International Journal of Innovation and Applied Studies
ISSN 2028-9324 Vol. 25 No. 1 Dec. 2018, pp. 149-161

http://www.ijias.issr-journals.org/

Economic assessment of medicinal plants debarked by riparian population of Lokoli swampy forest (Southern Benin)

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ABSTRACT: The relevance of Non-Timber Forest Products (NTFPs) to community members no longer needs to be proven; these resources contribute mainly to nutrition and health care in many rural areas in Africa. This study aims at identifying medicinal plant species subject to tree bark commercialization in the Lokoli swampy forest and its surrounded farmlands located in southern Benin (West Africa). We analyzed the economic profitability of medicinal tree bark. Three groups of collectors were identified: G1 sells bark locally (G1), G2 at medium-distant markets (< 50km) and G3 at distant markets (> 50 km).
We identified a total of 17 medicinal plant species belonging to 13 families of which 11 tree bark species were commonly recorded: *Anogeissus leiocarpa*, *Bridelia ferruginea*, *Khaya senegalensis*, *Kigelia africana*, *Lannea acida*, *Maranthes polyandra*, *Nauclea diderrichii*, *Parkia biglobosa*, *Pterocarpus erinaceus*, *Syzygium owariense* and *Terminalia glaucescens*. The net income as well as the economic profitability depended on the group to which collectors belonged. Bark collectors make returns from 31.7±5.45 to 319.0±26.35$ US, annually. The economic profitability ranged from 23% to 54% of the invested costs. The break-even point and safety margin were higher for G3 than G1 and G2 collectors. Similar results were registered for net income and profitability. The most valuable tree bark species were *K. africana, M. polyandra, S. owariense,* and *K. senegalensis*.

KEYWORDS: medicinal plants; plant bark; net income, economic profitability; safety margin.

1 INTRODUCTION

Besides timber, forests contain many Non-Timber Forest Products (NTFPs) which are useful goods and services of commercial value for people [1]. Over the past few decades, NTFPs have received increasing attention as an alternative to reduce the pressure exerted by humans on timber products ([2]; [3]). According to the reference [4], NTFPs have the potential to enhance the income and create employment opportunities particularly for poor and disadvantaged people. They are harvested, transported and traded in both rural and urban settings, generating economic opportunities to vulnerable segments of the population ([5]; [6]; [7]; [8]). It has been suggested that the harvest and trade of NTFPs provide an incentive for biodiversity conservation because of the positive implications for rural livelihoods ([9]; [3]). But this suggestion is not without controversy. In fact, other studies have found that NTFPs benefits are more modest (e.g. [10]; [11]; [12]). The NTFP trade is complex and dynamic, influenced by a suite of interrelated factors ([13]; [14]; [15]; [16]; [8]).

NTFPs include items such as natural dyes, mushrooms, honey, latexes, gum resins, medicinal plants and many others. Despite the widespread availability of Western medicine in Africa, medicinal plants remain an important source of health care [17] contributing to the well-being of local populations. Almost 80% of the Africans depend on medicinal herbs for their primary health care [18]. Many rural communities still prefer cheaper traditional healing methods over the more expensive treatments by western practitioners. As an example, 70% of South Africa's population visits a traditional healer on average three times per year ([19]; [20]). Over 10% of the medicinal plants of North Africa have the potential for commercial exploitation as a source of drugs and pharmaceuticals [21]. In West Africa, an estimated 951 tons of crude herbal medicine were recorded to be sold at Ghana's herbal markets, with a total value of around US$ 7.8 million [22]. In Central Africa, about 27 tons of medicinal plant

products, worth US$ 1.5 million, are sold annually mainly to Gabonese markets [23]. A general concern exists that trade in herbal medicine threatens wild plant populations in the tropics ([24]; [25]), which can in turn affect their availability for primary health care ([26]; [27]). Commercial harvesting of medicinal plant has been proven to become an environmentally destructive activity in several African countries to meet a growing urban population ([28]; [29]). Increasing harvesting pressures exerted on wild supply areas are linked to a growing shortage in supply of medicinal plant species ([20]; [30]; [31]). It is estimated that in South Africa, approximately 20,000 tons of indigenous plant material are used per annum [20].

The most important medicinal plant parts are leaves, roots and bark. Nowadays, there is an increased use of tree bark as remedies against several diseases. This plant part is also involved in medicinal plant commercialization with negative impacts on resources [31]. For instance, bark trade of *Prunus africana* led to deforestation and habitat loss [33]. Economic assessments of medicinal plants are essential for understanding their importance for local people and to identify plant species with resource management priorities [34]. In Benin, some economic studies have been undertaken on medicinal plants. But most of these studies have focused on evaluating economic importance of medicinal plants in markets especially in the southern and the centre of Benin ([35]; [36]; [7]; [36]; [38]; [39]; [40]; [34]; [41]). Assessing economic importance for local populations will allow identifying which tree species are under high human pressure and which ones need conservation measures. Studies at the local-level often provide important data that complement regional or national studies ([42]; [43]). The present study aimed at (1) assessing economic profitability of bark sale in a community forest in southern Benin and (2) determining the most profitable tree bark for the local population via sensitive analyses of tree bark trade.

2 MATERIAL AND METHODS

2.1 STUDY AREA

The study was conducted in four villages surrounding the Lokoli Swampy Forest (Lokoli forest) (979 ha; 7°02 to 7°05 N and 2°15 to 2°18 E), located in Southern Benin. The Lokoli forest is a community forest with free access to resources. It covers an area of 3,000 ha and hosts about 125 plant species belonging to 55 families. Harvesting of tree bark is mostly done during the dry season and this forest suffers from anthropogenic pressure.

