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Research Paper

Quantifying the domestic market in herbal medicine in Benin, West Africa



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ABSTRACT

Ethnopharmacological relevance: Herbal medicine markets are essential in understanding the importance of medicinal plants amongst a country's inhabitants. They are also instrumental in identifying plant species with resource management priorities. To document the diversity of the medicinal plant market in Benin (West Africa), to quantify the weight of traded species in order to evaluate their economic value, and to make a first assessment of their vulnerability for commercial extraction.

Materials and methods: We quantitatively surveyed 22 market stalls of 16 markets in the country's eight largest urban areas. We collected all plant (parts) following standard botanical methods and recorded uses, prices and local names, and weighed and counted the numbers of sales units.

Results: We recorded 307 medicinal products corresponding to ca. 283 species. Thirty-five species were encountered in at least 25% of the surveyed stalls, from which ten are locally endangered or red-listed by the IUCN. Examples of vulnerable species included *Caesalpinia bonduc*, which has been declared extinct in the wild but is largely cultivated in home gardens, and was exploited for its seeds, roots, and leaves, and *Zanthoxylum zanthoxyloides* which was harvested for its bark, roots, and leaves. Other top-selling fruits and seeds included red-listed species: *Monodora myristica*, *Xylopia aethiopica*, and *Schrebera arborea*. Top-selling woody plant parts included the roots of *Sarcocephalus latifolius*, *Mondia whitei*, and the barks of *Khaya senegalensis* and *Pteleopsis suberosa*. All but *Sarcocephalus latifolius* and *Pteleopsis suberosa* were species with some threat status. Plants sold at the market were mainly used for ritual purposes, women's health, and to treat malaria and its symptoms.

Conclusion: Our results suggest that the domestic medicinal plant market in Benin is of substantial economic importance. A volume of approximately 655 metric tons worth 2.7 million USD is offered for sale annually. Traditional spiritual beliefs seem to be a major driving force behind the trade in herbal medicine.

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1. Introduction

Herbal markets are essential to understand the importance of medicinal plants for a country's inhabitants. These markets provide a snapshot of a country's medicinal flora (Van Andel et al., 2007, 2012), reflect distinct cultural preferences (Schippmann and Cunningham, 2006), and are instrumental in identifying plant species with resource management priorities (Martin, 1995). Despite the widespread availability of Western medicine in Africa, medicinal plants remain an important source of health care in the continent. It is estimated that 70–80% of the continent's population depends on herbal medicine

(Cunningham, 1993; WHO, 2008), however, these figures lack the support of empirical data. Nonetheless, most authors agree on the preference and considerable reliance on herbal treatments by a wide range of peoples throughout the continent (Magassouba et al., 2007; Mafimisebi and Oguntade, 2010; Williams et al., 2013). In addition, medicinal plants are harvested, transported, and traded in both rural and urban markets, generating economic opportunities for vulnerable groups, especially women and farmers facing decreasing agricultural income (Cunningham, 2001; Mander et al., 2007; Vodouhé et al., 2008). Because of the positive implications for rural livelihoods, it has been suggested that the harvest and trade of non-timber forest products provide an incentive for biodiversity conservation (Padoch, 1992; Neumann and Hirsch, 2000).

In spite of their benefits, medicinal plant harvest and trade are not exempted from controversy. With an increasingly large global

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demand for herbal medicine (TRAFFIC, 1999, 2013), profit margins still remain remarkably low (Vodouhé et al., 2008). This scenario, coupled with the selective nature of market demand, is changing the traditional subsistence-based use systems into market-oriented production ones (Arnold and Ruiz Pérez, 2001). Exacerbated by the popularity of wild-crafted medicinal plant harvesting and lack of opportunities in the formal job market, this could lead to an overexploitation of wild and rare medicinal plant species (Cunningham, 1997; Bussmann and Sharon, 2009).

