Volume, value and floristic diversity of Gabon's medicinal plant markets

Alexandra M. Towns, Diana Quiroz, Lieke Guinee, Hugo de Boer, Tinde van Andel

Journal of Ethnopharmacology 155 (2014) 1184–1193

Contents lists available at ScienceDirect

Journal of Ethnopharmacology

journal homepage: www.elsevier.com/locate/jep

Volume, value and floristic diversity of Gabon's medicinal plant markets

Alexandra M. Towns [a,*], Diana Quiroz [a,b], Lieke Guinee [c], Hugo de Boer [a,d,e], Tinde van Andel [a]

[a] Naturalis Biodiversity Center, Leiden University, Darwinweg 4, P.O. Box 9517, 2300 RA Leiden, The Netherlands
[b] Biosystematics Group, Wageningen University, P.O. Box 6700 AP, Wageningen, The Netherlands
[c] Utrecht University, P.O. Box 80125, 3508 TC Utrecht, The Netherlands
[d] Department of Organismal Biology, Uppsala University, Norbyvägen 18 D, SE-752 36 Uppsala, Sweden
[e] The Natural History Museum, University of Oslo, P.O. Box 1172 Blindern, NO-0318 Oslo, Norway

ARTICLE INFO

Article history:
Received 24 April 2014
Received in revised form
24 June 2014
Accepted 25 June 2014
Available online 1 July 2014

Keywords:
Non-timber forest products (NTFPs)
Informal economy
Central Africa
Trade
Herbal medicine
Plant conservation

ABSTRACT

Ethnopharmacological relevance: African medicinal plant markets offer insight into commercially important species, salient health concerns in the region, and possible conservation priorities. Still, little quantitative data is available on the trade in herbal medicine in Central Africa. The aim of this study was to identify the species, volume, and value of medicinal plant products sold on the major domestic markets in Gabon, Central Africa.

Materials and methods: We surveyed 21 herbal market stalls across 14 of the major herbal medicine markets in Gabon, collected vouchers of medicinal plants and documented uses, vernacular names, prices, weight, vendor information and weekly sales. From these quantitative data, we extrapolated volumes and values for the entire herbal medicine market.

Results: We encountered 263 medicinal plant products corresponding with at least 217 species. Thirteen species were encountered on one-third of the surveyed stalls and 18 species made up almost 50% of the total volume of products available daily, including the fruits of *Tetrapleura tetraptera* and seeds of *Monodora myristica*. Although bark comprised the majority of the floristic diversity (22%) and the highest percentage of daily stock (30%), the resin of IUCN red-listed species *Aucoumea klaineana* represented 20% of the estimated daily volume of the entire herbal market. Plants sold at the market were mainly used for ritual purposes (32%), followed by women's health (13%), and childcare (10%). The presence of migrant herbal vendors selling imported species, especially from Benin, was a prominent feature of the Gabonese markets.

Conclusion: An estimated volume of 27 t of medicinal plant products worth US$ 1.5 million is sold annually on the main Gabonese markets. *Aucoumea klaineana* and *Garcinia kola* are highlighted as frequently sold species with conservation priorities. The herbal market in Gabon is slightly higher in species diversity but lower in volume and value than recently surveyed sub-Saharan African markets.

1. Introduction

The role of medicinal plants as non-timber forest products (NTFPs) in Africa has been well established in conservation, ethnobotany and sustainable development literature (Cunningham, 1993; Shackleton and Shackleton, 2004; Ticktin, 2004; Gaoue and Ticktin, 2007). The sale and trade of these plants form part of the informal economy of many African countries and contribute to the economic wellbeing of plant vendors, many of whom are women (Dold and Cocks, 2002; Jusu and Sanchez, 2013; Quiroz et al., 2014). Medicinal plants make substantial contributions to the income of plant vendors involved in the industry as well as to the health of consumers; the majority of sub-Saharan African populations use traditional medicine to meet their healthcare needs (Anyinam, 1995). This pattern is prevalent in rural communities, where health clinics are often poorly equipped (Pouliot, 2011), but also in urban centers, where biomedical treatment is readily available in hospitals and health centers (Cocks and Dold, 2006; Osamor and Owumi, 2010).

The combined effects of the profitability of medicinal plants, the high demand by local populations, and the fact that most plants are harvested from the wild (Schippmann et al., 2002) have contributed to the concern that commercialized species may be

* Corresponding author. Tel.: +31 71 75 17 267.
E-mail addresses: alexandra.towns@naturalis.nl (A.M. Towns), diana.quiroz@wur.nl (D. Quiroz), liekeguinee@gmail.com (L. Guinee), hugo.deboer@naturalis.nl (H. de Boer), tinde.vanandel@naturalis.nl (T. van Andel).

http://dx.doi.org/10.1016/j.jep.2014.06.052
0378-8741/

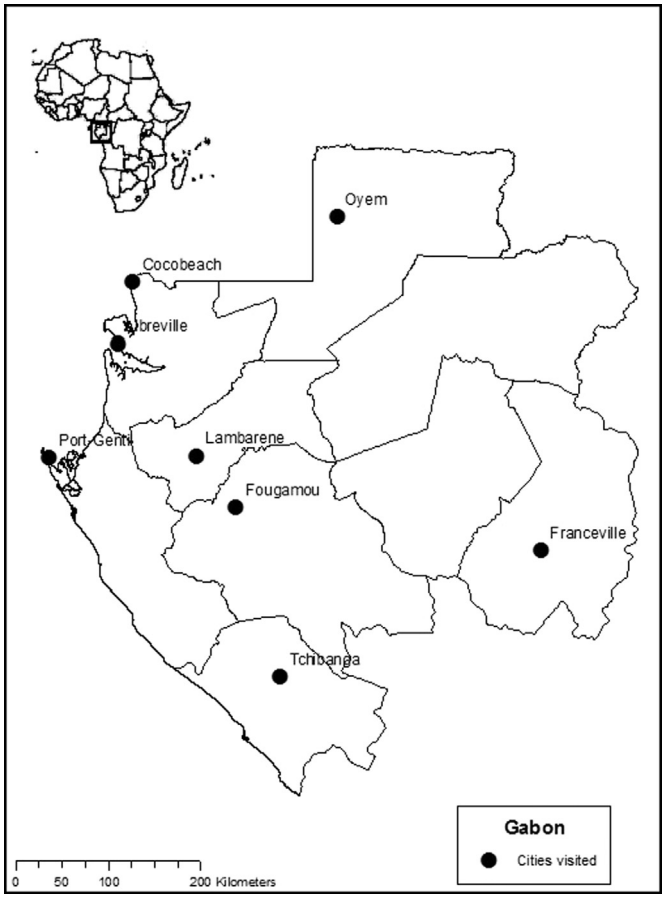

Fig. 1. Map of Gabon with market cities visited during our quantitative market survey in 2012.

overexploited resources. In several African countries, there is evidence that the commercial harvest of herbal medicine to meet a growing urban population has become an environmentally destructive activity (Cunningham, 1993; Dold and Cocks, 2002). Market sellers in Western Africa have been shown to use a larger variety of plants and more vulnerable species than harvesters who collect plants for personal use (Towns et al., 2014), suggesting that studying the medicinal plant trade is useful in investigating the exploitation of wild plants of a larger area (Cunningham, 2001; Williams et al., 2009). Studying the medicinal plant market can contribute to improved decision-making in sustainable land-use management and livelihoods (Jusu and Sanchez, 2014).