2.2 ECONOMIC SURVEY

The economic survey was carried out from January to March 2013 in the villages next to Lokoli forest (Lokoli, Dèmè, Samionta and Koussoukpa). During the pre-survey, three groups of collectors were identified: Group 1 (G1) are collectors who sell tree bark harvested in the villages next to the forest; Group 2 (G2) and Group 3 (G3) are collectors who sell collected tree bark at medium- (< 50 km) and distant markets (> 50 km), respectively. To recruit collectors of different groups we relied on a snowball technique, to know where recruits are and answered the getting names of them. The survey was based on interviews using questionnaires (Supplement) with 30 collectors (10 respondents per collector group) who harvested tree bark directly in the forest and its surrounding farmland and sold it at different markets.

We collected the following data: (i) Tree bark species and quantities as well as their selling prices; (ii) All costs induced by the activity, such as purchase, travelling costs (round trips for bark harvesting and travelling to the market), costs of material used and their depreciation, number of persons involved in the activity as well as the number of working days before going to the market; (iii) All taxes paid by the collectors and the number of times they went to the market per month (Supplement, Table 1). Annual economic parameters were obtained by extrapolating monthly values. Since collectors were active only during the dry season, we considered a period of six months for estimating annual values.

2.3 DATA ANALYSIS

2.3.1 PROFIT AND LOSS ACCOUNTS ANALYSIS

The profit and loss accounts analysis estimates the Net Income (NI) over one year. It is the Operation Income (OI) (Eq. 1) after subtracting different costs.

$$\mathrm{OI} = \mathrm{Qt} * \mathrm{SP} \ (\mathrm{Eq.}\ 1)$$

With Qt: bark quantity and SP: selling price.

All costs (total costs: TtCost) (Eq. 2) faced by economic activities can be broken into two main categories: fixed costs and variable costs. Fixed costs (FC) are those that do not change, while variable costs (VC) change depending on the company or a

private individual's activity. Fixed costs are linked to the labour, to taxes and to equipment while variable costs represent costs linked to transportation, packaging and the purchasing of tree bark.

$$\mathrm{TtCost} = \mathrm{FC} + \mathrm{VC}\ (\mathrm{Eq.}\ 2)$$

Net Income (NI) (Eq. 3) is the difference between OI and TtCost.

$$\mathrm{NI} = \mathrm{OI} - \mathrm{TtCost}\ (\mathrm{Eq.}\ 3)$$

The Economic Profitability (EP) (Eq. 4) was then calculated as the ratio between NI and the sum of TtCost induced by the economic activity:

$$EP = \frac{NI}{TtCost}\ (Eq.4)$$

2.3.2 SENSITIVITY ANALYSIS

The economic analysis was based on computation of the Break-even Point (BP) (Eq. 5) and the safety margin (SM) (Eq.6).

BP is the ratio from the product of OI and FC divided by OI - VC. SM is OI minus BP.

$$BP = \frac{OI * FC}{OI - VC}\ (Eq.5)$$

$$SM = OI - BP\ (Eq.6)$$

2.3.3 STATISTICAL ANALYSIS

Statistical analyses were performed in R [44].The significance level was set to α = 0.05. A mixed model ANOVA (random intercept linear mixed model) was performed, independently for each variable of the Profit and Loss Account Analysis and the Sensitivity Analysis using the R library lme4 [45]. Each time 'collector group' and 'tree species' were fixed factors and 'respondent' a random factor. Mean values and standard errors were computed per collector group and per tree species to highlight significant differences in returns from tree bark sale.

3 RESULTS

3.1 TREE BARK SALE PATTERNS OF LOKOLI SWAMPY FOREST POPULATION

Tree bark sale activity is carried both by men (30 %) and women (70 %) within an age range from 35 to 55, sometimes requiring family labour involving children or other ones. Occasionally, the lead collector makes use of employee collectors for gathering tree barks or carrying collected tree barks from the site of collection to storage. Such occasional labour is paid at the rate of 1.5$ US a day. Sometimes, entire trees are felled down to maximize tree bark harvesting and this was mostly done by men. Equipment necessary for bark gathering includes machete, axe, basin, and plastic bags. Collectors stated that they collected on the average five trees daily in the swampy forest and about 10 trees a day in the fields and fallow lands or at the edges of the forest. Each workday is about 6 hours-long. It takes about four days of work to have a sizeable amount ready for sale. The number of debarked trees per gatherer is about 30 per week. However, collectors of G3 (who sell bark in distant markets > 50 km Cotonou, Abomey-Calavi and Allada markets) spent almost one month for collecting tree barks before going to market. The majority of collectors of G1 (who sell bark locally) and G2 (who sell bark at medium market distant < 50 km Abomey and Bohicon markets) declare selling at least two or three times per month, while those who sell in far-away markets go there about once a month. Women collectors purchase part of their goods from village gatherers to maximize how much is available for them to sell.

3.2 HARVEST, OPERATING INCOME AND COSTS

Tree barks from a total of 17 tree species, belonging to 13 families were collected and sold by harvesters. Eleven tree species were commonly harvested by all three groups of collectors: *Anogeissus leiocarpa*, *Bridelia ferruginea*, *Khaya senegalensis*, *Kigelia africana*, *Lannea acida*, *Maranthes polyandra*, *Nauclea diderrichii*, *Parkia biglobosa*, *Pterocarpus erinaceus*, *Syzygium owariense* and *Terminalia glaucescens*. Per market visit, collectors of G1 and G2 sold an average of four different bark species while G3 collectors sold up to eight bark species per market visit. During the survey, ten species were recorded by G1 collectors while G2 and G3 collectors harvested 15 species each.