Albeit their importance, medicinal plant markets remain understudied in West Africa. Numerous studies have explored different aspects of medicinal plant markets in Nigeria (Sofidiya et al., 2007; Olowokudejo, 2008; Osemeobo, 2009), Togo (De Souza et al., 2011), Niger (Ikhiru and Saadou, 1984), Burkina Faso (Fernandez de la Pradilla, 1982; Ky et al., 2009), Mali (Maiga et al., 2005; Diallo et al., 2010), and Ghana (Asase et al., 2005). Where these studies have documented marketed species, only one of them has recorded sales frequencies and volumes sold (Van Andel et al., 2012). In Benin, particularly, studies on herbal medicine markets have focused on few species, limited regions, on supply chains only, and most are not published in scientific journals (Allagbé, 1987; CENPREBAF, 1999; Hermans et al., 2004; Fassinou, 2008; Vodouhé et al., 2008; Legba, 2010; Djègo et al., 2011; Adomou et al., 2011, 2012). Moreover, official records about the amount of exported medicinal plant products from Benin only include airborne shipments.

Benin's economy is half the size of neighbouring Ghana (CIA, 2013), while land surface and floristic diversity is much smaller (Adomou, 2005; Akoegninou et al., 2006). Furthermore, Vodoun or Orisha, an ancient animist cult of West-Africa, is recognised as one of the country's official religions, and its practice is widely accepted amongst its inhabitants (U.S. Department of the State, 2012). Therefore, we expected Benin's herbal markets to be smaller in volume and less floristically diverse than Ghanaian markets, but to specialise more on plants used for rituals. In order to test our hypotheses we addressed the following questions: (1) Which medicinal and ritual plant species are commercialised in Benin, and what percentage is this of the total number of species used for these purposes in the country? (2) What is the volume and annual value of commercialised plant species? (3) Which are the species in highest demand? (4) What are the most salient health issues covered by the market? In light of the wealth of work on Benin's medicinal flora and the sustainability issues for some of its species, the objectives of this study were to document the diversity of the country's medicinal plant market, to quantify the bulk of traded species, and to evaluate their economic value and possible ecological impact.

2. Materials and methods

2.1. Study area

We performed a systematic quantitative market survey from July to September 2011 and in January 2012 in selected herbal markets of Benin. With a population of almost ten million, Benin is one of the most densely populated countries in West Africa (CIA, 2013). Located in the Dahomey Gap, southern Benin's vegetation is a forest-savannah mosaic that consists of fallows, fields, and intermittent semi-evergreen, deciduous and swamp forest islands. The north is essentially a "patchwork" of woodlands and savannahs with a few inselbergs and riparian vegetation along rivers (Adomou, 2005).

2.2. Quantitative market survey

Similarly to Van Andel et al. (2012), we classified market stalls in four categories, according to their size and the type of products

sold. Stalls selling more than 1 m³ of plant products (herbs, bark, and wood) were classed as "large herb stalls", and those with less than 1 m³ as "small herb stalls". Stalls selling mostly medicinal fruits and seeds were called "seed stalls", and those selling a few plants and mostly animal carcasses (which were sold for the elaboration of charms) were called "vodoun stalls". We counted all plant products and total amount of sales units (bags, bundles, bottles, and loose units) per stall, and noted their fresh or dry weight using a portable digital scale. Additionally, we estimated the total weight of stock kept separately (usually at the back of the stall). We noted the vendors' ethnicity and gender and interviewed them about their weekly sales of medicinal plant products, so we could estimate annual sales for surveyed stalls and extrapolate this to the entire market. We also asked them to indicate those species that had become (or were becoming) expensive because they were difficult to obtain, and to explain other reasons for increasing (or decreasing) prices. We then calculated the volume of plant material offered for sale per stall in order to estimate the total amount of herbal medicine available daily on the surveyed markets. The average price per kilogram of each product was calculated from prices and weights of several sales units. This figure was then multiplied by the volumes of the species in question encountered during our survey to obtain the total economic value of herbal medicine at each market. Last, we summed all figures for all species and extrapolated this information to estimate the annual volume and value for the entire Beninese market.

Plant collection was done following standard botanical methods. Vouchers were deposited at the National Herbarium of Benin (BEN) and the Wageningen branch of the National Herbarium of the Netherlands (WAG), now part of Naturalis Biodiversity Center. Collected plant specimens were identified in the herbarium using local flora keys (Akoegninou et al., 2006) and literature including vernacular plant names (Adjahoun et al., 1989; De Souza, 1988). Market wood samples were identified by a wood anatomist using microscopic methods and the InsideWood database (2004-onwards) and by means of DNA analysis (see Supplementary File 1). Finally, we verified the threat status of all encountered plant species using the IUCN red list (<http://www.iucnredlist.org/>), and a red list for Benin (Adomou et al., 2011).