Before focused efforts can be made on estimating the effect of commercial plant harvesting on the surrounding vegetation, baseline figures are needed on the species, value, quantities, and characteristics of the marketplaces in question. Recently, quantitative surveys of herbal markets have become available for African countries, including South Africa (Williams et al., 2000; Dold and Cocks, 2002; Williams et al., 2009), Tanzania (McMillen, 2008), Morocco (El-Hilaly et al., 2003), Benin (Quiroz et al., 2014), Ghana (Van Andel et al., 2012) and Sierra Leone (Jusu and Sanchez, 2013). Much less information, however, is available on markets in the Central African region, including Cameroon (Betti, 2002) and Equatorial Guinea (Ondo, 2001). Gabon is of special interest to conservation given its unique biodiversity (Olson and Dinerstein, 1998) and its current ranking as the country with the highest rate of loss of primary forest in Africa (FAO, 2010), but little information is available on its herbal medicine trade.

In order to fill the gap of knowledge on Gabonese commercialized medicinal plant species, we conducted a market survey in the major cities of Gabon. The aim of our study was to identify the species, volume, and value of medicinal plant products sold domestically on major markets in Gabon. We also sought to identify the most frequently sold species and plant parts and the most salient health concerns treated by plants sold at the market. Given Gabon's lower population density and higher standards of living than other African countries, we hypothesized that the Gabonese medicinal plant markets would be smaller in volume and floristic diversity than those in West Africa, Tanzania and South Africa. The outcomes of this market survey can be used to identify priority species for conservation, contribute to an understanding of the role of medicinal plant sales on the socioeconomic wellbeing of market vendors, and highlight the populations' salient health concerns.

2. Materials and methods

2.1. Study area

Gabon is located in Central Africa, bordering the Atlantic Ocean to the west, the Republic of the Congo to the east and south, and Equatorial Guinea and Cameroon to the north. Up to 80% of Gabon has been estimated to be covered with forest (Sosef et al., 2006), with approximately 65% considered primary forest and remaining land consisting of swamps, mangroves, and savannas (FAO, 2010). The Gabonese population is around 1.6 million people, mainly of Fang, Bapounou, Nzebi, and Obamba ethnic groups (CIA, 2013).

Data collection took place between June and November 2012, in which we visited major herbal medicine markets in the provinces of Estuaire, Woleu-Ntem, Haut-Ogooué, Ngounié, Moyen-Ogooué, Ogooué-Maritime, and Nyanga. We started our data collection in the capital city of Libreville, visiting the two main medicinal plant markets several times a week to speak with vendors and purchase plant species to be processed into botanical vouchers. This regular contact built up the trust necessary to begin our quantitative market surveys and familiarized us with the most common commercial species, local names, and salient health concerns treated with herbal medicine in Gabon. We then conducted a systematic quantitative survey of 21 market stalls, across 14 markets, in major and regional cities in Gabon: Libreville (pop. 619,000), Port-Gentil (pop. 80,000), Franceville (pop. 56,000), Oyem (pop. 38,000), Lambaréné (pop. 24,000), Tchibanga (pop. 24,000), Fougamou (pop. 4100), and Cocobeach (pop. 1200) (Fig. 1).

2.2. Quantitative market survey

Following the methodology carried out in market surveys in Ghana (Van Andel et al., 2012) and Benin (Quiroz et al., 2014) and the guidelines for ethnobotanical market inventories (Cunningham, 2001), we began our quantitative survey by counting the number of herbal medicine stalls at each marketplace ($n=192$). We categorized the stalls into five different types: (1) herb stalls (including barks and woody plant parts), (2) spice stalls (with dual purpose food/medicinal fruits and seeds including the palm wine bark *Garcinia kola*), (3) Bwiti stalls (plants used in spiritual practices and ceremonies), (4) ambulant vendors (market vendors on foot), and (5) Beninese herbal stalls (migrants from Benin selling imported plant species). We also collected general data on each market, including type of products sold and number of open days per week.

We then sampled individual stalls by randomly inviting 21 vendors to participate in our market survey. We counted the number of products sold, recorded the price of each product, collected ethnobotanical data of each product (local name, medicinal use, and preparation), tallied the total amount of sales units per stall (bags, bundles, bottles, and individual pieces), and

measured each product's weight with a portable digital scale. All plant products recorded for sale are listed in Appendix I, together with the local and scientific names, plant parts sold, collection numbers, medicinal uses, weights, and prices. We also estimated the total weight of stock in storage. For each surveyed stall, we asked the vendor to estimate his/her weekly sales and to report general information on challenges to selling plants. We also collected basic demographic data from each vendor, including ethnic group, sex, age, and name. Our market survey was part of a larger ethnobotanical inventory on medicinal and ritual plants in Gabon.

2.3. Plant collection and identification

For each new species we encountered at the market, we purchased the plant and made botanical vouchers following standard botanical collection methods (Martin, 2004). If market samples were too dry or fragmented to be properly identified or lacked fertile plant parts, we later accompanied market vendors into the field to match market specimens with fertile species in the wild. We deposited vouchers at the Herbier National du Gabon (LBV) and exported duplicates to the Wageningen branch of the National Herbarium of the Netherlands (WAG), now part of Naturalis Biodiversity Center (L). We identified the plants using local botanical literature (Flore du Gabon, 1960–2008; Raponda-Walker and Sillans, 1961; Hawthorne and Jongkind, 2006; Sosef et al., 2006) and the extensive herbarium collections of Gabonese material at Wageningen. Three collections were too difficult to identify with standard botanical keys, two of which were sent to a wood anatomist who utilized microscopic methods and the InsideWood database (InsideWood, 2004-onwards) and one which was identified by DNA analysis following the methodology detailed in Quiroz et al. (2014). We also assessed the conservation status of each species according to the International Union for Conservation of Nature Red List (IUCN Red List of Threatened Species, 2014) and the Convention on International Trade of Endangered Species list (CITES, 2014). Species and author names were updated using the Plant List (www.theplantlist.org). Full names, including authors, of all species are listed in Appendix I.

2.4. Data analysis

We first calculated the average weight (in kg) and reported price (in US$) of each medicinal plant product. We converted CFA currency prices into US dollars based on the exchange rate at the start of our market survey (US$ 1=535 CFA in July 2012). We then totaled the number of sales units of each product sold on the 21 surveyed stalls and calculated the volume (in kg) and monetary value of plant material offered for sale per market stall. We then multiplied these numbers by the number of stalls per marketplace, extrapolating the weight and values to the entire Gabonese market. Average weights were used for those products that we were unable to weigh (183 g for a piece of bark, 144 g for leaves, 104 g for herbs, 101 g for fruits, 78 g for roots, 67 g for wood, and 41 g for seeds). We estimated the price per kilogram for species for which we did not know the price based on average price per sales unit of purchased products (wood US$ 4.67, roots US$ 3.74, bark US$ 1.85, leaves US$ 1.76, entire plant US$ 1.64, fruit US$ 1.60, seed US$ 1.03, and fungus US$ 0.93). We created a map of the cities visited during the market survey (Fig. 1) in ArcGIS 10.1 using open source geospatial data from DIVA-GIS (http://www.diva-gis.org/).