The amount of bark sold differed significantly between collector groups (Table 1). G3 collectors sold more bark per market visit and annually than G2 and G1 collectors (Figure 1a, b). However, the quantity of bark sold did not differ significantly between tree species, neither per market visit nor annually (Figure 1c, d). Nonetheless, there was a significant interaction between collector groups and tree species (Table 1) indicating that collector groups differed in their usage (frequency and bark quantity) of tree species. For instance, *P. biglobosa* was mainly, and *Azadirachta indica* only, harvested by G3 collectors, while *P. africana* was collected only by G2 collectors. The most harvested tree species and sold by all the three groups of collectors were respectively *B. ferruginea*, *N. diderrichii*, *L. acida* and *K. africana*.

The tree bark prices differed significantly between collector groups and according to species (Table 1). One kilogram of bark was more expensive when bought from G2 and G3 collectors than from G1 collectors (Figure 2). The most expensive trees were *M. polyandra*, *K. africana*, *V. paradoxa*, *A. occidentale*, and *K. senegalensis*, which all cost around 0.60 US$ per Kg, while *A. indica* and *F. trichopoda* selling prices was below 0.4 US$ (Figure 2).

Operating income (OI) was highest for G3 collectors, whose value per market visit was around seven times and almost three times higher than those for G1 and G2 collectors, respectively (Figure 3a). This accounted for five times and twice as high OIs, on an annual scale. *K. africana*, *K. senegalensis* and *M. polyandra* had the highest OI values per market visit and annually (Figure 3b, c).

Mean Ttcost expenditure per market visit and per annum differed significantly between collector groups but any significant difference was noted according to species (Table 1). Annually, G3 collectors expended twice and six times as much money than G2 and G1 collectors, respectively (Figure 4a). The bark of *P. biglobosa* and *F. trichopoda* had the highest expenditure costs for G3 collectors (Figure 4b, c).

Table 1. Results of mixed model ANOVAs for bark price bark quantity, costs, net income, economic profitability, break-even point, safety margin, across collector groups and debarked tree species.

Assessment parameters		**Statistics**	**Group**	**Species**	**Group*Species**
		Df	2	16	22
Bark price per kg		F	50.48	4.22	1.45
		P	< 0.001	< 0.001	0.0972
Bark quantity per :	market visit	F	9.74	1.23	1.71
		P	< 0.001	0.2505	***0.0312***
	annual	F	2.90	1.07	2.09
		P	0.0577	0.3836	***0.0048***
Total Cost per:	market visit	F	50.63	2.42	0.75
		P	< 0.001	0.1218	0.3884
	annual	F	17.96	2.14	1.06
		P	***0.0001***	0.1451	0.3059
Net Income per:	market visit	F	24.94	2.76	0.91
		P	< 0.001	< 0.001	0.5869
	annual	F	27.44	3.51	1.24
		P	< 0.001	< 0.001	0.2254
Economic Profitability		F	9.21	3.67	1.54
		P	< 0.001	< 0.001	0.0679
Break-even Point per:	market visit	F	3.56	1.18	1.00
		P	***0.0306***	0.2854	0.4626
	annual	F	0.76	0.90	0.97
		P	0.4683	0.5745	0.5001
Safety Margin per:	market visit	F	35.17	3.19	1.06
		P	< 0.001	< 0.001	0.3907
	annual	F	24.69	3.28	1.41
		P	< 0.001	< 0.001	0.1174