2.3. Data analysis

Using EstimateS version 8.2 (Colwell, 2010) we calculated Fisher's alphas, to assess cumulative diversity. We built sample-based rarefaction curves to verify whether our sampling effort had been sufficient to cover the floristic diversity of Benin's herbal market (Williams and Balkwill, 2005). In order to assess whether the markets of Ghana were larger and more diverse than those of Benin, we compared the diversity in products and species of the different stalls sampled by Van Andel et al. (2012) with those sampled by us and performed a Mann-Whitney U test using SPSS® version 20.0.

2.4. Ethics

Informants read and signed a Free and Prior Informed Consent (OAU, 2000). Whenever informants were not able to read and write, they were informed of our intent and their verbal permission was obtained. All informants were rewarded with a small sum of money to compensate for their time and for sharing their knowledge. The amount was convened with them prior to the interview.

3. Results

3.1. Benin's medicinal plant markets

During our survey we sampled 22 stalls in 16 different markets in eight of Benin's largest urban areas (Fig. 1). Apart from the Avogbamana market in Bohicon, that exclusively sold vodoun products, medicinal plant markets in Benin do not stand on their own. They form part of larger markets selling a plethora of daily-use goods such as household products and foods, amongst others (Table 1). Herbal medicine stalls are usually found clustered together within the premises of a market. Large and small herb stalls sell mostly dried and fresh leaves and herbs, woods, barks, roots, and a few seeds and fruits, especially calabashes (*Crescentia cujete* and *Lagenaria siceraria*). The latter ones are cultivated in different shapes and both species' fruits are often used as containers for herbal medicine and ceremonial offerings. Seed stalls, as their name suggests, specialise in medicinal seeds and a few fruits, but also sell products used in traditional ceremonies such as feathers, beads, kaolin, soaps, perfumes, ironware, and special fabrics. The Avogbamana market in Bohicon and Kobo Kobo in Parakou are known as fetish markets. Just as other vodoun stalls found in the Beninese markets, they specialise in ingredients for rituals. These ingredients include, for its greatest part, the carcasses of animals such as birds, rodents, reptiles, and mammals.

Many markets in Benin, especially those in rural areas, take place only once or twice a week (usually in intervals of three to five days). During these days vendors come from nearby villages to sell their goods. Located near Porto Novo, the Adjara and Agbokou markets are characterised by the predominance of stalls that sell plant products wholesale. In Adjara, seeds, fruits, and fibres (the latter ones derived from species such as *Ficus thonningii* and *Raphia* sp.) are the most common plant products, whereas Agbokou specialises in roots, barks, and woods. Markets in cities, or settlements with a distinct urban character, take place almost daily (but some of them close on Sundays). Although the ethnic backgrounds of the vendors we interviewed were different, Fon and Yoruba were the vernaculars most often used for plant names. In Parakou, some plant products were also marketed with their Dendi or Bariba names. Half the herb sellers we interviewed indicated that they considered themselves of mixed ethnicity. Where vodoun stalls were almost without exception owned by men, female vendors (86%) outweighed male ones in the medicinal plant trade.

3.2. Volume and value of Benin's medicinal plant trade

We calculated the total amount of medicinal plants available for sale at all surveyed Beninese markets at 46,815 kg per day. Over a third of the total herbal remedies present as daily stock were concentrated in the markets of Cotonou (15,572 kg). Other urban markets situated at important crossroads in the country stored considerable amounts of daily stock as well (Table 1). However, not all plants offered for sale were actually sold that same day. Although 86% of the medicinal plants we encountered during our survey were sold dry (see Supplementary File 2), our informants indicated discarding an average of 4.12 kg per week. They also indicated selling, on average, 25 kg of herbal medicine weekly (with large herb stalls selling 33 kg, small herb stalls 36 kg, seed stalls 18 kg, and vodoun stalls 5 kg). Further, they pointed out that markets take place every week of the year. By multiplying weekly sales by 52 and subtracting discarded volumes, we estimate the annual amount of medicinal plants sold at the surveyed Beninese markets at 655,252 kg.

