF DEBARKED MEDICINAL PLANTS IN SOUTHERN BENIN: THE CASE OF LOKOLI SWAMPY FOREST AND LAMA PROTECTED FOREST

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ABSTRACT

This study was focused on identifying medicinal plants species subject to bark harvesting in two forests of Southern Benin (Lama Protected Forest and Lokoli Swampy Forest). Ethnobotanical survey was conducted in nine surrounding villages of both forests. 261 survey participants of various socio-professional groups (traditional healers, bark collectors, farmers, and others) answered questionnaires. Collected data provided information about the species being debarked, diseases treated, the frequency and debarking methods applied as well as the people perception of their impact on the health of trees after debarking and the sustainable palliative debarking method applied or proposed by local population.

A total of 70 medicinal species belonging to 26 families were identified of which 26 bark species were mostly used. The use of tree bak was locality and socio-prefessional groups dependents as well as ethny, age and sex. Species with highest used score were: Khaya senegalensis, Anogeissus leiocarpa, Dialium guineense, Adansonia digitata, Mangifera indica and Diospyros mespiliformis in Lama Forest and Nauclea diderrichii, Bridelia ferruginea, Syzygium owariense and Ficus trichopoda in Lokoli Forest. The most important human diseases recorded were stomach pains, dysentery and frotalen. According to socio-professional groups, Traditional

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healers were mostly related in tree bark used in spirituality while Collectors harvested mainly species involved in commercialization.

Stakeholders with a negative impact on the resources seem to be collectors applying unsustainable debarking procedures such as tree logging or girdling. However, certain sustainable debarking method have been proposed such as cambium protecting (by collectors) and botanical gardens set up (by traditional healers).

Keywords: medicinal plants; bark, unsustainable debarking methods, diseases.

1. INTRODUCTION

Tropical forest ecosystems host at least two-thirds of Earth's terrestrial biodiversity and provide significant local, regional, and global benefits to humans through goods and services (Gardner et al., 2009). In developing countries, non-timber forest products (NTFPs) play an important role in the daily needs of local populations. These products are used as food, fuel, or medicinal plants, and are extremely important to households, especially during lean seasons. Medicinal plants contribute substantially to the well-being of local populations (Kokwaro, 1993; Sofowora, 1993). According to the International Union for Conservation of Nature and the World Wildlife Fund, there are between 50,000 and 80,000 flowering plant species used for medicinal purposes worldwide. In India, it is reported that traditional healers use 2,500 plant species and 100 plant species serve as regular sources of medicine (Siddalinga Murthy and Vidyasagar, 2013). For example, between 60 to 95% of Africans depend on medicinal herbs for their primary health care (Anyinam, 1995; WHO, 2000; Cunningham, 2000), and as many as 5000 plant species in Africa are used medicinally (Taylor et al., 2001). Therefore, it is important to know which factors affect the availability of medicinal plant products.

Global demand for herbal medicine is not only large, but also steadily growing (Nalawade, et al. 2003; Light et al., 2005; Cole et al. 2007). However, about 15,000 species are threatened with extinction from overharvesting and habitat destruction (Bentley, 2010) and 20 % of their wild resources have already been nearly exhausted with the increasing human population and plant consumption (Ross, 2005). Overexploitation is a growing problem for many medicinal species in Africa, where human population growth, lack of access to western medicine, poverty, and growing markets medicinal herbal with unsustainable harvesting practices (Cunningham, 1993; Anyinam, 1995;). Although there have been intensive efforts to identify medicinal plants and explore their biochemistry (Hage et al, 2010; Olurishe et al., 2013; Dedehou et al.2016), very few studies have investigated the most important actors which intensively impact on plant ecology and different harvesting method used by local population.

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Nowadays, the use of medicinal plant barks is becoming increasingly important, especially for species with high economic value. High levels of unemployment, rapid urbanization, and low levels of formal education among rural-to-urban migrants are some of the reasons behind the increasing trade in herbal medicine, especially in West Africa (van Andel et al., 2014). This results in over-harvesting of target species from both protected and unprotected areas, posing a major challenge to resource managers and this situation is worsened by missing of basic data on resource exploitation. In fact, it is difficult to develop mechanisms/recommendations for sustainable use of those resources and for forest protection.

In Benin, over-harvesting is a severe problem (Vodouhè, 2005; Déléké, 2010; Djego et al., b2011), especially in community forests where the local population has free access to the resources which leads to overexploitation (‘tradegy of the commons’, Hardin, 1968, Felipe et al. 2006b; Felipe et al. 2011). For example, the tree *Nauclea diderrichii* is a vulnerable species according to the IUCN red list because of unrestrained bark harvesting (Vodouhè, 2005). But also *Detarium microcarpum*, *Parkia biglobosa*, *Lannea kerstingii*, *Burkea africana* and *Afzelia africana* are highly sensitive to insect attacks subsequent to bark removal (Devaux et al., 2009). So, over-exploited species end up having shortened lifespans, in addition to reduction in numbers.

In order to assess the diversity of debarked medicinal plants in southern Benin together with the harvesting methods applied, we studied both a protected forest and a community forest to determine (i) the pattern of used of most debarked medicinal species, (ii) the different bark harvesting method used, (iii) the users perception on plant debarked impacts and (iv) different sustainable debarking methods used by local population.

2. MATERIAL AND METHODS

2.1 Study Area

This study was conducted in villages surrounding a community forest, the Lokoli Swampy Forest (979-ha; 7°02 to 7°05 N and 2°15 to 2°18 E), and a protected forest, the Lama Protected Forest (16,250 ha; 6°55' to 7°00’ N and from 2°04’ to 2°12’ E). Both forests belong to the same agro-climatic zone and are last remnants of the Dahomey gap. Yet while the former is a dense swampy forest with degraded vegetation, including-cultivated Macabo (*Colocasia esculenta*) (Araceae), the latter, is a dense semi-deciduous forest with a rich floral diversity (Sinsin et al., 2002; Dan, 2003, 2009; Adomou, 2009). Lokoli forest is a community forest with free access to resources while Lama forest is managed by foresters. Despite commencing decentralization in 2002 to decrease pressure on resources by fostering involvement of local officials in the management of community forests, Lokoli forest continues to suffer from over-harvesting.