** denotes interaction term; Df = degree of freedom; italic and bold letters indicate significance at p ≤ 0.05*

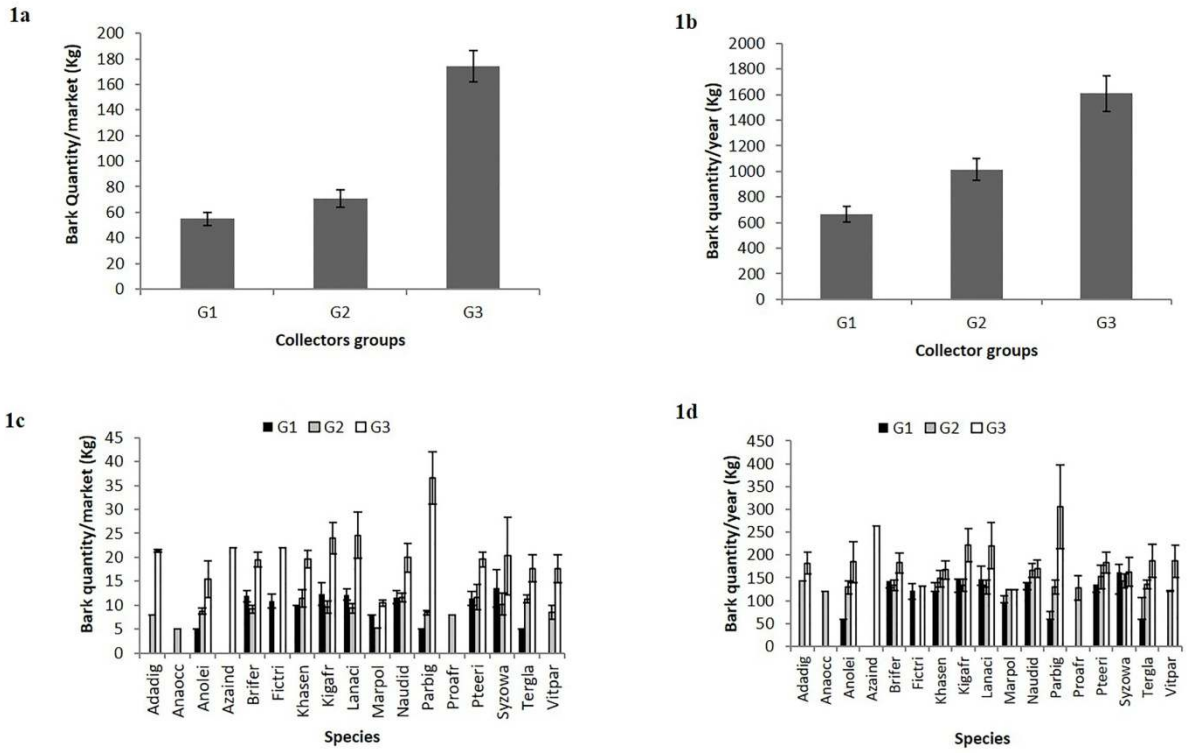

Fig. 1. Quantity of bark sold (a) per market visit, (b) per year, (c) per species/market and (d): per species/year by different group collectors. G1 (who sell bark locally); G2 (who sell bark at medium market distant < 50 km); G3 (who sell bark in distant markets > 50 km).

Adadig: Adansonia digitata, Anaocc: Anacardium occidentale, Anolei: Anogeissus leiocarpa, Azaind: Azadiracta indica, Brifer: Bridelia ferruginea, Khasen: Khaya senegalensis, Kigafr: Kigelia africana, Lanaci: Lannea acida, Marpol: Maranthes polyandra, Naudid: Nauclea diderrichii, Parbig: Parkia biglobosa, Proafr: Prosopis africana, Pteeri: Pterocarpus erinaceus, Syzowa: Syzygium owariense, Tergla: Terminalia glaucescens, Vitpar: Vitellaria paradoxa.

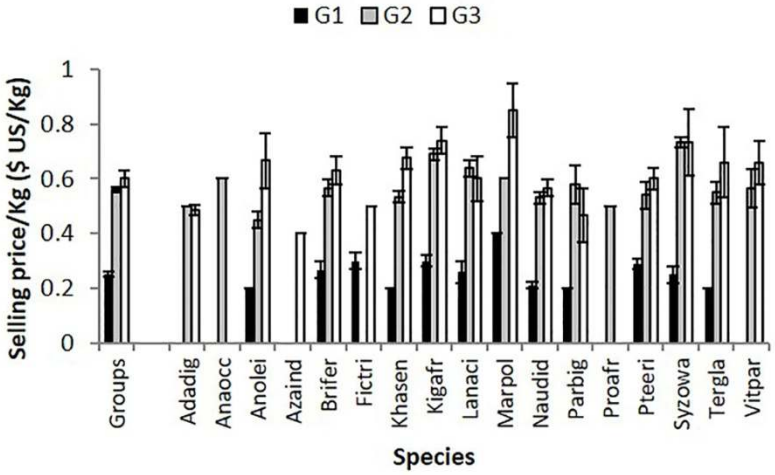

Fig. 2. Bark selling price per species and per collector groups. G1 (who sell bark locally); G2 (who sell bark at medium market distant < 50 km); G3 (who sell bark in distant markets > 50 km). (For species names see Figure 1)

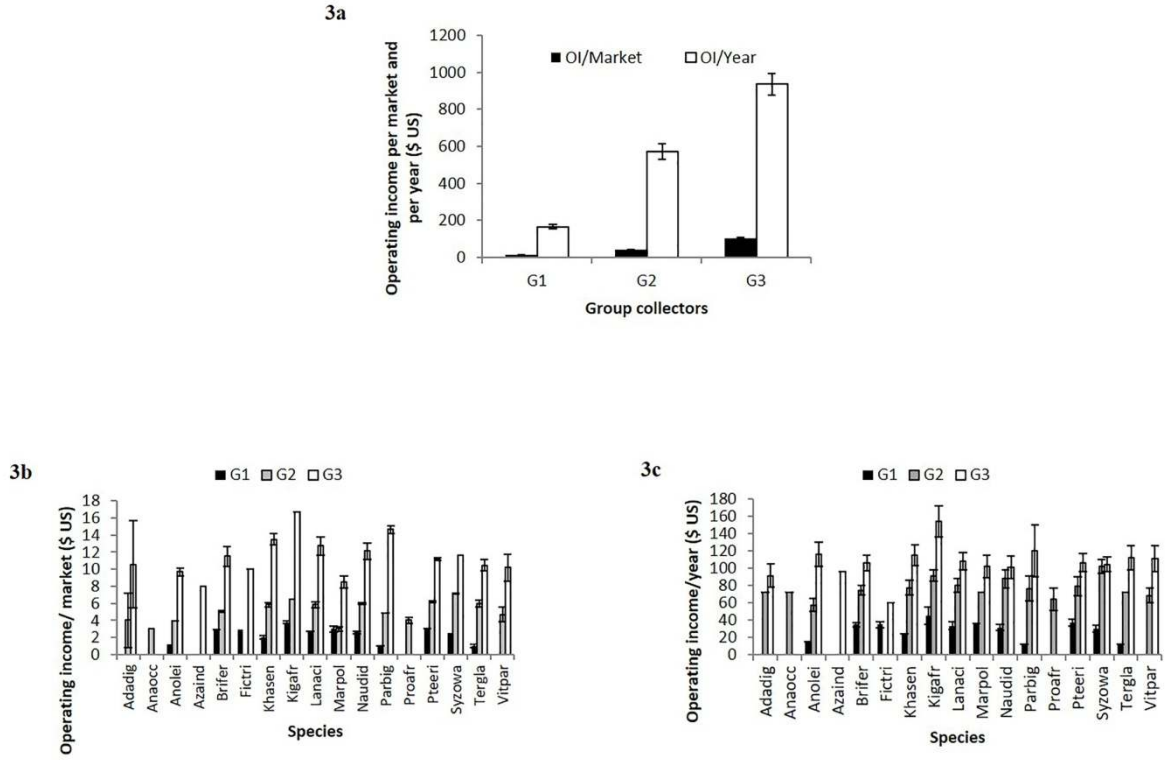

Fig. 3. Operating income (a) per group collectors (market/year); (b) per species/market; (c) per species/year. G1 (who sell bark locally); G2 (who sell bark at medium market distant < 50 km); G3 (who sell bark in distant markets > 50 km). (For species names see figure 1)