We performed a Detrended Correspondence Analysis (DCA) in PC-ORD v 5.33 in order to assess the similarity in floristic diversity among the four main stall types (McCune and Mefford, 2006). All plant species cited by the 21 vendors were entered into presence–absence data matrices, which identified the two main axes that caused the distribution of the vendors and sold species. We plotted the 1st and 2nd axes in two-dimensional graphs to visualize the variation and overlap in plant species used by different market stalls and the variations in stall diversity between Gabonese and migrant vendors. In order to assess whether we sampled enough stalls, we created species-accumulation curve based on the Shannon diversity index of the number of plant products and species from the sampled market stalls. We calculated Shannon diversity indices in EstimateS version 9.10 (Colwell, 2013).

2.5. Ethics

Following the Code of Ethics of the International Society of Ethnobiology (2006), we adhered to all protocols with partner institutions and universities, including the acquisition of formal invitations, research permits, and plant export permits. At each market setting, we carefully explained the nature of our research and obtained prior informed consent from each participant. In addition to purchasing the market plants with which we made botanical vouchers, we also offered financial compensation, equivalent to local norms, for vendors' involvement in the research.

3. Results

3.1. Market characteristics

The 14 markets we visited during our quantitative market survey varied from the large metropolitan markets of Libreville with a variety of spice, herb, and Bwiti stalls to the small village market of Cocobeach with only two spice stalls (Table 1). Out of the 192 stalls we counted, the majority were spice stalls ($n=108$), followed by herb stalls (56), Bwiti stalls (16), and Beninese vendors (11). We encountered only one ambulant seller on the main market in Mont Bouët, which was left out of Table 1. The Libreville stalls, with a combined total of 5045 kg of medicinal plant stock, comprised nearly 75% of the total weight of medicine plant products available daily for sale in Gabon (out of the total 192 stalls). Although spice stalls are fairly evenly distributed across the country, Libreville housed the main trade in herbal medicine. Marché Bornave in Port-Gentil housed the most Bwiti stalls out of all the markets we visited. The medicinal plant vendors were largely part of the main markets containing food, fish, clothes, and small sundry items and sold products six or seven days a week. The marketplaces were dominated by female vendors; 90% of the surveyed stalls were managed by women.

Although 81% of the sampled market stalls was headed by vendors of Gabonese nationality, we also encountered several vendors from other Western African countries, including Benin, Cameroon, Niger, Nigeria, and Togo. Beninese vendors were the most frequently encountered migrants selling herbal medicine. Migrant sellers sold distinct species not marketed by the Gabonese vendors. For example, large quantities of *Afrostyrax* sp. (DQ 1106) fruits reported to be imported from Cameroon were found on a spice stall of a Cameroonian vendor, and imported savanna barks such as *Lannea barteri* and *Pteleopsis suberosa* were observed on the Beninese herbal stalls. In Fig. 2, the 21 stalls are arranged by similarity of species composition. Points that are closely clustered have many species in common. Points that are farther apart have less botanical similarity. Gabonese herb and spice stalls, as well as the migrant spice and Bwiti stalls, were similar in floristic composition. The Togolese spice stall was unique in that it contained only one species, the bark of *Scorodophloeus zenkeri*, which was also found on one herb stall and one additional spice stall. The outlying herb and spice stalls clustered near the *x* axis

Table 1
Characteristics of 14 marketplaces visited during 2012 Gabon herbal market survey.

Location (market)	Sales frequency (days/wk)	Description	Spice stalls	Herb stalls	Bwiti stalls	Benin stalls	No. of sampled stalls (% of total)	Est. % of total floristic diversity	Total daily stock (kg)
Cocobeach	7	Small village market, border with Equatorial Guinea	2	0	0	0	0	6	17
Fougamou	7	Canned food, sandals, plastic buckets, smoked fish	4	0	0	0	0	6	33
Franceville (Grand Marché Poto-Poto)	7	Fruits, vegetables, bush meat, clothes	7	2	0	0	0	8	135
Lambaréné (Marché Issac)	7	Mainly fish, food	8	0	0	0	0	7	73
Libreville (La Peyrie)	6	Medicinal plants, herbs fresh, sellers harvest on mondays	0	13	0	0	4 (31)	36	1623
Libreville (Mont Bouët main market)	6	Food, clothes	16	0	9	8	4 (12)	13	1030
Libreville (Mont Bouët)	6	Medicinal plants, herbs fresh, sellers harvest on mondays	0	38	0	0	5 (13)	39	1987
Libreville (Nkembo)	6	Food, fish, clothes	49	0	0	0	4 (8)	6	404
Oyem (Marché Akouokam)	7	Vegetables, fruits, and food	5	0	0	0	1 (20)	6	41
Oyem (Marché Ngouema)	7	Vegetables, fruits, and food	12	1	0	0	2 (15)	15	138
Port-Gentil (Marché Balise)	7	Vegetables, fruit, clothes	0	0	0	3	0	3	19
Port-Gentil (Marché Bornave)	7	Ritual plants	0	0	7	0	1 (14)	11	1050
Port-Gentil (Marché Grand Village)	7	Vegetables, fruit, clothes	4	0	0	0	0	6	33
Tchibanga (Marché de la Gare Routière)	6	Fresh vegetables, dry fish	1	2	0	0	0	7	86
TOTAL			**108**	**56**	**16**	**11**	**21[a] (11)**	**100%**	**6807**

[a] Including one ambulant seller.

have unique species not recorded on other Gabonese stalls. The species and weights counted on each stall are reported in full detail in Appendix II. The Beninese herbal stall that we surveyed clearly stood out as an outlier among the sampled herb stalls. The Beninese stall sold common species from the Beninese herbal medicine market (Quiroz et al., 2014) not present on Gabonese herb stalls. The ambulant seller was selling only two species, *Annickia affinis*, which was found abundantly on herb stalls, and *Cymbopogon citratus*, which was also commonly sold on the market but not present on the stalls we surveyed.

3.2. Floristic diversity

Over the course of our six month study, we encountered 263 medicinal plant products, belonging to 217 individual species, of which 160 were identified to species level, 36 to genus level, and three to family level (Appendix I). The remaining 18 were unidentified due to insufficient sample material. We encountered more plant products than species since many plant parts sold individually were from the same species (for example the resin and bark of *Aucoumea klaineana*). The plant families with the most number of species for sale on the market were Leguminosae (33 spp.), Rubiaceae (16 spp.), Euphorbiaceae (12 spp.), Annonaceae (11 spp.), Apocynaceae and Malvaceae (10 spp. each), Zingiberaceae (8 spp.), and Asteraceae and Solanaceae (7 spp. each). After sampling 21 stalls, we encountered 66% (174 out of 263) of the total plant products and 71% of the existing botanical variation (155 out of 217 species). Plant mixtures were excluded from this calculation since they combined many species, most of which were also sold separately. Our sampling represented approximately 10% of the total number of medicine stalls on the 14 marketplaces we visited. Although our accumulation curves (Fig. 3) do not level off completely, the flattening of the line suggests that our sample size was adequate to give a representative overview of the diversity of medicinal plant species and products sold on the marketplaces in 2012.