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2.2 Study design

2.2.1 Ethnobotanic Survey

In nine villages surrounding Lama forest (Akpè, Koto, Massi, Agadjaligbo, Zalimè) and Lokoli forest (Koussoukpa, Lokoli, Dèmè, Samionta), structured and semi-structured interviews were carried out from September 2012 to February 2013 to identify the main tree species used to harvest tree barks. At least 30 informants per village have been interviewed. They included different socio-professional groups (Table 1), such as collectors (harvesting bark to sell it), Traditional healers (harvesting bark for medicinal purposes), farmers and others (craftsmen, housewives etc) from different socio-cultural groups (Fon, Holli and Aïzo). To recruit Traditional healers and collectors we relied on a snowball technique, to know where are recruits participated and answered the getting names of them. Farmers and others were randomly questioned. The first part of our questionnaire asked for socio-demographic details of the respondent. The second part addressed the purpose, harvesting method, harvesting frequency(daily, weekly, monthly etc.) and identity of trees bark-harvested, different diseases healed, the processing method (decoction, maceration etc.) as well as 'awareness' questions (e.g.do you remark some debarking impacts on the tree after harvesting?). Variables such as: *Sap Loss*, *Crown Decimation, Flowers Abortion, Leaves Loss, Insect Infection* and *Change Shape* were asked (for details see Table Annex 2). A total of 261 informants were interviewed during this survey, 104 from the Lama forest and 157 from the Lokoli forest. It is worthwhile mentioning that in the Lama forest people were less willing to participate, therefore we could not get higher sample sizes. Using data from the '*Institut National de la Statistique et de l'Analyse Economique*' (INSAE, 2004), the population sizes in the villages surrounding Lokoli forest and Lama forest were estimated to 1452 and 1919 inhabitants, respectively. Hence, the sample sizes correspond to 10.8% of Lama forest's and 5.4 % of Lokoli forest's inhabitants.

Table 1: Ethnobotanic survey sample

Forest	Professional groups				
	Traditional healers	Farmers	Collectors	Others	Total
Lama	7	48	0	49	104
Lokoli	30	60	23	44	157
Total	37	108	23	93	261

2.2.2 Data analysis

All statistical analyses were performed in R (R Core Team, 2014) and the significance level was set to $\alpha = 5\ \%$.

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Bark uses and tree species : The different diseases cited by respondents were ordered for each forest using the Fidelity Level (FL) of Friedman *et al.* (1986):

$$FL_j = 100 \cdot \frac{n_j}{N_f}$$

Where n_j is the number of respondents who reported the cure of a given disease using the bark of a given tree species j and N_f is the total number of respondents for each forest.

This was made in order to select tree barks which were cited for diseases with FL ≥ 5% and presented with processing method in healing disease. Fisher's exact test was used to test significant differences in bark uses in term of disease healed between Lama forest and Lokoli Forest. Patterns in bark uses (times a tree was mentioned) in the two considered forest types were assessed with Correspondence Factor Analysis (CFA) performed on professional groups and tree species involved in the cure of diseases.

Identification of most debarked tree species : We proceeded by weighting the response (as use score R) given by respondents as following: all plants harvested daily or weekly are scored as 5; plants used monthly or quarterly are weighted as 3 and those harvested biannual or annual are scored as 1. The use intensity (*UI*) for each tree species was determined as the average use score (*R*):

$$\mathrm{UI}_j = \frac{\sum_{i=1}^{N} \mathrm{R}_{ij}}{\mathrm{N}}$$

Where R_{ij} is the use score of the tree species j by the respondent i from a given group of sample size N.

In each forest, using Wilcoxon rank sum test ($UI_j \neq 0$), we tested in which forest tree species were more debarked . A cluster analysis was then performed to group the most important debarked species according to their UI_j values computed per professional group for each forest. Principal components analyses (PCA) was furthermore applied to the UI_j data to characterize relevant clusters in terms of professional group and forest.

Multiple comparison tests under Kruskal-Wallis rank sum test were then performed in the R library *agricolae* (de Mendiburu, 2014) to assess variations in harvesting score with respect to forest, ethnic group, age, sex and professional group.

Assessment of debarking method: A Correspondence Factor Analysis (CFA) was performed to highlight the use of bark according to professional group and harvesting method debarking method recorded during the survey.

Assessment of users' relative impact on debarked tree species and sustainable debarking methods used: The perceptions of plant bark users on the impact of debarking on trees were assessed using *Impact01* (yes/no) and six impact type variables namely *Sap Loss*, *Crown Decimation, Flowers Abortion, Leaves Loss, Insect Infection* and *Change Shape*. Generalized linear models (probit) were fitted to assess the variability of these seven binary perception variables against forest type, ethny, age, sex and profession. The R function *step* was used to reduce model through backward selection of model terms.

Furthermore, a Correspondence Factor Analysis (CFA) was performed to relate the use of sustainable debarking method according to professional group.

3. RESULTS

3.1 Pattern of medicinal bark used

3.1.1 Bark used and tree species

A total of 69 bark uses involving 70 different tree species were recorded belonging to 26 families. However, only 20 uses had a Fidelity Level (FL) ≥5 % and involved 26 tree species (Table 2). Most frequent bark uses concerned the treatment of stomach ache, involving mostly *Khaya senegalensis* (FL = 23.6 %) in Lama forest against mostly *Nauclea diderrichii* (FL = 62.4 %) and *Parkia biglobosa* (FL = 33.6 %) in Lokoli Forest (Table 2). A second spread bark use was for enhancing baby muscular tone, involving mainly *Anogeissus leiocarpa* (FL = 40.9 %), *Ficus trichopoda* (FL = 38.9 %) and *Pterocarpus erinaceus* (FL = 28.9 %) in Lokoli Forest (Table 2). Indeed, there were often significant differences in the FLs of specific bark uses in Lama forest and Lokoli Forest (Table 2), respondents using mainly different tree species bark for a given disease. Other very frequent uses were the treatment of dysentery which involved bark of *Syzygium owariense* (FL = 22.1 %) in Lokoli Forest and the treatment of frontalen which involved *Terminalia glaucescens* (26.4 %) in Lama forest (Table 2).

Results of a CFA showed that 73.1 % of the information about the distribution of bark uses among professional groups was summarized into a two dimensional space (Figure 1). Respondents from the Lama forest mainly used 12 of the 26 significantly used tree species and form the group G1 on figure 1 which shows some intra-group specificities for Traditional healers (main reporters of *Anogeissus leiocarpa* and *Khaya senegalensis* uses) and farmers (main reporters of *Diospyros mespiliformis, Terminalia glaucescens* and *Afzelia africana* uses).

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Two main groups were identifiable in Lokoli Forest: group G2 gathered Traditional healers who mainly used *Ficus trichopoda, Zanthoxylum xanthoxyloides, Bridelia ferruginea, Ficus exasperate, Spondianthus preussii* and *Alstonia congensis*; bark collectors, farmers and other respondents form the group G3 and mostly used *Lannea microcarpa*, *Kigelia africana* (which were mainly for bark collectors), *Parkia biglobosa, Pterocarpus erinaceus, Syzygium owariense, Nauclea diderrichii* and *Anacardium occidentale* (which were mainly for farmers and other respondents).