We calculated the average price of herbal medicine at 21 USD/kg. Vendors indicated that they sold on average 83 USD of herbal medicine per week. Vodoun stalls earned only 6 USD per week, whereas seed stalls made as much as 212 USD in the same time period. The contrast is explained by the fact that vodoun stalls made most of their gains from the sales of animal carcasses (which we did not include in our calculation). Seed stalls, on the other hand, made their earnings from the sale of plant products with the highest prices per kilogram (seeds and fruits, both sold at an average of 27 USD/kg). Small and large herb stalls had a weekly income of 45 and 46 USD, respectively. Based on this information we estimated the annual value of medicinal plant trade in Benin at 2,735,310 USD.

3.3. Market's floristic diversity

Throughout the entire fieldwork period, we have documented 307 plant products sold at the herbal medicine markets of Benin. From these 307 products, we have been able to identify 283 to the species level, 11 to the genus level, and 11 to the family level. Two products remained unidentified due to insufficient sample material. All plant species and products encountered during our surveys and visits to the Beninese markets are listed in the supplementary File 2. Herbs, sold as whole individual plants, made up for the largest percentage of plant diversity sold, while the leaves of shrubs and trees represented the bulk of plant parts available as daily stock (Fig. 2).

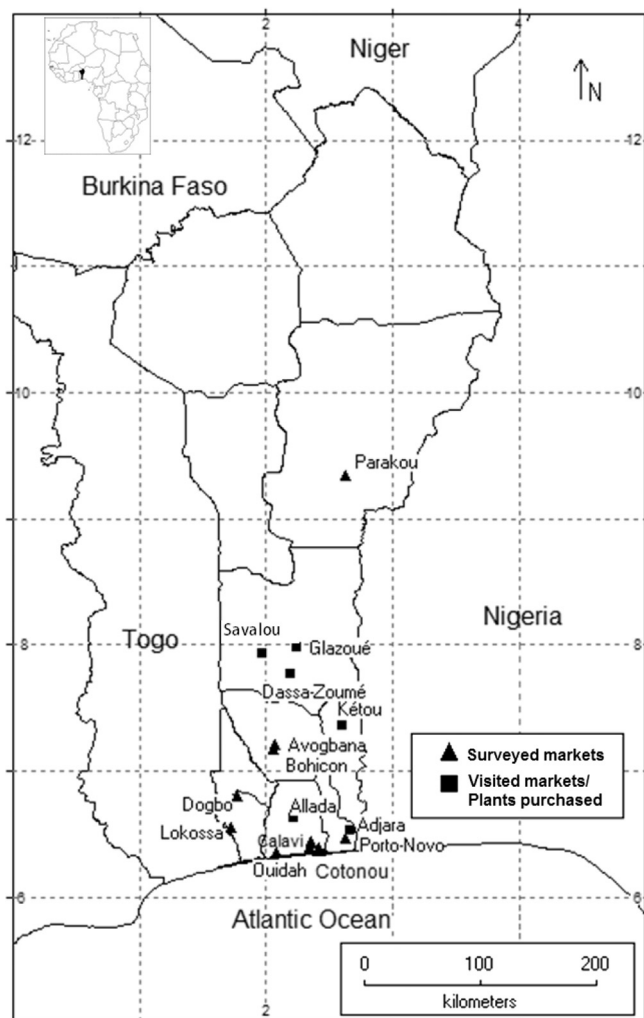


Fig. 1. Map of visited and surveyed markets in Benin in 2011–2012.

Table 1
Main characteristics of surveyed markets in Benin in 2011 and 2012.