Barks comprised the largest percentage of plant diversity (22%), followed closely by the entire plant (19%), fruits (13%), and leaves (13%) (Fig. 4a). Those plant parts that made up less than 1% of the total (rhizome, branch, oil, palm stalks, and fibers) were combined under the heading "other." Bark was also sold in the greatest volume (in kg) on the marketplaces that we visited (30%) (Fig. 4b), followed by resin (20%), fruits (14%), and seeds (13%).

3.3. Prices, frequencies, and volumes

The average price per sales unit of medicinal plant products in Gabon did not vary greatly (bark US$ 1.85, leaves US$ 1.76, entire plant US$ 1.64, fruit US$ 1.60, seed US$ 1.03, and fungus US$0.93), except for wood and roots that were US$ 4.67 and US$ 3.74 respectively. The most expensive species were found on a Bwiti stall at Marché Bornave in Port-Gentil: the inflorescences of *Streptogyna crinita*, which were sold in very small quantities (1 g) at the rate of US$ 1869 per kilo, unidentified seed "kandrina" (Bapounou) (AMT 1354), which was sold by piece at the rate of US$ 623 per kilo, and unidentified fruit "kiliguu" (Mitsogho) (AMT 1041), which was sold by piece at the rate of US$ 748 per kilo. It should be taken into account that these products are always sold in very small quantities. The remaining prices of plant products ranged from US$ 359 per kilo for the wood of *Nauclea diderrichii* to US$ 1.25 per kilo for the leaves of *Cymbopogon citratus* (Appendix I). We calculated the average price of all medicinal plant species sold on the 21 surveyed stalls to be US$ 56 per kilo.

The reported weekly sales varied greatly by market vendors with whom we spoke. The estimated weekly sales figures represented the value of products sold per week but it did not include transportation and collection costs. Therefore, the average income of each market vendor is likely lower than the reported sales. On average, Bwiti stalls reported sales of US$ 327 a week, herb stalls

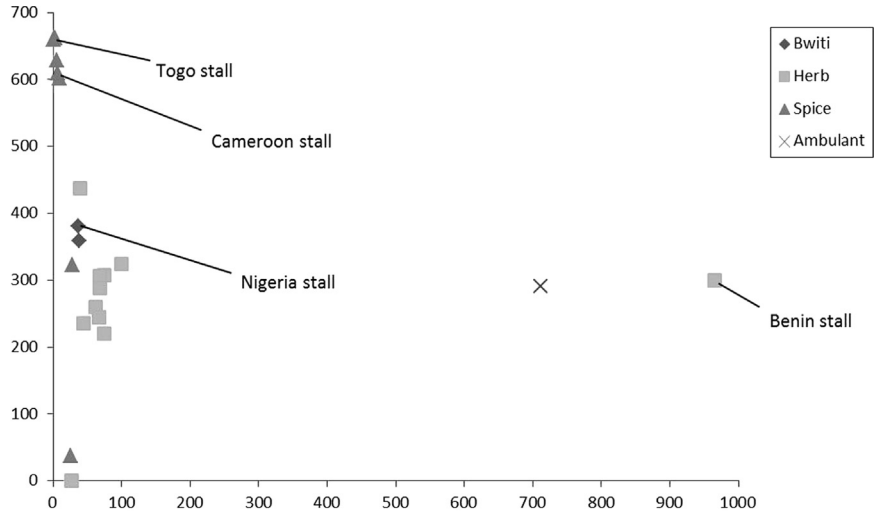

Fig. 2. Detrended Correspondence Analysis indicating the similarity in floristic diversity among the four main stall types surveyed in Gabon [Herb ($n=11$); Spice ($n=7$); Bwiti ($n=2$) and Ambulant ($n=1$)].

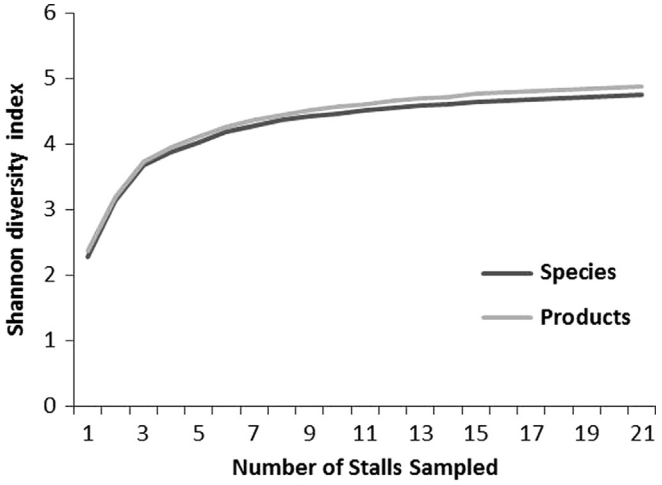

Fig. 3. Shannon diversity index cumulative curve for species and products sold on the 21 markets stalls sampled in Gabon (2012).

reported sales of US$ 197 a week (with a range of US$ 654 by a wholesale vendor selling mainly barks to US$ 22 a week for a small herb stand), spice stalls reported sales of US$ 131 a week, Beninese vendors reports sales of US$ 56 a week and ambulant sellers reported sales of US$ 6 a week. The relatively higher reported weekly sales of Bwiti stalls may be reflective of the higher price of ritual plants, the possibility that this figure included the sale of animal products (which were generally more expensive than plant products), and/or the basis of the Bwiti calculation on only one vendor (which may not reflect the weekly sales of an average Bwiti vendor). Based on these reported average sales, we estimated the annual value of medicinal plant trade in Gabon to be US$ 1,538,936 in 2012.

The species encountered most frequently in the 21 surveyed market stalls were the fruits of *Tetrapleura tetraptera*, the seeds of *Monodora myristica*, and the resin of *Aucoumea klaineana* (Table 2). Although *Aucoumea klaineana* resin was sometimes found to be sold alone, it was typically wrapped in the bark of *Xylopia aethiopica* to form the interior of an indigenous torch used in ceremonies.

The majority of the species that we frequently encountered on the market stalls were also sold in the greatest bulk (Table 3). Eighteen species made up almost 50% of the total volume of products available daily on the Gabonese market. *Aucoumea klaineana* was sold in the highest quantity, with an estimated daily available stock of nearly 950 kg. Although the resin of this species represents only 1% of the diversity of plant products sold (Fig. 4a), it represents 20% of the daily stock (Fig. 4b). Dual purpose species that are used both as food additives and medicine were also well represented in the daily available stock, such as the barks of *Garcinia kola*, seeds of *Monodora myristica*, and the fruits of *Afrostyrax* sp. The seeds of *Irvingia gabonensis* were not included in our market calculations since they were only used as a food additive, but due to their prevalence on the market, we estimated ca. 118 kg to be sold at the main Mont Bouët market in Libreville and ca. 20 kg on the market in Lambaréné.

We calculated the total volume of medicinal plants available for sale on the Gabonese market to be 6807 kg per day (Table 1). Vendors acknowledged discarding stock regularly, yet absolute numbers of discarded plant material were not reported. This material should be recognized as contributing to the entire volume harvested (available stock) but not sold on the market. By dividing the estimated annual value of the medicinal plant trade (US$ 1,538,936) by the average per kilo price (US$ 56), we estimated the annual volume of medicinal plants available on the entire Gabonese market in 2012 to be approximately 27,481 kg.