3.1.2 Most debarked tree species

Among the 70 recorded tree species, 40 had significantly non null use intensity ($UI_j \neq 0$) in at least one forest type. UI_j values per professional group allowed distinction of four tree species clusters with 82.68 % of information conserved (dendrogram on figure 2). The first cluster (CL1) gathered six tree species (*D. guineense, K. senegalensis, A. leiocarpa, A. digitata, M. indica* and *D. mespiliformis*) which are the most used in Lama forest with use average intensity UI = 0.61. CL4 gathered four tree species (*B. ferruginea, N. diderrichii*, *S. owariense* and *F. trichopoda*), the most used in Lokoli forest (average UI = 1.37). Six tree species (*P. erinaceus, K. africana, A. occidentale, L. microcarpa, P. biglobosa* and *T. glaucescens*) were retained in the second cluster (CL2). With CL1, CL2 forms a tree species group with intermediary average use intensity in Lokoli Forest (UI = 0.44 for CL1 and UI = 0.43 for CL2). The third cluster (CL3) gathered the less used tree species (average UI<0.1) in Lama forest and/or in Lokoli Forest. Results of Principal Component Analysis showed that 83.77 % of the variability in use intensity of species in clusters CL1, CL2 and CL4 was summarized into a two dimensional space. Figure 3 shows Traditional healers and collectors are main users of bark, other professional groups showing lowest UI values. Tree species of CL1 were mainly used by Traditional healers: five species namely *D. guineense, K. senegalensis, A. digitata, M. indica* and *D. mespiliformis* were mainly used by Traditional healers in Lama forest whereas the sixth species (*A. leiocarpa*) was intensively harvested by mainly Traditional healers in Lokoli Forest. All species of CL2 and CL4 were intensively harvested mainly by collectors in Lokoli forest. It is worthwhile noticing that even if in the same professional group, Traditional healers from different forest zones used to harvest different tree species.

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Table 2. Processing method and Fidelity Level (FL) of 19 bark uses (FL≥5%) involving 25 tree species in Lama Protected Forest and Lokoli Swampy Forest

Disease	Treespecies	Processing method	FL (%)	
			Lama	Lokoly
Baby Purgative	*Terminalia glaucescens*	Decoc.	8.2	-
Aneamia	*Anogeissus leiocarpa*	Decoc.	5.5	-
	Ficus trichopoda	Decoc.	-	8.1
	Khaya senegalensis	Decoc.	-	8.1
	Lannea microcarpa	Decoc.	0.9	8.1
	Mangifera indica	Powder,Decoc.	16.4	11.4*
	Pterocarpus erinaceus	Decoc.	1.8	8.1
Baby infection	*Bridelia ferruginea*	Decoc.	0.9	6.7
	Parkia biglobosa,	Decoc.	-	8.7
	Maranthes polyandra	Decoc.	-	5.1
Baby muscular tone	*Anogeissus leiocarpa*	Macer.,Decoc.	11.8	40.9
	Ficus trichopoda	Decoc.	0.9	38.9
	Khaya senegalensis	Decoc.	0.9	6.0
	Mangifera indica	Macer.,Decoc.	9.1	3.4*
	Pterocarpus erinaceus	Decoc.	2.7	28.9
	Spondias mombin	Decoc.	5.5	-
	Syzygium owariense	Decoc.	-	19.5
Baby thinness	*Adansonia digitata*	Macer.,Decoc.	14.5	18.1*
	Bridelia ferruginea	Decoc.	0.9	9.4
	Lannea acida	Decoc.	8.2	12.1*
Charm	*Afzelia africana*	Macer.	8.2	1.3
	Milicia excelsa	Macer.	9.1	-
Constipation	*Anacardium occidentale*	Decoc.	2.7	6.7*
	Kigelia africana	Decoc.	8.2	0.7
Cough	*Acacia polyacantha*	Decoc.	5.5	-
	Anacardium occidentale	Decoc.	3.6	12.1
	Anogeissus leiocarpa	Powder,Decoc.	8.2	0.7
	Mangifera indica	Decoc.	3.6	9.4*
Cyst	*Nauclea diderrichii*	Decoc.	-	6.7
Diarrhoea	*Ficus exasperata*	Decoc.	-	7.4
Dysentery	*Anogeissus leiocarpa*	Powder,Decoc.	9.1	1.3
	Syzygium owariense	Decoc.	0.9	22.1
Dysmenorrhae	*Khaya senegalensis*	Macer.,Decoc.	10.0	4.0*
Fever	*Maranthes polyandra*	Decoc.	-	16.5
	Khaya senegalensis		5.8	2.5*
Frontalen	*Ficus trichopoda*	Decoc.	-	8.1
	Terminalia glaucescens	Macer.,Decoc.	26.4	3.4
Icterus	*Diospyrosmespiliformis*	Macer.,Decoc.	9.1	4.7
Malaria	*Acacia mangium*	Decoc.	8.2	-
	Alstonia congensis	Macer.,Decoc.	-	8.1
	Dialium guineense	Decoc.	1.8	5.4
	Khaya senegalensis	Macer.,Decoc.	8.2	4.0
	Mangifera indica	Macer.,Decoc.	15.5	12.1
	Nauclea diderrichii	Macer.,Decoc.	-	8.7
Stomach ache	*Khaya senegalensis*	Macer.,Decoc.	23.6	8.1

	Nauclea diderrichii	Macer.,Decoc., Manduc.,	2.7	62.4
	Parkia biglobosa	Manduc.,Decoc.	-	33.6
	Spondianthus preussii	Decoc.	0.9	5.4
	Spondias mombin	Decoc.	5.5	0.7
Tooth decay	*Zanthoxylum xanthoxyloides*	Manduc.	-	11.4
Ulcer	*Bridelia ferruginea*	Decoc.	-	8.1
	Nauclea diderrichii	Decoc.	0.9	6.0
	Syzygium owariense	Decoc.	-	5.4
Wound	*Parkia biglobosa*	Macer.,Decoc., Poultice	0.9	8.1

Decoc. = Decoction; Macer. = Maceration;Manduc. = Manducation; Upperscript (*) indicates that Fidelity Level in Lama forest and Lokoli forest are not significantly different at 5 % level (Fisher's exact test).