Location (Market)	Products sold	Sales frequency (days per week)	Total number of stalls	Big herb stalls (> 1 m ³)	Small herb stalls (< 1 m ³)	Seed stalls	Vodoun stalls	No. of sampled stalls (%)	No. of herbal medicine products (%)	Total daily stock (kg)
Lokossa	Herbs, produce, clothing, kitchenware	1	500	1	2	4	6	4 (30)	62 (27)	635
Calavi	Herbs, produce, meat, fish, fabrics, pulses, kitchenware	7	200	11	0	12	8	2 (6.4)	119 (52)	3990
Godomey	Herbs, produce, meat, fish, fabrics, pulses, kitchenware	7	200	8	0	1	16	2 (8)	92 (40)	2610
Cotonou (Dantokpa)	Herbs, produce, meat, fish, fabrics, pulses, kitchenware, electronics, livestock, clothing	7	3000	38	8	36	52	2 (1.4)	112 (49)	10419
Cotonou (Fifadji)	Herbs, produce, meat, fish, fabrics, pulses, kitchenware	7	150	3	4	3	1	1 (9)	29 (12)	3876
Cotonou (Gbegamey)	Herbs, produce, meat, fish, fabrics, pulses, kitchenware	7	200	12	8	7	0	1 (3.7)	23 (10)	571
Cotonou (Saint Michel)	Herbs, produce, meat, fish, fabrics, pulses, kitchenware	7	200	1	2	7	2	1 (8.3)	55 (24)	706
Parakou (Arzeke)	Herbs, produce, fabrics, pulses, kitchenware, clothing	7	1000	0	11	28	12	1 (1.9)	15 (6)	2331
Parakou (Kobo Kobo)	Herbs, clothing, animal carcasses	7	1000	0	0	6	8	1 (7)	31 (13)	3440
Parakou (Dépot)	Herbs, produce, meat, fish, fabrics, pulses, kitchenware	7	500	7	8	7	2	1 (4)	14 (6)	4550
Dogbo	Herb, produce, pulses, kitchenware	1	900	1	2	16	20	1 (2.5)	13 (5)	2847
Porto Novo (Grand Marché)	Herbs, produce, meat, fish, fabrics, pulses, kitchenware, clothing	7	1000	12	3	18	8	1 (2.4)	49 (21)	2241
Porto Novo (Agbokou)	Produce, pulses, livestock, wholesale herbal medicine	1	100	27	19	8	5	1 (1.6)	44 (19)	2843
Bohicon	Herbs, produce, meat, fish, fabrics, pulses, kitchenware, clothing	7	1000	11	21	24	0	1 (1.7)	49 (21)	2145
Bohicon (Avogbamana)	Herbs and animal carcasses	7	20	0	0	1	16	1 (5.8)	15 (6)	1802
Ouidah (Zobé)	Herbs, produce, fabrics, pulses, kitchenware, clothing	7	300	6	14	5	9	1 (2.9)	115 (50)	1846
Total				149	168	362	180	22 (3.7)	226 (100)	46852

Sample-based incidence of plant products and species, which was measured with Fisher's alpha, increased with the number of sampled stalls. The curves show a sharp increase in the first four samples, afterward the increase becomes gradual. By the 19th sample, we had already covered 97% of the total plant products and 98.5% of the species we encountered in our quantitative survey. This suggests that our sampling effort of 22 stalls has been sufficient (Fig. 3).

After surveying 22 market stalls, we had covered 226 (73%) of the total number of plant products encountered during the fieldwork, and between 198 and 205 (73–75%) of the total number plant species. The number of plant products is higher than that of species because the different organs of several plant species were exploited as separate products (e.g. for *Kigelia africana* we recorded four different products: fruits, leaves, bark, and roots). Seventy plant products (30% of the total) were recorded only once during the entire survey. The families most encountered in the market survey were Leguminosae (33 spp.), Rubiaceae (19 spp.), Compositae (10 spp.), Apocynaceae and Malvaceae (9 spp. each), Euphorbiaceae and Cucurbitaceae (8 spp. each), Poaceae and Anacardiaceae (7 spp. each), Annonaceae and Lamiaceae (6 spp. each).

3.4. Prices, rare plants, and the provenance of some commercial species

With an average weight of 112 g and an average price of 1.38 USD per sales units, barks were the most expensive plant products we encountered during our survey. Roots (113 g) were sold at 0.75 USD per sales unit, fruits (21 g) at 0.58 USD, seeds (9 g) at 0.25 USD, and whole herbs (55 g) at 0.23 USD. The prices per

kilogram for individual plant species varied from 0.06 to 866 USD (see [supplementary File 2](#)). We noticed that species used for ritual purposes and plants with a low weight per sales unit were amongst the most expensive products. The bulbs of a *Cyperus* sp. and the seeds of *Martynia annua*, and an unidentified species of Anacardiaceae (DQ 246) were the three most expensive plants. All of them had a weight per sales unit of 1 g. In contrast to our observations, all informants agreed that plants were expensive because they were scarce. Only two vendors mentioned that increasing prices were also due to retailers controlling the trade who raised prices as they would see most convenient.