3.4. Vulnerable species

Out of the 18 species sold in the highest quantity on the Gabonese marketplace (Table 3), we found two species that were considered vulnerable by the IUCN, *Aucoumea klaineana* and *Garcinia kola*. *Aucoumea klaineana* was encountered on nearly half of the market stalls we surveyed. Another possibly vulnerable species was *Afrostyrax* sp. (Table 3), but our plant material was only identified to the genus level and we were unable to confirm whether it was the vulnerable species *Afrostyrax lepidophyllus* Mildbr. *Daniellia klainei* was considered lower risk/near threatened by the IUCN. None of the species encountered most frequently or sold in the highest volume were listed as restricted for international trade by the Convention on Trade in Endangered Species (CITES). Out of the 217 total species encountered at the Gabonese market (Appendix I), three additional species were listed as vulnerable by the IUCN: *Nauclea diderrichii*, *Brillantaisia lancifolia*, and *Baillonella toxisperma*.

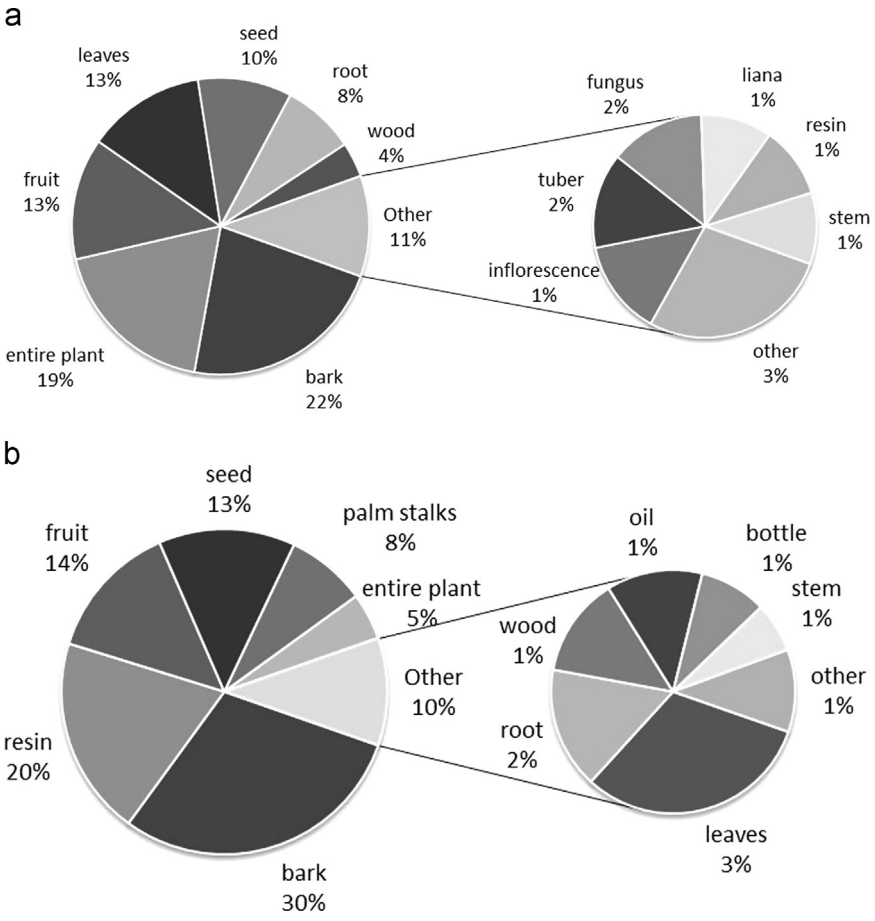

Fig. 4. Plant parts sold on herbal markets sampled in Gabon 2012, (a) percentage of the total number of products ($n=263$), and (b) percentage of daily stock (excluding stock stored behind stalls).

Table 2
Species encountered in more than one-third (29%) of the 21 surveyed stalls in Gabon 2012.

Species	Frequency (%)	Total volume on 21 stalls (kg)	Traditional use	Habit	IUCN threat status
Tetrapleura tetraptera	52	14.42	Ritual, spice	Tree	
Monodora myristica	52	18.29	Ritual, spice, women's health	Tree	
Aucoumea klaineana	45	134.10	Ritual, skin infections, good luck	Tree	VU[a]
Pterocarpus soyauxii	38	9.50	Ritual, skin ointment, red kaolin	Tree	
Capsicum annuum	38	2.83	Childcare, digestive, ritual, women's health, spice	Herb	
Annickia affinis	38	25.94	Malaria	Tree	
Aframomum melegueta	38	0.40	Childcare, spice	Herb	
Xylopia aethiopica	36	13.62	Digestive, ritual, spice	Tree	
Massularia acuminata (G.Don)	33	10.07	Sprained limbs, ritual, women's health	Shrub	
AMT 787	29	0.41	Ritual	Fungus	
Tabernanthe iboga	29	6.09	Ritual	Shrub	
Pentaclethra macrophylla	29	17.46	Ritual, women's health	Tree	
Cymbopogon densiflorus	29	2.18	Ritual, mourning	Herb	

[a] Vulnerable.

3.5. Most salient health issues and traditional uses

Over one-third of the 263 medicinal plant products documented for sale was reported to be used in rituals, which we defined as those plants used in spiritual ceremonies, as good luck charms, as protection against bad spirits or sorcery, and for attracting or keeping a spouse (Fig. 5). The use of medicinal herbs for good luck baths, such as *Emilia coccinea*, was one of the most common uses of market plants. Women's health ailments comprised 13% of the total number of uses, including plant remedies for vaginal cleanses, fertility, pregnancy, childbirth, postpartum recovery, and increasing breastmilk production. Childcare was the third most common health category of medicinal plants encountered on the market, and included infant health ailments such as diarrhea, cough, and diaper rash, but also local cultural bound concepts such as encouraging children to walk early, closing the fontanels, and treatment of "la rate" (in French), an illness characterized by low body weight and pain on the left side of the body. The category "other" included those health ailments that were only mentioned once or twice by a vendor such as toothache, muscle pain, and jaundice.

Table 3
Species representing 50% of total daily volume, extrapolated to the entire Gabonese market.

Species	Part	Traditional uses	Daily market stock (kg)	Habit	IUCN threat status
Aucoumea klaineana	Resin, bark, leaves, wood	Ritual, skin infections	948.35	Tree	VU[a]
Raphia sp.	Palm stalks	Ritual	378.40	Tree	
Monodora myristica	Seed	Ritual, women's health	312.70	Tree	
Garcinia kola	Bark	Ritual, palm wine	242.26	Tree	VU[a]
Tetrapleura tetraptera	Fruit	Ritual	224.94	Tree	
Ricinodendron heudelotii	Seed	Medicinal oil, spice	155.92	Tree	
Afrostyrax sp. (DQ 1106)	Fruit	Ritual, spice	155.57	Tree	[b]
Xylopia aethiopica	Bark, fruit	Digestive, ritual, spice	148.70	Tree	
Annickia affinis	Bark	Malaria	140.65	Tree	
Pentaclethra macrophylla	Fruit, bark	Ritual, women's health	124.59	Tree	
Copaifera religiosa	Bark	Anemia, ritual	121.48	Tree	
Daniellia klainei	Bark	Ritual, sore body	92.85	Tree	LR/NT[c]
Garcinia lucida	Bark	Anti-poison	92.41	Tree	
Distemonanthus benthamianus	Bark	Good luck	76.09	Tree	
Croton oligandrus	Bark	Ritual, women's health	67.78	Tree	
Terminalia catappa	oil from Seeds	Childcare	64.72	Tree	
Erythrophleum ivorense	Bark	Ritual, swollen limbs/feet	62.34	Tree	
Massularia acuminata	Fruit	Ritual, sprained limbs, women's health	59.92	Shrub	

[a] Vulnerable.
[b] Some species vulnerable.
[c] Low risk/near threatened.