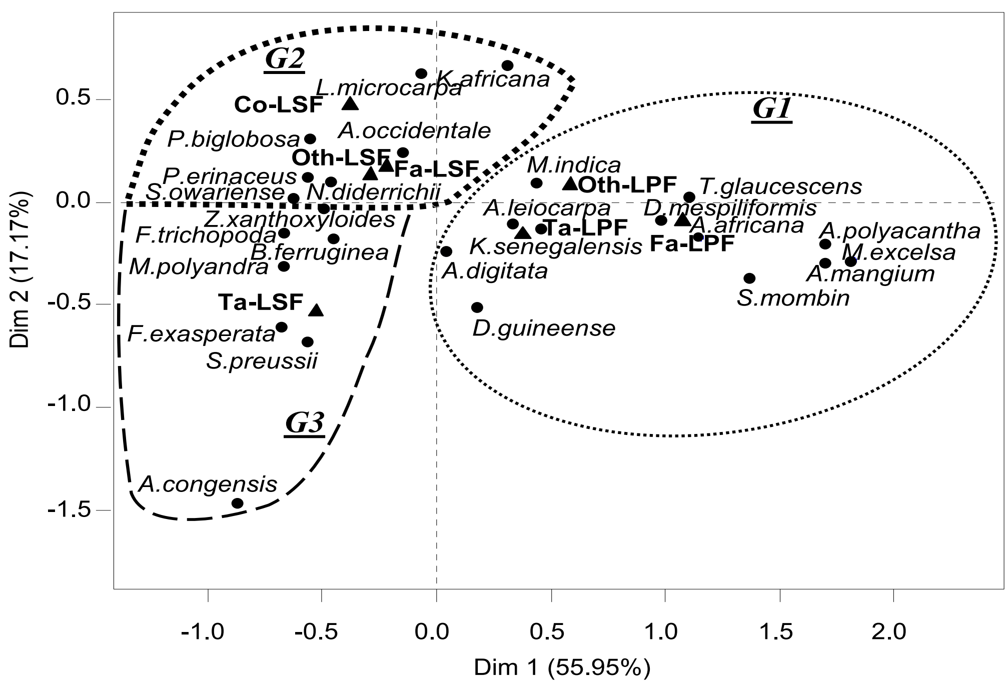

Figure 1. Factor Correspondence Analysis on tree species debarked and professional groups. Co: collectors, Fa: farmers, Tp: Traditional healers, Oth:other.

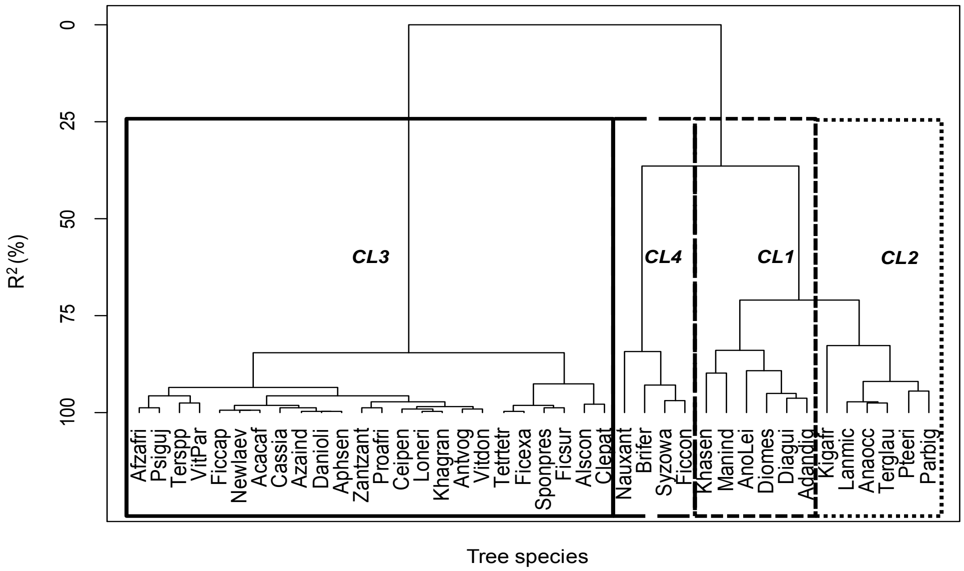

Figure 2. Dendrogram of significantly used tree species clustered according to use intensity by professional group (*CL1* = cluster 1; *CL2* = cluster 2; *CL3* = cluster 3; *CL4* = cluster 4)

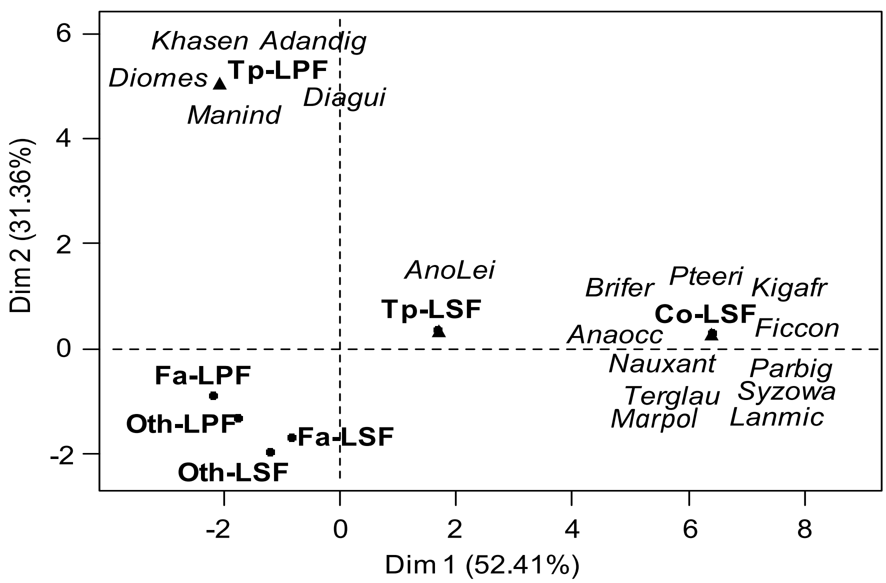

Figure 3. Projection of professional groups in the principal space of PCA.

Tree species were added to reflect correlations between principal components (Dim.) and species *UIj* data; Khasen = *Khaya senegalensis*, Diomes: *Diospyros mespiliformis*; Diagui: *Dialium guineense*; Adandig: *Adansonia digitata*; Manind: *Mangifera indica*; Anolei: *Anogeissus leiocarpus*; Brifer: *Bridelia ferruginea*; Pteeri: *Pterocarpus erinaceus*; Kigafr: *Kigelia africana*; Anaocc: *Anacadium occidentale*; Ficcon: *Ficus trichopoda*; Nauxant: *Nauclea diderrichii*; Parbig: *Parkia biglobosa*; Terglau: *Terminalia*

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glaucesens; Syzowa: *Syzygium owariense*; Lanmic: *Lannea microcarpa*. Co = collectors, Fa = farmers, Tp = Traditional healers, Oth = other, LPF = Lama Protected Forest and LSP = Lokoli Swampy Forest

According to socio-professional group, locality, age, sex and ethny, results of Kruskall-Wallis tests (Table 3) showed that use score did not vary significantly between forest types (Prob = 0.0761) but it did vary with respect to ethnic group (Prob = 0.0216), age (Prob = 0.0458) and professional group (Prob = 0.0001). Moreover, significant interactions were detected between ethny and age; and between professional group and all other factors, namely forest type, ethny, age, and sex (Prob = 0.001).