From the 283 species in our product list (see [Supplementary File 2](#)), 28 were listed as threatened (from which 10 species were globally threatened). The average price per kilogram of these species was 16 USD. From the 28 threatened species, 11 were said to be scarce by our informants: *Milicia excelsa*, *Caesalpinia bonduc*, *Pterocarpus erinaceus*, *Azelia africana*, *Garcinia kola*, *Mondia whiteii*, *Khaya senegalensis*, *Bridelia ferruginea*, *Carissa spinarum*, and *Acridocarpus smeathmannii*. Other non-red-listed plant products perceived as rare by our informants include the roots of *Morinda lucida*, *Anthocleista vogelii*, *Chassalia kolly*, and *Sansevieria liberica*; and the barks from species such as *Parkia biglobosa*, and *Psychotria vogeliana*. On average, these plants were sold for 6.5 USD/kg. The vendors we interviewed in the rural markets of Lokossa and Dassa indicated that all of the plants they sold, except for seeds and barks, were collected by themselves. Interviewees in large urban centres such as Cotonou (Dantokpa, Saint-Michel, Gbegamey, and Fifadji), Abomey-Calavi, and Godomey indicated that they purchased their plants from the market in Pahou (a town near Ouidah, Southern Benin, which hosts the forest of Pahou),

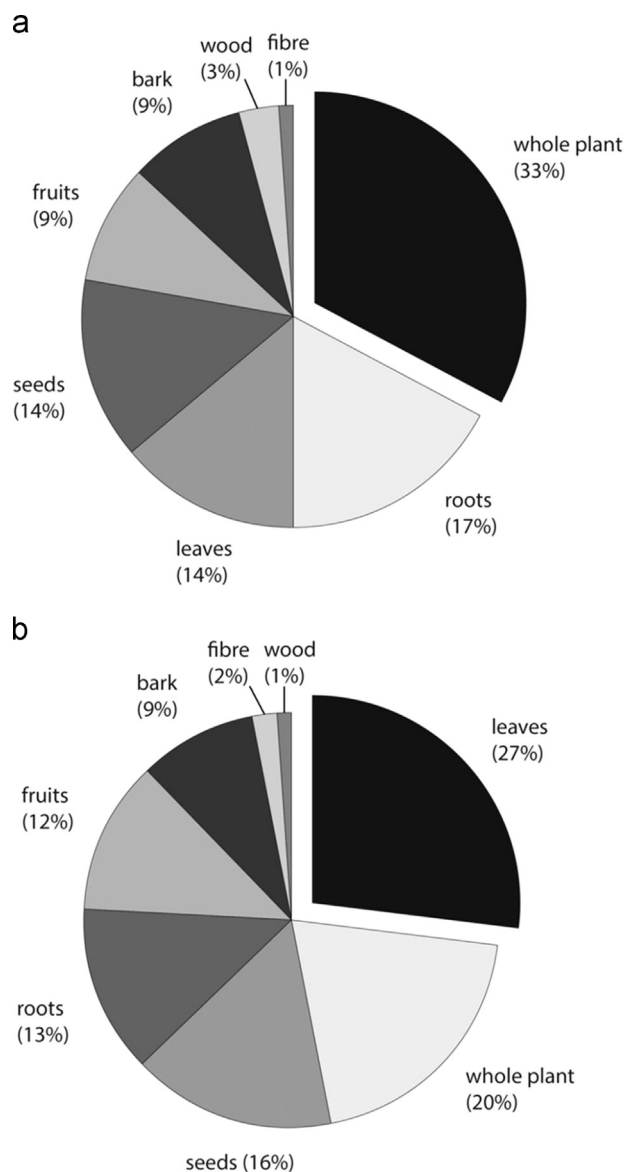


Fig. 2. Plant parts sold in Beninese herbal markets sampled in 2011, (a) as percentage of the total number of products ($n=226$), and (b) as percentage of the daily stock (excluding stock packed behind stalls).

or that they were delivered to them by small-scale collectors or middlemen.