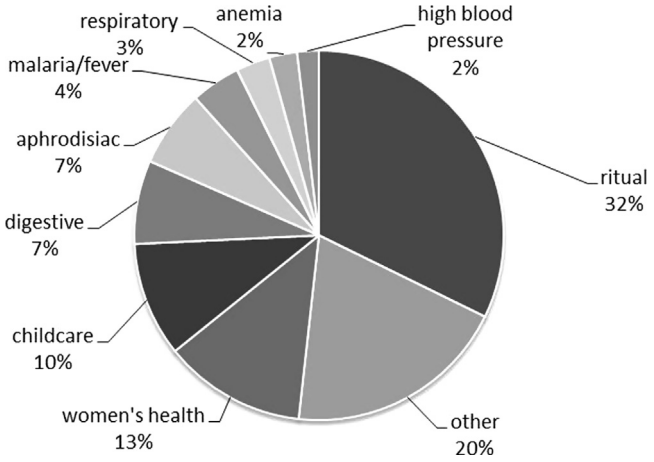

Fig. 5. Most salient health ailments treated by plants sold on the Gabon herbal market in 2012.

3.6. Plant vendor concerns

The vendors reported four main obstacles to the domestic medicinal plant trade: high middleman prices, demolishing of medicinal plant markets, negative societal reputation, and loss of collection habitat. Although most of the women from Libreville reported self-collection of medicinal plants, barks were often purchased from a specialized bark harvester. According to the vendors, the selling price of the barks was often lower than their purchase price, resulting in a loss of profit. Secondly, vendors reported that the medicinal herb stalls of Libreville were once joined under one roof, but the former building was demolished, forcing the herbal medicine market to become divided between the La Peyrie and Mont Bouët annex markets (Table 1). The Bwiti medicine sellers in Port-Gentil reported a similar situation in which they were once part of the larger market Marché Grand Village, but have since been moved farther away to a separate market, Marché Bornave. These changes resulted in difficulties securing a fixed place to sell. Several vendors explained that this situation was linked to a tension with some members of the general public against traditional medicine, stigmatizing the vendors in a negative way. Lastly, many of the harvesters we accompanied to collect fresh material reported that the rapid expansion of Libreville has resulted in a loss of habitat to collect medicinal plants, causing further travel in search of material and increased collection costs.

4. Discussion

4.1. Comparison with other African medicinal markets

We calculated Gabon's domestic annual herbal medicine trade to contain 27 t worth of medicinal plant products with a value of approximately US$ 1.5 million. This volume and economic value were generally smaller than other markets in Africa, including the Eastern Cape Province of South Africa with a total of 525 t worth US$ 3 million (Dold and Cocks, 2002), Ghana with 951 t worth US$ 7.8 million (Van Andel et al., 2012), and Benin with 655 t worth US $ 2.7 million (Quiroz et al., 2014). Gabon's annual herbal trade was more valuable than Sierra Leone, estimated to be worth US$ 64,000 (Jusu and Sanchez, 2013).

The average price of herbal medicine in Gabon was $56 per kg, more expensive than in Ghana (US$ 8.2/kg) or Benin (US$ 21/kg), resulting in a fairly high value for a low volume of plant material for sale. The pattern of products sold in low quantities at high prices, such as the most expensive products sold only at Bwiti stalls, has also been documented for markets in South Africa (Williams et al., 2009). The lower value and volume of the Gabonese market could also be attributed to Gabon's relatively low population, 1.6 million, compared to other African countries. The high reported weekly salaries of the herbal vendors may be reflective of Gabon's per capita income, US$ 19,200 a year, which is four times higher than most sub-Saharan African countries (CIA, 2013). The migrant Beninese vendors reported sales of around US$ 56 a week, which was only slightly higher than the estimated US$ 45 weekly sales reported by market vendors in Benin (Quiroz et al., 2014). The presence of medicinal plants on the market stresses the role of herbal medicine in relatively wealthy African countries with heavily urbanized populations.

The bulk of the daily stock of plant parts in Gabon was sold as bark (30%), followed by resin (20%). In comparison with West African markets, Ghana's daily stock was dominated by fruits and seeds, Benin was mainly leaves and whole plants, and Sierra Leone was mainly barks and leaves. In South Africa (Dold and Cocks, 2002), bulbs, tubers and roots represented over 60% of the most frequently traded plant species, where roots represented only 2% of the daily stock in Gabon. In Tanzania, barks and roots were most prevalent on the market (McMillen, 2008). Given that 80% of Gabon's surface is covered in forest, the dominance of rainforest barks on the market is not a surprising finding.

Although the rainforest vegetation in Central Africa varies greatly with the savanna-mosaic vegetation of Benin and Ghana, the three countries had some commercialized medicinal plants species in common, such as the seeds and fruits that doubled as food additives and medicine (*Xylopia aethiopica*, *Monodora myristica*, and *Aframomum melegueta*). Like the markets in Benin and Ghana, Gabon's most salient health products included those used in ritual and for women's health. Although the volume and value of the herbal material sold in Gabon was much lower than other African markets, the floristic diversity of the market (217 spp.) was higher than in Cameroon (35 spp.) (Betti, 2002), Sierra Leone (43 spp.), South Africa (166 spp.), and Ghana (209 spp.), and slightly lower than in Benin (283 spp.) and Tanzania (250 ethnospp). Since our market survey captured only six months out of the year and did not include some smaller markets across the country, the total plant diversity of Gabon's markets is likely to be higher than our estimates.

4.2. Migrant sellers and imported plants

A notable attribute of the herbal medicinal plant trade in Gabon is the presence of market vendors from neighboring African countries, e.g. Benin, Cameroon, Nigeria, Niger, Togo, who sold medicinal plant products imported into Gabon. From our previous work on Beninese herbal markets (Quiroz et al., 2014), we were able to recognize and identify many Beninese plant products. Previous work on sub-Saharan African markets has documented the presence of non-African vendors, including Chinese herbal medicine in Tanzania (Hsu, 2002) and the sale of Indian herbs in South Africa (Williams et al., 2005; Wojtasik, 2013), but also migrants from other African countries, such as Beninese vendors in Ghana (Van Andel et al., 2012). Since nearly 20% of the Gabonese population is made up of immigrants, and Beninese migrants are the third largest immigrant group (The World Bank, 2011) it is possible that Beninese medicinal plant sellers are catering to the demand of Beninese migrants in Gabon. However, the market women that we accompanied in the field mentioned collecting species such as *Cassytha filiformis* specifically for West African immigrants, suggesting that the Gabonese vendors also cater to immigrant healthcare needs. The presence of imported products and vendors at major medicinal plant markets in Gabon may suggest that there is a demand for diverse medicinal products from non-forest vegetation types. The trade of imported herbal medicine has further implications for the sustainability of the national, regional, and continent-wide herbal medicine trade and is an area for future research.