SNK tests showed that mean use score was higher for Aizo people (3.50 ± 0.25) than for Holli (2.86 ± 0.07; Prob = 0.0115) and Fon (2.88 ± 0.08; Pro = 0.0063) people. Also, elders showed a higher mean use score (3.05 ± 0.09) than young people (2.8 ± 0.08; Prob = 0.0456). Collectors showed the highest mean use score (4.91 ± 0.09) far above mean use score of Traditional healers (2.95 ± 0.12; Prob = 0.001). Traditional healers' mean harvesting scores was not different from farmers's one (2.77 ± 0.07; Prob = 0.2322). Other respondents had lowest mean harvesting score (2.59 ± 0.08), lower than Traditional healers' one (Prob = 0.0131) but not different from farmers' one (Prob = 0.0699).

Figure 4a shows that use score is homogenous within young people whereas within olds, Aizo people showed greater mean harvesting score (3.00 ± 0.30) than Holli (2.83 ± 0.11; Prob = 0.0079) and Fon (2.78 ± 0.09; Prob = 0.0037) people. Figure 4b shows that use score is homogenous with respect to forest type within all professional groups except Traditional healers who showed greater mean harvesting score in LSP (3.07 ± 0.12) than in Lama forest (2.43 ± 0.37; Prob = 0.0347).

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Table 3. Results of Kruskall-Wallis rank sum tests: variation of use score with respect to forest type, ethny, age, sex and professional group

Source of variation in harvesting Score	Degree of freedom	χ^2-statistic	Prob
Forest type	1	3.14	0.0761
Ethny	2	7.67	***0.0216***
Age	1	3.99	***0.0458***
Sex	1	0.15	0.6944
Professional group	3	108.99	***0.0001***
Forest type*Ethny	5	10.02	0.0748
Forest type*Age	3	5.96	0.1137
Forest type*Sex	3	3.42	0.3314
Forest type*Professional group	6	115.23	***0.0001***
Ethny *Age	5	13.17	***0.0219***
Ethny *Sex	5	8.12	0.1497
Ethny *Professional group	10	117.00	***0.0001***
Age*Sex	3	6.98	0.0725
Age*Professional group	7	110.22	***0.0001***
Sex*Professional group	6	109.17	***0.0001***

* denotes interaction term; Prob = P-value; italic bold figure in Prob indicates significance at 5 % level

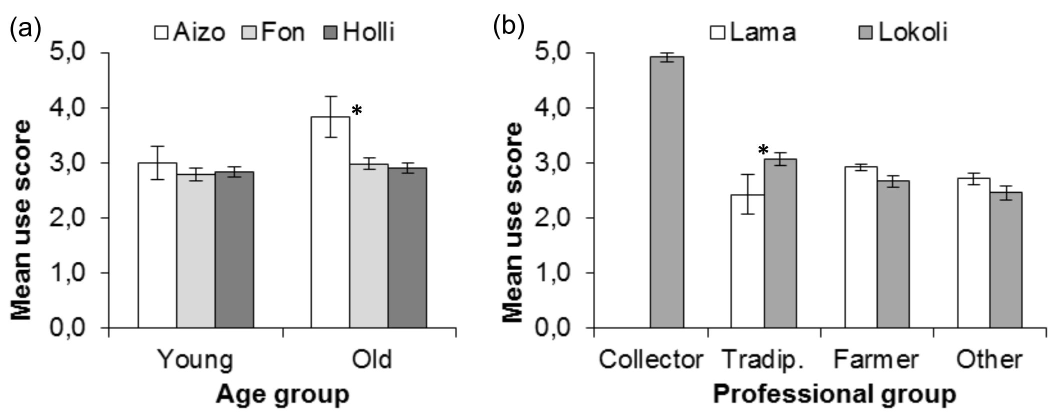

Figure 4. Mean use score of ethny by age group (a) and forest type by professional group. Tradip. = Traditional healers * mean harvesting scores separated by an upperscript (*) are significantly different at 5 % level;

3.2 Use of debarking methods

Respondents used various harvesting techniques to debark trees, including *Partial* debarking techniques (Two-Sizes: debarking at two opposite sizes of stem, One-Size*:* bark harvesting at

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one size of the trunk), *Girdling* (debarking of 100% of the trunk circumference), *Cutting-Down* (to cut the tree down before debarking) and *Other Techniques* (point picking with rituals). A Factor Correspondence Analysis allowed to represent debarking method and professional groups per forest type in a two dimensional space accounting for 99.79 % of the total variability. The factor map (figure 5) shows that *Partial* debarking and *Other* Techniques were indifferently used by Traditional healers, farmers and other respondents whereas collectors used more often *Cutting-down* and *Girdling* methods.

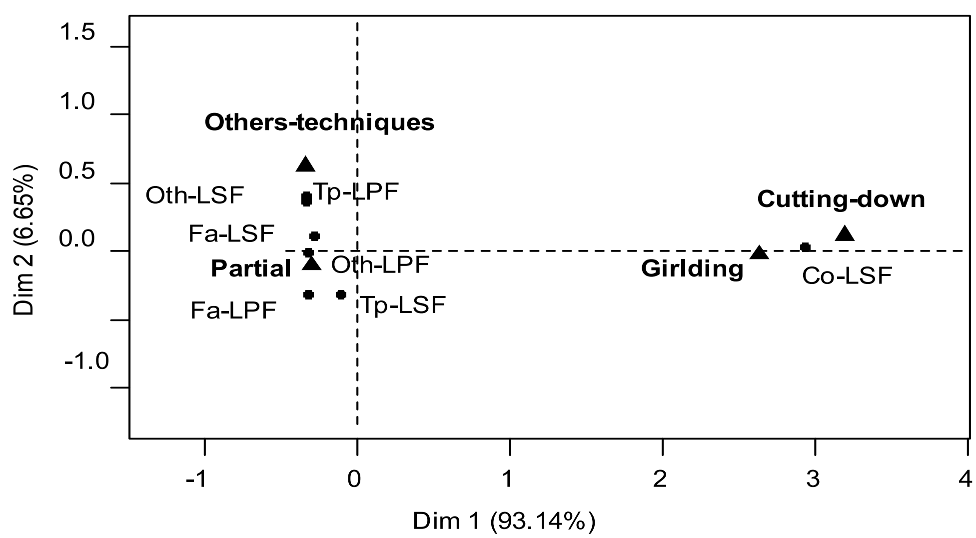

Figure 5: Factor Correspondence Analysis on debarking techniques and professional groups of respondents in Lama Protected Forest (Lama forest) and Lokoli Swampy Forest (LSP). Co = collectors, Fa = farmers, Tp = Traditional healers, Oth = other