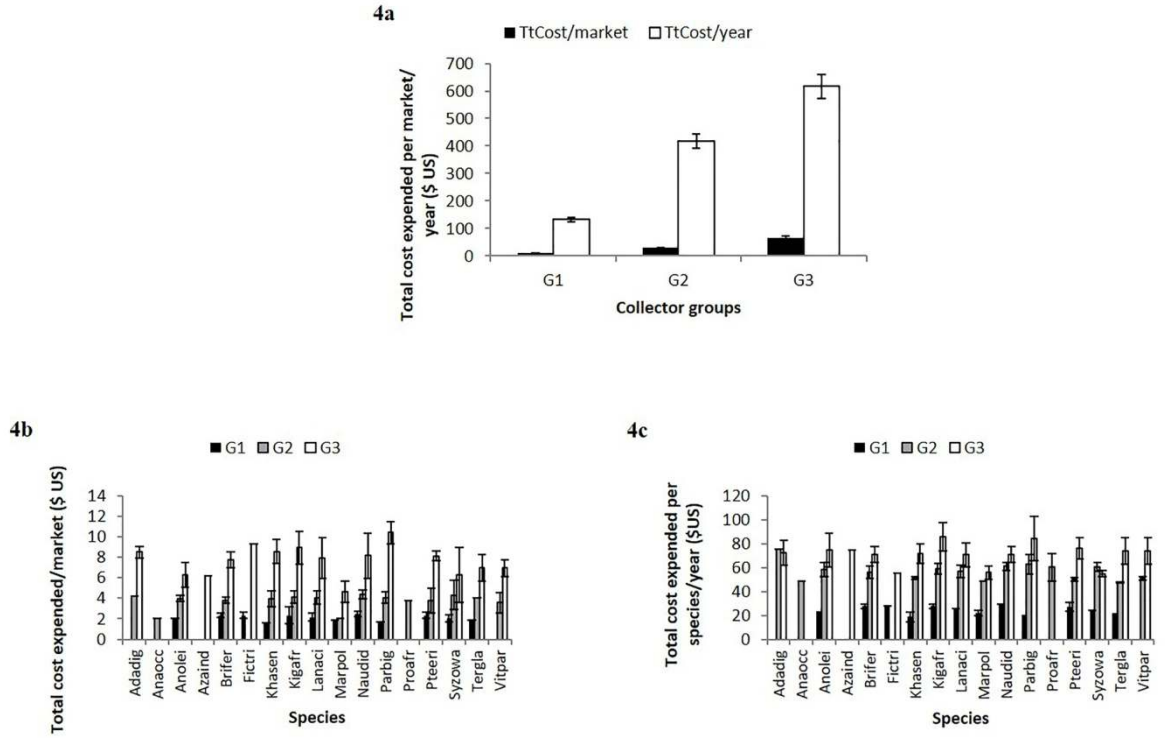

Fig. 4. Total cost expended by collector groups per (a) market/year and per species (b) per market, (c) per year. G1 (who sell bark locally); G2 (who sell bark at medium market distant < 50 km); G3 (who sell bark in distant markets > 50 km). (For species name see figure 1).

3.3 NET INCOME (NI) AND ECONOMIC PROFITABILITY (EP)

G3 collectors earned on average 3.5 and 13.5 times as much as G2 and G1 collectors, respectively and this was statistically different between groups (Figure 5a, Table 1). For all three group collectors, *K. africana*, *K. senegalensis* and *S. owariense* yielded the highest mean net income whereas the lowest values were obtained for *F. trichopoda* and *P. africana*. Concerning each group separately, G1 collectors had negative NI for *A. leiocarpa*, *P. biglobosa* and *T. glauscensens* while G2 collectors recorded negative NI for *A. digitata* and *A. leiocarpa* (Figure 5 b,c). For G3 collectors, none of tree species yielded negative NIs, the lowest was obtained for *F. trichopoda* (Figure 5b,c).

The economic profitability of bark sale varied significantly between collector groups as well as debarked tree species (Table 1). EP values were high for G3, intermediate for G2 and low for G1 (Table 2). With regard to tree species, high EP values were recorded for *K. africana*, *M. polyandra*, *S. owariense*, *K. senegalensis*, *V. paradoxa*, *L. acida.*, *P. erinaceus* and *T. glaucescens*. Almost 70 % of the G3 collectors and 30 % of the G2 collectors had EP larger than 50 %, while none of G1 collectors realised such profitability.