It is likely that Gabonese medicinal plants are exported outside of the country, especially *Tabernanthe iboga* (Neuwinger, 1996). The Gabonese branch of the Wildlife Conservation Society in Libreville expressed concern about the unsustainable export-oriented harvest of *Tabernanthe iboga* (R. Starkey, personal communication July 2012), a concern echoed by the antipoaching canine unit implemented by the Agence Nationale des Parcs Nationaux (ANPN) (Wagtail UK, 2013), but no official data on exported species or volumes were available.

4.3. Comparison with other Gabonese industries

Although US$ 1.5 million is a substantial value for this informal economy, it is dwarfed by the major natural resource industries of Gabon, namely the US$ 15 billion oil industry (CIA, 2013) and the US$ 1.8 billion timber industry (Forest Legality Alliance, 2014). Nevertheless, the income derived from the medicinal plant trade makes substantial contributions to the economic well-being of the plant vendors in Gabon, the majority of whom are women. This pattern has been documented in other countries in Africa (Dold and Cocks, 2002; Williams et al., 2009; Van Andel et al., 2012; Jusu and Sanchez, 2013; Quiroz et al., 2014), highlighting the necessity of understanding gender dynamics in the trade of NTFPs (Shackleton and Paumgarten, 2011).

4.4. Potential species of concern

Out of the five IUCN red-listed species, only the resin of *Aucoumea klaineana* and bark of *Garcinia kola* were found in high quantities on the market stalls. *Aucoumea klaineana* is historically the most popular tree exported from Gabon by the timber industry (Global Forest Watch, 2000; Forest Legality Alliance, 2014), suggesting that the timber industry has had a large role in the overharvesting of this rainforest tree. In neighboring Cameroon *Garcinia kola* is commonly cultivated, highlighting local responses to managing commercially important resources (Fondoun and Manga, 2000). Further investigation is needed to make more substantial claims about the sustainability of these rainforest trees' harvest for medicinal use including harvesting methods and frequency, natural distribution, population assessments, impact studies and measurements on the rate of extraction versus the rate of natural regeneration (Ticktin, 2004; Guinee, 2013). Our results can contribute to improved resource management strategies, securing not only the survival of these species, but also the availability of these resources to people who rely on them for their physical, spiritual, and economic well-being (Dold and Cocks, 2002). It should also be noted that most of the species that we encountered on the market were not yet assessed by the IUCN, which opens the possibility for additional threatened species.

4.5. Salient traditional uses

Plants used in rituals comprised the majority of the medicinal plants sold on the market in Gabon, reflecting the importance of Bwiti practices to modern urban culture in Gabon. Although Bwiti customs are closely associated with the use of *Tabernanthe iboga* (Pope, 1969), the indigenous torches represent the greatest volumes of all plant products for sale. *Tabernanthe iboga* was sold in much smaller volumes, suggesting that the many other ritual plants are commercialized and sold in larger volumes. Women's health issues and childcare comprised the next two largest health domains of commercialized plant products. Medicinal plants are used widely in Gabonese women's healthcare, especially for vaginal cleanses (Towns and Van Andel, 2014).

5. Conclusion

This market survey contributes to the literature on the Central African medicinal plant trade, shedding light on the current trade of species in the region, salient health needs and traditional uses met by the market, and the monetary value of this informal economy. With an estimated annual volume of 27 t of medicinal plant material worth US$ 1.5 million, Gabon's market is smaller than herbal markets in other parts of Africa but generally higher in floristic diversity. Dominated by barks, the Gabon market also

offers large quantities of IUCN vulnerable *Aucoumea klaineana* resin for sale. Including this highly valued timber species, only 2% of the 217 species encountered on the market has conservation concerns.

The herbal markets in Libreville housed 75% of the total stock of medicine plant products available for sale daily. The markets in Libreville also featured many migrant vendors, the majority of whom were Beninese, selling imported species not for sale at herbal stalls of Gabonese vendors. Bwiti stalls were concentrated mainly in Port-Gentil while spice stalls selling dual purpose food and medicine products were common throughout the 14 markets we visited. Over 30% of the medicinal plant products from the herbal market were used for ritual purposes, highlighting the role of traditional spiritual practices and ceremonies in urban life in Gabon. Our results serve to fill the gaps in knowledge of a major medicinal market in a conservation-priority country of Central Africa, stress the role of herbal medicine in a relatively wealthy African country, and contribute to the overall understanding of the complexity of the African herbal medicine trade.

Acknowledgments

Most of all, we thank the market vendors who shared their time, patience, and knowledge with us during the survey. The Netherlands Organization for Scientific Research (NWO) provided funding for this research, (ALW-Vidi Grant no. 864.09.007), but had no additional involvement in the study. The fieldwork was supported by the research staff at L'Institut de Pharmacopée et de Médecine Traditionnelles (IPHAMETRA), the National Herbarium of Gabon (LBV), Henri Bourobou, le Centre National de la Recherche Scientifique et Technologique (CENAREST), and the Agence Nationale des Parcs Nationaux (ANPN). A special thanks to Sofie Ruysschaert and Esther van Vliet for assistance with the fieldwork. In the Netherlands, we would like to thank Marc Sosef for logistical support, Pieter Baas for assistance with the wood anatomy analysis, Barbara Gravendeel for DNA barcoding, and the botanists at the former Wageningen Branch of the National Herbarium of the Netherlands for their assistance with plant identification.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.jep.2014.06.052.