3.3 Users' perception on impact of debarking on trees

More than half of respondents (54 %) indicated that debarking affected trees. Results from probit analysis showed that respondents' perception on whether debarking impacts trees varied significantly across forest types (Table 4; Prob = 0.001), ethnic groups (Prob = 0.0105) and professional groups (Prob = 0.0022) whereas variations with respect to sex or age was not significant. However, differences between sex groups of a given ethny varied significantly across ethnic groups (Prob = 0.0038). Indeed, Odd ratio (women/men) was significantly less than one for Holli people (OR = 0.62; Prob<0.05) whereas it equaled one for Fon (OR = 1.14, Prob>0.05) and Aizo (OR = 0.41; Prob>0.05) people (Figure 6a). Furthermore, variation across forest types for a given professional group was significantly different across professional group (Prob = 0.0080). Indeed, whatever the forest type, most of farmers and other users (> 50 %) recognized to impact trees through debarking, with a greater percentage in Lama forest (about 72 %) than in

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LSP (about 54 %). On the contrary, whereas a large majority of Traditional healers from Lama forest (86 %) recognized to impact trees, only a few people among Traditional healers (17 %) were aware of their impact on debarked trees in LSP (Figure 6b).

Table 4. Results of GLM on perception of respondents on whether debarking impacts trees

Term	Forest	Ethny	Sex	Profession	Forest*Sex	Ethny*Sex	Forest* Profession
Resid.Df	259	257	256	253	252	250	248
Resid.Dv	334.14	325.03	324.49	309.91	309.91	298.78	289.13
Prob	***0.0001***	***0.0105***	0.4634	***0.0022***	0.9708	***0.0038***	***0.0080***

* denotes interaction term; Resid.Df = residual degree of freedom; Resid.Dv = residual deviance; Prob = P-value; italic bold figure in Prob indicates significance at 5 % level

Figure 6. Percentage (%) of respondents who recognized to impact trees through debarking

Tradip. = tradipractitioner; Percentage with upperscript (*) are different at 5 % (Fisher's exact test)

Many effects of debarking were indexed by respondents who recognized to impact trees. The most reported was *sap loss* (92 % of respondent in Lama forest and 69 % in Lokoli Forest) far from *insect attack* (13 % in Lama forest and 29 % in Lokoli Forest) and *leaves loss* (2 % in Lama forest and 17 % in Lokoli Forest); *change of tree shape* (2 % and 16 %); *crown decimation* (10 % in Lokoli Forest) and *abortion of flowers* (5 % in Lokoli Forest). Results of probit analyses showed that the importance of all those perceptions on impact of debarking varied across forest types and professional groups (Table 5; Prob<0.05), except importance of *change of tree shape* which did not vary across professional groups. The sex of respondents also affected significantly perceptions about *sap loss* (Prob = 0.0210), *Crown decimation* (Prob = 0.0350), and *Change of tree shape* (Prob = 0.0084) and influenced variations of perceptions about *Insect attack* across

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forest types (Prob = 0.0457). Ethny and age did not affect perceptions, but age did influence variations across professional groups (Prob = 0.0178).

Table 5. Results of GLM on perception of respondents of their impact on debarked trees

RDF = Residual degree of freedom, RDev = Residual deviance, Pro = P-value, Prof. = professional group

Impact	Term	Forest	Ethny	Age	Sex	Prof.	Forest*Sex	Age* Prof.
Saploss	RDF	117	-	-	116	113	-	-
	RDev	106.44	-	-	101.10	81.79	-	-
	Prob	***0.0010***	-	-	***0.0210***	***0.000***	-	-
Crown decimation	RDF	117	-	-	116	113	-	-
	RDev	38.58	-	-	34.14	24.82	-	-
	Prob	***0.0028***	-	-	***0.0350***	***0.0253***	-	-
Abortion of flowers	RDF	117	-	-	116	113	-	-
	RDev	23.61	-	-	21.47	13.32	-	-
	Prob	***0.0361***	-	-	0.1427	***0.0431***	-	-
Leaveloss	RDF	117	-	116	-	113	-	110
	RDev	63.53	-	63.50	-	52.05	-	41.95
	Prob	***0.0017***	-	0.8524	-	***0.0095***	-	***0.0178***
Insect attack	RDF	117	-	-	116	113	112	-
	RDev	117.57	-	-	114.26	103.63	99.61	-
	Prob	***0.0289***	-	-	0.0689	***0.0137***	***0.0457***	-
Change of tree shape	RDF	117	115	-	114	-	-	-
	RDev	60.27	54.72	-	47.78	-	-	-
	Prob	***0.0038***	0.0625	-	***0.0084***	-	-	-

3.4 Use of sustainable debarking methods

The awareness of surrounded forest population on the use of some sustainable debarking methods was tested. Essentially five different sustainable debarking methods such as: "*partially bark harvesting*" (one size; two size/four), "*unnalated*" (avoiding harvesting on 100% of the circumference of the tree), "*uncut*", "*Botanic garden*" and "*unwounded cambium*" were identified (Fig 7). From the FCA, it clearly appeared that sustainable debarking methods proposed depend on professional group. In Lama forest, people proposed that it better to harvest tree bark partially than girdling while in Lokoli Forest, tradiprationers suggested establishing botanic garden of medicinal tree species instead of harvesting wild trees species. Collectors thought that harvesting without wounded cambium would allow tree for highly healing by bark recovering as well as avoiding tree cutting.

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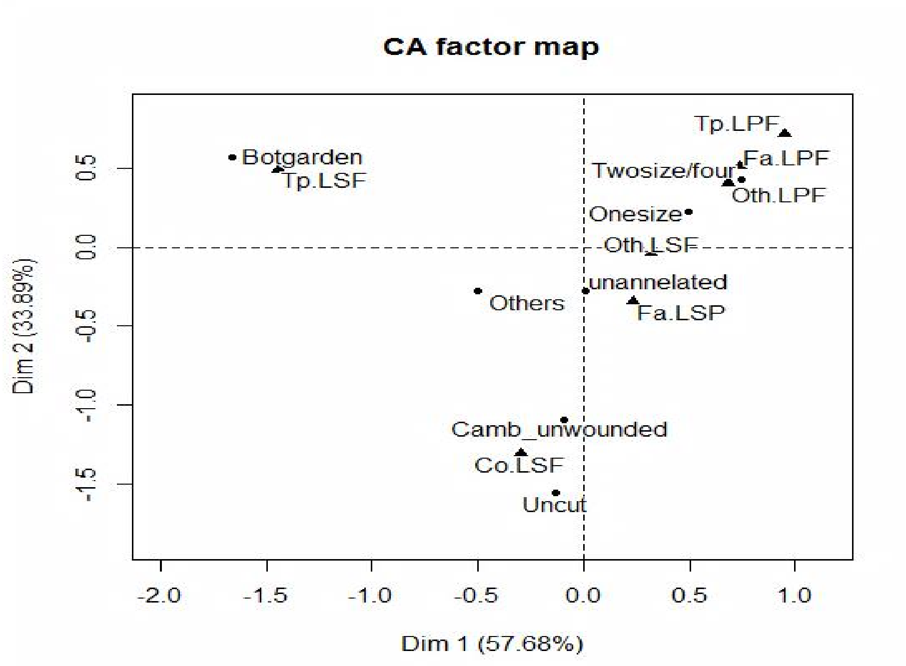

Figure 7. Factor Correspondence Analysis of sustainable debarking techniques and professional groups of respondents in Lama Protected Forest and Lokoli Swampy Forest. Co = collectors, Fa = farmers, Tp = Traditional healers, Oth = other.