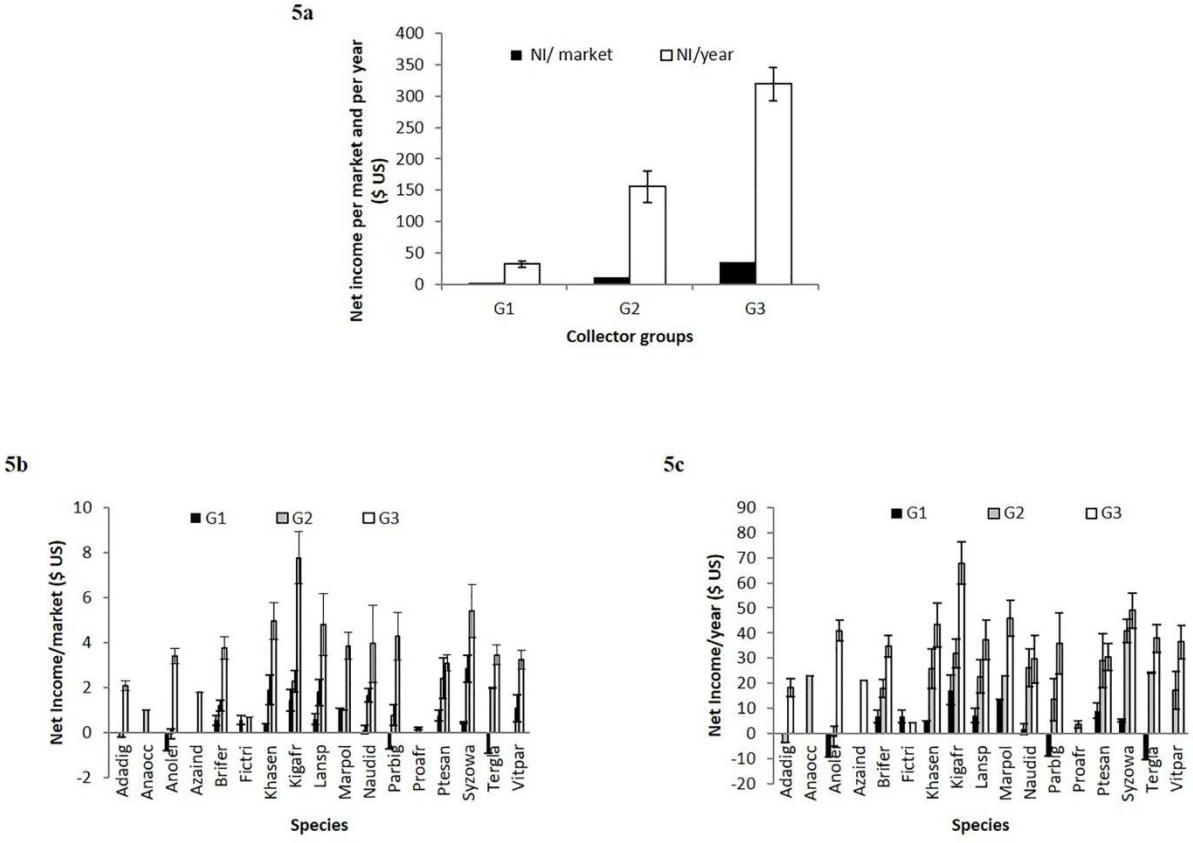

Fig. 5. Net income per (a) collectors groups (market/year); (b) species (market); (c) species (annually). G1 (who sell bark locally); G2 (who sell bark at medium market distant < 50 km); G3 (who sell bark in distant markets > 50 km). (For species names see Figure 1).

3.4 SENSITIVITY ANALYSIS

The break-even point (BP) per market visit differed significantly between collector groups, but no difference was observed across tree species (Table 1). The BP also did not differ significantly at the annual scale (Table 1). Before obtaining benefits the collector groups must reach minimum BPs that vary between 10.3 ± 0.61$US and 28.2 ± 3.09$US per market visit (Table 2) or between 123.7 ± 7.31$US to 246.6 ± 16.93$US annually (Table 2) depending on collector group. Depending on bark species, collector groups needed to reach amounts of 1.4 ± 0.00$US to 6.7 ± 0.00$US with the highest value for *F. trichopoda*.

Safety Margin (SM) differed significantly across collector groups and debarked tree species per market visit as well as per annum (Table 1). G3 collectors had the highest SMs amounting to 689.45 ± 54.93$US yearly. This is equivalent to 17 times and twice the amount for G1 and G2 collectors, respectively. With regard to SM per tree species, *K. senegalensis*, *K. africana*, *M.*

polyandra, *S. owariense*, *T. glaucescens* and *V. paradoxa* were species giving the best returns which around 6$ US per market visit or 60$ US annually (Table 2).

Table 2. Economic profitability (EP), Break-even Point (BP) and Safety margin (SM) per species per market and per year