References

Anyinam, C., 1995. Ecology and ethnomedicine: exploring links between current environmental crisis and indigenous medical practices. Social Science and Medicine 40, 321–329.
Betti, J., 2002. Medicinal plants sold in Yaoundé markets, Cameroon. African Study Monographs 23, 47–64.
CIA. 2013. CIA - The World Factbook: Gabon. www.cia.gov/library/publications/the-world-factbook/geos/gb.html (accessed 29.04.13.).
CITES. 2014. CITES. www.cites.org (accessed 14.04.14.).
Cocks, M.L., Dold, A.P., 2006. Cultural significance of biodiversity: the role of medicinal plants in urban African cultural practices in the Eastern Cape, South Africa. Journal of Ethnobiology 26, 60–81.
Colwell, R.K. 2013. EstimateS: Statistical estimation of species richness and shared species from samples. Version 9. http://purl.oclc.org/estimates (accessed 08.04.14.).
Cunningham, A., 1993. African medicinal plants: setting priorities at the interface between conservation and primary healthcare, People and Plants Initiative. UNESCO, Paris.
Cunningham, A.B., 2001. Applied Ethnobotany: People, Wild Plant Use and Conservation. Earthscan, London.
Dold, A., Cocks, M., 2002. The trade in medicinal plants in the Eastern Cape Province, South Africa. South African Journal of Science 98, 589–597.
El-Hilaly, J., Hmammouchi, M., Lyoussi, B., 2003. Ethnobotanical studies and economic evaluation of medicinal plants in Taounate province (Northern Morocco). Journal of Ethnopharmacology 86, 149–158.
FAO. 2010. Global Forest Resources Assessment 2010. Rome. www.fao.org/docrep/013/i1757e/i1757e.pdf.
Flore du Gabon. 1960 – 2008. Various editors, volume 1–38. Paris: Muséum National d'Histoire Naturelle.
Fondoun, J., Manga, T., 2000. Farmers indigenous practices for conserving *Garcinia kola* and *Gnetum africanum* in southern Cameroon. Agroforestry Systems 48, 289–302.
Forest Legality Alliance. 2014. Gabon. http://risk.forestlegality.org/countries/gabon (accessed 10.04.14.).
Gaoue, O.G., Ticktin, T., 2007. Patterns of harvesting foliage and bark from the multipurpose tree Khaya senegalensis in Benin: variation across ecological regions and its impacts on population structure. Biological Conservation 137, 424–436.
Global Forest Watch, 2000. A First Look at Logging in Gabon. World Resources Institute, Washington DC, pp. 1–50.
Guinee, L., 2013. Sustainability aspects of medicinal bark, root and wood harvest in Gabon: a rapid assessment of sustainability issues using market surveys and species distribution models (Masters thesis). Utrecht/Leiden University, Leiden.
Hawthorne, W.D., Jongkind, C.C.H., 2006. Woody plants of western African forests: a guide to the forest trees, shrubs and lianes from Senegal to Ghana. Kew: Royal Botanic Gardens, 1–1023.
Hsu, E., 2002. "The medicine from China has rapid effects": Chinese medicine patients in Tanzania. Anthropology and Medicine 9, 51–53.
InsideWood. 2004-onwards. http://insidewood.lib.ncsu.edu.
International Society of Ethnobiology. 2006. http://ethnobiology.net/code-of-ethics/. International Society of Ethnobiology Code of Ethics (with 2008 additions). http://ethnobiology.net/code-of-ethics/.
IUCN Red List of Threatened Species. 2014. IUCN 2014. Version 2013.2. www.iucnredlist.org (accessed 14.04.14.).
Jusu, A., Sanchez, A., 2013. Economic importance of the medicinal plant trade in Sierra Leone. Economic Botany 67, 299–312.
Jusu, A., Sanchez, A., 2014. Medicinal plant trade in Sierra Leone: threats and opportunities for conservation. Economic Botany 68, 16–29.
Martin, G.J., 2004. Ethnobotany: A Methods Manual. Earthscan, London.
McCune, B., Mefford, M. 2006. PC-ORD v5. Multivariate analysis of ecological data. Glaneden Beach: MjM Software Design.
McMillen, H., 2008. Conserving the roots of trade: Local ecological knowledge of ethnomedicines from Tanga, Tanzania markets (PhD thesis). University of Hawaii, Manoa.
Neuwinger, H.D., 1996. African Ethnobotany: Poisons and Drugs: Chemistry, Pharmacology, Toxicology. Chapman and Hall, London.
Olson, D., Dinerstein, E., 1998. The Global 200: a representation approach to conserving the Earth's most biologically valuable ecoregions. Conservation Biology 12, 502–515.
Ondo, C., 2001. Estudio de productos forestables no maderables en tres mercados de Guinea Ecuatorial. Anales Del Jardín Botánico de Madrid 59, 275–286.
Osamor, P.E., Owumi, B.E., 2010. Complementary and alternative medicine in the management of hypertension in an urban Nigerian community. BMC Complementary and Alternative Medicine 10, 36.
Pope, H., 1969. *Tabernanthe iboga*: an African narcotic plant of social importance. Economic Botany 23, 174–184.
Pouliot, M., 2011. Relying on nature's pharmacy in rural Burkina Faso: empirical evidence of the determinants of traditional medicine consumption. Social Science and Medicine 73, 1498–1507.
Quiroz, D., Towns, A.M., Sènan, I., Swier, J., Brière, S., Sosef, M., van Andel, T., 2014. Quantifying the domestic market in herbal medicine in Benin, West Africa. Journal of Ethnopharmacology 151, 1100–1108.
Raponda-Walker, A., Sillans, R., 1961. Les plantes utiles du Gabon (Sepia.). Fondation Raponda-Walker, Paris.
Schippmann, U., Leaman, D., Cunningham, A., 2002. Impact of cultivation and gathering of medicinal plants on biodiversity: global trends and issues, Biodiversity and the Ecosystem Approach in Agriculture, Forestry and Fisheries: 12–13 October 2002. Inter-Departmental Working Group on Biological Diversity for Food and Agriculture, Rome.
Shackleton, C., Shackleton, S., 2004. The importance of non-timber forest products in rural livelihood security and as safety nets: a review of evidence from South Africa. South African Journal of Science 100, 658–664.
Shackleton, S., Paumgarten, F., 2011. Opportunities for enhancing poor women's socioeconomic empowerment in the value chains of three African non-timber forest products (NTFPs). International Forestry Review 13, 136–151.
Sosef, M.S.M., Wieringa, J.J., Jongkind, C.C.H., Achoundong, G., Azizet Issembé, Y., Bedigian, D., van den Berg, R.G., Breteler, F.J., Cheek, M., Degreef, J., Faden, R.B., Goldblatt, P., van derMaesen, L.J.G., Ngok Banak, L., Niangadouma, R., Nzabi, T., Nziengui, B., Rogers, Z.S., Stévart, T., van Valkenburg, J.L.C.H., Walters, G., de Wilde, J.J.F.E., 2006. Check-list des plantes vasculaires du Gabon – Checklist of Gabonese vascular plants. Scripta Botanica Belgica 35, 1–438.
The World Bank. 2011. Migration and Remittances Factbook 2011. http://data.worldbank.org/data-catalog/migration-and-remittances (accessed 14.04.14.).
Ticktin, T., 2004. The ecological implications of harvesting non-timber forest products. Journal of Applied Ecology 41, 11–21.
Towns, A.M., Ruysschaert, S., Van Vliet, E., Van Andel, T.R., 2014. Evidence in support of the role of disturbance vegetation for women's health and childcare in Western Africa. Journal of Ethnobiology and Ethnomedicine 10, 42.

Towns, A.M., Van Andel, T.R., 2014. Comparing local perspectives on women's health with statistics on maternal mortality: an ethnobotanical study in Bénin and Gabon. BMC Complementary and Alternative Medicine 14, 113.
Van Andel, T., Myren, B., van Onselen, S., 2012. Ghana's herbal market. Journal of Ethnopharmacology 140, 368–378.
Wagtail UK. 2013. Gabon's Sniffing Detectives. www.wagtailuk.com/gabons-sniffing-detectives/ (accessed 23.04.14.).
Williams, V., Balkwill, K., Witkowski, E., 2000. Unraveling the commercial market for medicinal plants and plant parts on the Witwatersrand, South Africa. Economic Botany 54, 310–327.
Williams, V.L., Witkowski, E.T.F., Balkwill, K., 2005. Application of diversity indices to appraise plant availability in the traditional medicinal markets of Johannesburg, South Africa. Biodiversity and Conservation 14, 2971–3001.
Williams, V., Witkowski, E.T.F., Balkwill, K., 2009. Volume and financial value of species traded in the medicinal plant markets of Gauteng, South Africa. International Journal of Sustainable Development and World Ecology 14, 584–603.
Wojtasik, E., 2013. Richness and diversity of alien ethnomedicinal plant taxa used and sold for traditional medicine in South Africa (PhD thesis). University of the Witwatersrand, Johannesburg.