4. DISCUSSION

4.1 Pattern use of tree bark by Lama Protected Forest and Lokoli Swampy Forest's surrounded population

The number of bark uses (69) and the species richness (70) of tree bark debarked for treatments of diseases are an indication of the rich tree diversity in the study area. In South Africa and Ghana countries for example, less diversity of tree bark were recorded (Tshisikhawe et al, 2012; Addo-Fourjour et al. 2008). Through this study, the use of tree species (in term of diversity and frequency) was locality and socio-professional groups dependents. For treating diseases, local population of both forest used differently tree barks for the same disease. One of the variables generally considered when explaining the traditional use of plants is their ecological availability (Menendez-Baceta et al. 2015). According to the "ecological apparency" hypothesis, the more apparent or salient a species is, the more likely that it will be used (Lucena et al., 2007). This means that surrounded forests inhabitants are accustomed to using the resources in their immediate environment (Medihoui et al. 2007, Vodouhè, 2009). Along this line, Diboug (2011) has argued that the diversity of species used by the people is correlated with how close they are to the lands where those species grow. While some studies seem to validate this hypothesis

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(Lucena et al., 2007; Thomas et al., 2009), others not (Silva and Albuquerque, 2005; Pardo-de-Santayana et al., 2007). Furthermore, a recent study shows that depending on the category of use, both statements can be true (Guèze et al., 2014). Inside of the same locality, there is a difference in using the tree bark according to socio-professional groups. Thus, while traditional healers essentially harvested *K. senegalensis*, *A. leiocarpus*, *D. guineense*, *A. digitata* and *M. indica* in Lama Forest, Farmers and others were used to debarked *D. mespiliformis, T. glaucescens* and *A. Africana* etc. In Lokoli Forest, Traditional healers mostly harvested *A. leiocarpus*, *F trichopoda, Z. xanthoxyloides, B. ferruginea, F. exasperata, S. preussii* and *A. congensis* while Collectors and others one debarked *L. microcarpa*, *K. africana*, *P.biglobosa, P. erinaceus, S. owariense, N. diderrichii* and *A. occidentale.* Tree barks mainly harvested by traditional healers were those ones which are used in Spirituality such as *F. exasperate*, *S. preussii* and *A. congoensis* whereas those harvested by Collectors were involved in medicinal plant bark trade.

It was clearly appeared that both surrounded forest villages used tree barks mainly against stomach pain, baby muscular tone, dysentery and frontalen. However they used differently tree barks for healing those aliments. While *K. senegalensis* was reported to be used in healing stomach ache in Lama Forest, *N. diderrichii* and *P. biglobosa* were used against this disease in Lokoli Forest. Our results are in line with Ambe et al, 2015 who recorded *K. senegalensis, P. biglobosa and N. diderrichii* as mostly harvested by local population. In Nigeria, the bark of *K. senegalensis* was reported to be mostly used against anemia (Adjadohoun et al, 1991). Globally bark of *K. senegalensis* was reported to heal more than 40 human diseases in West Africa (Adjadohoun et al, 1991; Astor et al, 1992; Asase et al, 2005; Orendu et al. 2016). This situation increases human pressure on the present species. Concerning *P. biglobasa,* Ghanaians used its cloves in healing stomach pain (Blench, 2006) and its bark was used against osteoarthritis, ache, lumbago etc. It shows that different plant parts of medicinal plant could be used in treating the same disease and indicates by the same time the diversity on uses of medicinal plant. Base on this, pharmacological analysis are very important for selecting which plant part harvesting could be more sustainable for tree species in order to decrease threat on wild medicinal plant. In West Africa, bark of *P. biglobosa* is used in healing more than 60 aliments (Malgras, 1992; Grønhaug et al, 2008; Adamu Harami, 2005). As for *N. diderrichii*, while it is used mostly against stomach ache and ulcer in West Africa, in East Africa the bark of this species was reported to heal nervous troubles (Mbuta et al, 2012). In the literature, it has been revealed the presence of anthraquinones carbohydrates, flavonoids, glycosides, saponins, sterioids, tannins, and terpenes in *K. senegalensis* (Olurishe et al., 2013) and in *P. biglobosa* (Hage et al, 2010; Dedehou et al.2016). Some of these phytochemical constituents such as flavonoids, tannins, terpenoids, and saponin have been reported to have possible gastro-protective effects (Arumugam et al., 2011; Balamurugan et al., 2013). In *N. diderrichii* bark, eleven single saponines were found (Lamidi et al. 1999). So besides ecological factors, a number of researchers have shown that chemical

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factors could be used in explaining the use of given medicinal species by human communities (Jain, 2004; Leporatti and Ghedira, 2009).

Through results found, Collectors were the most important bark harvesters in therm of frequence of collect followed by traditional healers. As Collectors are involved in tree bark trade, they debarked almost daily to maximize their profit. Furthermore, the use score of tree bark depends also on ethny, age and sex of respondents. Aïzo debarked more than Holli and Fon so they are mostly involved in the trade of tree bark. Moreover, young people harvested tree bark lower than old men. This can be explained by the fact that old people are more invested in used of tree bark and are more knowledgeable in term of use of medicinal plants than young. This result is similar to those obtained in ethnobotanical studies realized in Africa (Benkhnigue et al. 2010, Rhafouri et al.2015). The knowledge of utilization of medicinal plant and their properties is overall acquired further to a long experience cumulated and assigned from one to another generation (Medihoui et al. 2007). As suggested by some authors, cultural variables such as languages, ethny, beliefs and religion are essential in explaining the use medicinal plants by local population (Maffi, 2005, Ellen, 2009; Saslis-Lagoudakis et al., 2014; Pieroni and Quave 2005; Pieroni et al. 2011; Rexhepi et al., 2013).