Groups	Economic parameters	Adadig	Anaocc	Anolei	Azaind	Brifer	Fictri	Khasen	Kigafr	Lanaci	Marpol	Naudid	Parbig	Proafr	Pteeri	Syzowa	Tergla	Vitpar	Total
G1	EP	-	-	-0.4±0.0	-	0.3±0.1	0.2±0.1	0.3±0.0	0.5±0.1	0.3±0.1	0.6±0.0	0.1±0.1	-0.4±0.0	-	0.3±0.1	0.2±0.1	-0.5±0.0	-	0.2 ± 0.0
	BP (market event)	-	-	3.8±0.0	-	2.2±0.4	2.0±0.1	1.4±0.0	1.8±0.1	1.8±0.1	1.6±0.0	2.4±0.2	2.4±0.0	-	2.0±0.2	1.9±0.3	2.7±0.0	-	10.3 ± 0.6
	BP (annual)																		
	SM (market event)	-	-	-2.6±0.0	-	0.6±0.4	0.9±0.3	0.6±0.0	2.0±0.7	0.9±0.4	1.4±0.0	0.2±0.3	-1.4±0.0	-	1.1±0.3	0.6±0.0	-1.7±0.0	-	3.4 ± 0.7
	SM (annual)																		
G2	EP	-0.05±0.0	0.47±0.1	-0.02±0.06	-	0.3±0.1	-	0.5±0.1	0.6±0.1	0.4±0.1	0.5±0.0	0.4±0.1	0.2±0.1	0.05±0.0	0.6±0.2	0.7±0.1	0.5±0.0	0.3±0.1	0.4 ± 0.1
	BP (market event)	5.0±0.0	1.1±0.0	1.4±2.0	-	2.3±0.3	-	2.0±0.2	1.9±0.2	2.2±0.2	1.1±0.0	2.1±0.2	2.9±0.4	3.1±0.2	1.9±0.2	1.5±0.2	1.9±0.0	2.5±0.8	15.0 ± 1.0
	BP (annual)	90.6±0.0	27.6±0.0	12.9±34.1	-	34.9±5.6	-	25.8±1.9	28.3±4.3	32.7±6.1	27.6±0.0	30.2±1.9	44.8±7.7	50.0± 10.0	28.3±5.7	22.1±1.9	22.4±0.2	34.4±7.6	224.2 ± 23.2
	SM (market event)	-1.0±0.0	1.8±0.0	2.5±1.7	-	2.7±0.5	-	3.8±0.9	4.5±0.6	3.6±0.8	1.8±0.0	3.9±0.4	1.9±0.9	0.8±0.2	4.3±1.3	5.6±1.3	4.1±0.0	2.2±1.3	25.0 ± 3.4
	SM (annual)	-18.6±0.0	44.4±0.0	44.3±31.5	-	39.2±6.2	-	51.4±10.3	62.7±6.9	47.1±8.9	44.4±0.00	57.1±9.5	31.5±15.9	14.0±4.6	50.9± 16.2	79.5±9.6	49.6±0.2	33.6±16.2	349.2 ± 42.9
G3	EP	0.2±0.0	-	0.6±0.1	0.3±0.0	0.5±0.1	0.1±0.0	0.6±0.1	0.9±0.1	0.6±0.1	0.8±0.0	0.4±0.2	0.4±0.1	-	0.4±0.1	0.9±0.1	0.5±0.1	0.5±0.1	0.53 ± 0.0
	BP (market event)	4.6±0.4	-	2.1±0.5	3.4±0.0	3.5±0.7	6.7±0.0	3.6±0.8	2.6±0.2	3.5±0.6	1.5±0.1	3.9±0.4	4.9±1.0	-	3.8±0.5	2.4±0.8	2.5±0.4	2.7±0.5	28.2± 3.1
	BP (annual)	36.8±2.5	-	25.4±5.9	41.3±0.0	29.6±3.8	40.2±0.0	28.8±5.2	23.8±2.1	32.4±7.4	17.6±1.7	34.2±2.7	35.3±3.1	-	33±4.0	19.9±3.0	25.7±3.5	26.7±3.5	246.7 ± 16.9
	SM (market event)	5.9±0.6	-	7.5±0.9	4.6±0.0	8.0±0.9	3.3±0.0	9.9±1.1	14.1±1.5	9.2±1.9	7.0±1.2	8.2±2.3	9.7±2.0	-	7.4±0.5	9.3±2.0	7.9±0.6	7.5±0.8	73.8 ± 3.3
	SM (annual)	54.0± 11.1	-	90.6±10.9	54.7±0.0	76.0±9.7	19.8±0.0	85.9±12.5	129.8±16.5	75.6±9.6	84.4±14.5	66.4±15.4	84.7±30.8	-	73.2±9.7	84.1±10.2	86.1±19.4	83.7±14.0	689.4 ± 54.9

NB: Qt: quantity of bark sold, SP/Kg: selling price per kilogram, OI: operating Income, TtCost: Total Cost, NI: Net Income, Pro: Profitability, BP: Break-even Point, SM: Safety Margin. Adadig: *Adansonia digitata*, Anaocc: *Anarcadium occidentalis*, Anolei: *Anogeissus leiocarpa*, Azaind :*Azardiractaindica*, Briferr: *Bridelia ferruginea*, Fictri: *Ficus trichopoda*, Kigafr: *Kigelia africana*, Khasen: *Khaya senegalensis*, Lanaci: *Lannea acida*, Marpol: *Maranthes polyandra*, Naudid: *Nauclea diderrichii*, Parbig: *Parkia biglobosa*, Proafr: *Prosopis africana*, Ptesan: *Pterocarpus erinaceus*, Syzowa: *Syzygium owariense*, Terglau: *Terminalia glauscesens*, Vitpar: *Vitelaria paradoxa*.

4 DISCUSSION

The economic evaluation of bark selling identified 17 tree species sold by collectors from Lokoli forest. This value is lower than those recorded in Nigeria (43 species bark) and in South Africa (117 species bark) respectively ([46]; [47]). This reflects the species diversity importance in use of tree barks in these countries. The quantity of bark sold, the total cost (TtCost), the net income (NI) and hence also the economic profitability (EP) and the selling price (SP) differed significantly between collector groups. All these parameters were larger for collectors who sell tree bark in distant market (G3) than for those who sell them in medium distant market (G2) and for those who sell bark locally (G1). According to sensitivity analysis, G3 collectors were the most comfortable in term of benefiting from bark sale, so their safety margin (SM) was almost 17 times and twice those of G1 and G2 collectors respectively. Hence, travelling longer distances to markets result in larger revenues. These results can be explained by the fact that G3 collectors sell their barks in more developed geographical areas where the inhabitants have a higher purchasing power than people from nearby markets. Also the demand is higher which allows selling at higher prices. Due to increasing urbanization and rural migration, the subsistence-consumers are distanced from their harvesting areas [48], hence meeting this stratum of the society requires to travel very far from herbal sources. For example, in Cotonou, the economic capital of Benin, population density reaches 10,000 inhabitants per km², while the population density in regions next to the harvesting site is only around 800 inhabitants per km² [49]. A strategy adopted by G3 collectors is that they mostly commercialized the most expensive tree bark such as *S. owariense*, *K. africana*, and *K. senegalensis* while G2 collectors used to sell species such as *P. erinaceus, N. diderrichii and T. glauscescens* which have lower NIs and EPs as well as SMs as these species were sold at lower prices. Even though *S. owariense*, *K. africana*, and *L. acida*, were the most bark species harvested and sold by G1 collectors, their selling prices per kg were lower than those of other groups. In non-timber forest products (NTFP) commercialization, registering lower income has been explained by the lower quantity collected and sold by collectors ([50]; [51]; [8]). However, in such situation, increasing tree bark quantity would further increase the loss of collector returns because selling price would go further down as demand is lower. But collectors did not ascertain the deficit of special tree bark sale, because they sold three or four different barks species per market visit at different selling prices and those species with high selling prices covers the deficit of those with lower prices. For attenuating the deficit in tree bark selling, G1 and G2 collectors must switch to more profitable species. It was noted that *P. biglobosa*, even though it does not have the highest selling price, was between the most harvested and sold tree bark by G3 collectors. This could be explained by the fact that, the demand of this species was higher than for others and any quantity harvested can be sold. The reference [52] found that in addition to