4.2 Debarking method and impact on medicinal plant species

Collectors were not only the most important harvesters of tree barks, but they also used the most destructive debarking method such as girdling while Traditional healers, farmers and other ones used partial harvesting bark method by avoiding girdling. Our results are consistent to those of Makoe (1994) and Gustav et al., 2004 who recognized that as long as people harvest only what they need for treatment, a balanced ecosystem may be maintained leading to sustainable harvesting of the natural resources. However, when there are some marketable species, it's noted all overstatement of their use, thus resulting in overexploitation of the species. This leads to more extraction of medicine from wild stocks. A lot of research carried out in this field has assumed that ring barking, by completely removing a strip of bark around a tree's circumference, may lead to more or less immediate tree death (Geldenhuys *et al.* 2007; Vermeulen 2009; Delvaux, 2009; Purohit, 2001; Maundu et al, 2006; Muchugi et al., 2008; Stewart 2009; Catry, 2012; Kairu 2013, Vuyiya et al. 2014). Though more than half per cent of respondents recognized negatively impacting on tree species by debarking, their impact perception was only focused on loss of sapwood. Other impacts such as attacks of insects, loss of leaves, change of tree shape, crown decimation and flowers abortion were very few cited. However, Vuyiya et al, 2004 demonstrated that debarking correlated with canopy surface area and seedling density loss. Furthermore, Adomou et al, 2008 have noted the change in shape on *N. didderrichii* due to debarking in Lokoli Forest. Kairu et al. 2013 found that human activities caused the highest amount of threats

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to tree species while debarking was the most damaging form of threat. Some tree species was demonstrated to be negatively affected (insect attacks) by bark harvesting such as *K. africana* in Mozambic (Senkoro et al. 2014); *P. biglobosa* in Benin (Delvaux et al. 2009).

The present situation is worsened by the free access character of Lokoli Forest where a resource harvesting is not controlled by any real institution. This could be compared to what was qualified by Hardin, (1968) and Filipe et al, 2011 as "Tragedy of commons". Hardin (1968) argued that people are in systems that encourage them to increase, as much as possible, the exploitation of limited resources – a situation that leads to ruin for all. Hardin futher argued that the sulutions to the problems of resource depletion and degradation are not technical but rather lie in governmental control and regulation of resource use and suggested privatization as an optimal solution capable of avoiding the ruin for all (Berkes et al., 1989). But as explained by Mongbo, 2008, the management of Lokoli forest suffers from leadership as all institutions such as local population, local authorities from decentralization and foresters were fighting for it governance. From these results, it appeared that the most important human pressure on natural resources occurs in Lokoli Forest where the access is free to everybody, highlighted by bark collectors who are involving in bark commercialization and used destructive bark collecting method. But, in surrounded Lama Forest, local population is more aware of negative impact of debarking than those of Lokoli forest. This could be explained by the fact that they are living in protected area where State forest administration intervenes through committee inspection and population periodic awareness. However, it remains some unlawful use of resources in Lama Forest that is confirmed by Vitoule et al, 2014. According to Paré et al. 2009, human activities, in particular unlawful use, are considered a major threat to the future of the tropical forest reserve. Therefore, sustainable uses strategies are required to help surrounding people sustain their livelihood.

4.3 Use of sustainable debarking methods

Some sustainable debarking methods were however proposed by respondents. 100% of the interviewed traditional healers from Lokoli forest mentioned that botanic gardens are very important and will enable to decrease the pressure on the tree resources in the wild ecosystem while those from Lama forest suggested harvesting bark on small patch of the tree is better than one big part of harvesting so that it offers more surfaces of recovering to the tree (confirmed by Guedje et al. 2009). In other countries of Africa like Cameroun, Kenya and Nigeria, for palliating in the pressure on medicinal trees, they developed a conservation strategy that provides herbalists seeds of the medicinal trees to grow on their farms (Sunderland et al. 2002, Idu et al. 2010, Vuyiya et al.2014). However in Ghana and Uganda, traditional healers do not accept collecting medicinal plant in botanic garden (Okello and Ssegawa, 2007, Addo-Fordjour 2008). According to them cultivated medicinal plants are of less therapeutic efficacy compared to wild harvested plants. Despite the fact that majority of collectors girdling tree species, some of them

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suggested that avoiding injuring tree cambium will allow trees to faster recover. It is important to highlight that this sustainable debarking method was proposed by old women who were involved in bark commercialization.

Since the 1970s, non-timber forest products (NTFPs) have emerged to take their place among the many aspects of forest use that guide natural resource decision-makers (Sunderland et al.2004). The attention of both the conservation and the social development communities was captured, and it was put forward that through the harvest of NTFPs, the forest peoples of the world might capture valuable income and social benefits, whilst the aim of conserving of natural forests was achieved. But this trend is not often observed. This optimism, however, was based on exaggerated claims of economic potential which were often over-simplistic assessments of 'value' (Southgate et al. 1996) and a limited evaluation of the complexity of economic, social and market oriented issues surrounding the NTFP category (Lawrence 2003). The exploitation of wild-sourced NTFPs can be sustainable but this requires first an understanding of the plant's growth and reproductive characteristics and the application of harvesting practices that permit adequate reproduction or regeneration of the individual organism (Sunderland et al. 2004). Concerning debarked tree species, in context of growing world population, demand will ultimately intensify the pressure on wild populations and they may become exhausted. For taxa with a limited geographic range such as *N. diderrichii, S. owariense* and *F. trichopoda*; this exploitation will have serious impact on the wild population especially because of their particular habitat type. From this study, two medicinal plant groups were clearly appeared. The first group concerns trees species which barks are harvested with sustainable methods for only personal needs with low human pressure and the second group concerns those one involved in bark trade with high human pressure. Although the trade of these species could allow traders to get substantial revenue, debarking methods used by harvesters were not sustainable and the impact of this trading is prejudicial for tree species which may lead to the destruction of resources structures. Between these tree species, *K. senegalensis*, *N. diderrichii*, *P. erinaceus* are endangered and *K. africana*, is vulnerable species (Red list of Benin, 2011), so they are multipurpose tree species. Therefore their intensively use without replanting or without using sustainable harvesting technique may conduct to their extension. According to Newton, (2008), the following five conditions require to be met when it comes to conciliate exploitation and conservation of NTFP: (1) NTFPs harvesting of forest products must be sustainable, (2) harvesting of forest products must not interact positively with other threats; (3) commercialization of the forest product must be economically viable; (4) the economic benefits from commercialization must be received by those harvesting the wild resource; (5) the income received from commercialization must act as an incentive to conserve the tree species being harvested. In order to raise awareness among the population in the area, it is important to:

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- Campaign to raise awareness among bark collectors all the while involving older women who are knowledgeable about harmless debarking techniques. This could help them continue their business while preserving the resources by choosing resistant tree species;

- Involve local officials in the management of those resources for regulating access to resources;

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