the commercialization of the bark of this species, its seeds are highly involved in trade as it is transformed into mustard, traditionally called "Afitin" in Benin. It is known that high demand implies high applied price but in this case, the low selling price of *P. biglobosa* showed that it has several provenances for supplying markets. The high selling price of *K. africana*, *K. senegalensis* and *S. owariense* could be explained by the fact that their demand in the market was not only high but they were also rare.

EP varied between 22 % and 53 % depending on collector groups. However, this result compared to other ones is very low. Profitability assessment of NTFPs sale showed EP varying between 80 % and 100 % as this activity is generally considered as not needing a special technology and material [53]. Most economic assessment studies of NTFPs do not include all costs involved into the margin profit calculation ([54]; [53]). However, NTFPs profitability is highly dependent on the different costs involved such as labour, tools and transportation, which are rarely fully quantified in economic analysis. The theoretical model of the reference [55] identifies "distance to market" and "distance to forest" as important for economic profitability. Although, the reference of [56] included time spent to collecting NTFPs by women from South West Ethiopia to their analytic model, they did not transform this time into the monetary value in order to really estimate the income on NTFPs. But they expressed this time spent in collecting NTFPs as experience obtained which is positively linked to household incomes. This means that the economic profitability of those studies is overestimated because they did not include all costs which normally decrease the profitability of NTFP sales [3].

What is expected for NTFPs commercialization is to allow some substantial return to local population. However, it is not the case for all group collectors. Where commercialization is successful, however, these activities can make an important contribution to poverty decreasing and then regularly providing a satisfaction to local population [57]. The net income from selling forest products, though modest, constitutes an important source of money for local population, allowing some of them the means to supply the daily life necessities [58]. This is the case for G3 collectors for which tree bark sale allows reaching the minimum annual household expenditure of 215.334$ US per person in the district of Zogbodomey in Southern Benin [59]. Tree bark sale helps those collectors undertaking essential expenditure for well-being. The reference [60] suggested that some NTFP-related activities yield low returns, procuring little possibility for accumulating sufficient capital to avoid poverty. This applies for G1 and G2 collectors who did not reach this amount. It seems that as G1 collectors were involved in other income-generating activities such as Raffia wine extraction, they do not invest themselves in this activity thoroughly. G2 collectors who made this activity as prime revenue-generating income like G3 collectors have really to get more market information in order to choose more valuable species. As explained by the reference [61] household relying on NTFPs commercialization should determine the needs of their customers and analyze competitive advantages as well as select specific markets. Although the trade of these species could allow traders to get substantial revenue, those harvesters used unsustainable debarking techniques such as girdling and cutting down of tree species which could be injurious for tree species and may lead to the destruction of resource structures [42] Species such as *K. senegalensis*, *N. diderrichii*, *P. erinaceus* are endangered and *K. africana*, is vulnerable species [62]. Therefore their intensively use without replanting or without using sustainable harvesting technique may conduct to their extinction.

5 CONCLUSION

To sum up, the current research which allowed determining species involved in bark commercialization can serve as a case study for future research. This study showed that medicinal tree commercialization such as tree bark sale is undoubtedly a source of economic income. However, net income and profitability are species and market locality dependent. Species with high returns were *K. africana*, *S. owariense*, *K. senegalensis* while *P. biglobosa*, *T. glaucescens*, *A. leiocarpa*, *V. paradoxa* and *F. trichopoda* recorded the lowest NI. It is important to investigate the impact of debarking on medicinal tree survival. The present study provides a database and conservation tools for forest management decision-making.

ACKNOWLEDGMENTS

We thank DAAD for funding the current research. Special thanks to Prof. Gaudence Djego and Prof. Aristide Adomou for the identification of plant species. Our thanks go also to Dr. Thibault Lachat, for his advices in improving the present paper. We also thank Biao Christiane, Lamidi Konetché and bark collectors for their participation in the current study.

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ANNEXE

Supplement: Economic survey

What bark species do you sell?

How many quantities par species and per market do you sell?

For each species, gives the purchase, the selling price, and other cost such as travelling cost (go and back from forest, go and back from market).

How many persons are involved in this activity with you?

How many days do you work before selling the bark in market?

Do you use some manpower? If yes, how much do you pay per day?

Do you pay some taxes? If yes, how much?

What materials do you use for travelling (Forest, farmland and market) and how much they cost?

Table A1. Summary statement of economic data recorded

Species debarked and sold	Amount of bark sold	Provenance	Purchase	Selling price	Cost of material used for harvesting	Cost of material used for travelling to market	Taxes	Labour	Travelling cost