We had the opportunity to visit the home garden of one of the market vendors in Godomey, who cultivated plants that she reported as difficult to find in the wild, and had considerable demand at the market (e.g. *Caesalpinia bonduc*, *Morinda lucida* and *Chassalia kolly*). We also encountered *Kalanchoe crenata* and *Aloe* sp. growing in flowerpots in four of the stalls we surveyed. Avogbamana market had a piece of land of ca. 0.25 ha where medicinal plants were cultivated (e.g. *Merremia quinquefolia*, *Jatropha multifida*, *Jatropha gossypifolia*, *Musa* sp., *Carica papaya*). Except for *Merremia quinquefolia*, none of these species were found at the sampled stalls during our quantitative survey. *Carica papaya*, however, was one of the products we purchased during one of our visits prior to the survey.

Roughly 17% ($n=35$) of the medicinal plant species encountered during our survey were found in at least 25% of the sampled stalls. Amongst these plants, 11 (5% of the total) are locally threatened or IUCN red-listed species (Table 2). *Caesalpinia bonduc* (a locally threatened species) was the only species with both high

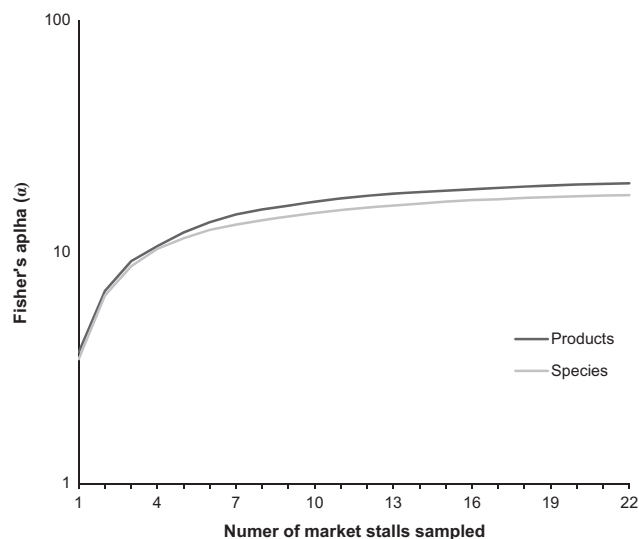


Fig. 3. Cumulative diversity curve for traded plant products and species in the 22 market stalls sampled in Benin in 2011–2012.

sales frequency and large stock. Plants that were present daily at the market in quantities higher than one (metric) ton included both wild and cultivated species, as well as herbs, trees, and shrubs (Table 3).

Sold at ca. 1 USD per piece, the seeds of *Dioclea reflexa* were commercialised as *Milicia excelsa* seeds. Vendors indicated that the seeds were expensive because “they were never found anywhere near an *Milicia excelsa* tree” (which seems obvious they did not correspond to the same species), thus they were perceived as very rare. Although not explicitly considered a rare plant, *Ipomoea argenteaurata* was sold in the markets of Parakou as a “Northern version” of *Dicoma tomentosa*, a plant widely commercialised for its ritual uses. Although *Ipomoea argenteaurata* was sold for double the price of *Dicoma tomentosa* (0.15 USD), we were able to confirm neither the rarity nor the provenance of these two species.

3.5. Salient ailments and their remedies at the Beninese markets

The 226 plant products recorded in the Beninese markets were used in 378 medical and ritual treatments. Most plants were used for ritual purposes (101 species, 27% of the total uses). All other use categories for the plants recorded in this survey are listed in Table 4. Ailments that could not be classified in any of the above categories and that were only mentioned once were classed as “other” uses. These comprise eight species (2%) and include: epilepsy, haemorrhoids, rheumatism, hernia, and utensils used to administer herbal remedies.

Some diseases could be classed in more than one category. *Sakpata* diseases, for example, were illnesses whose symptoms were characterised by pustules (i.e. rubeola, rubella, and varicella). This ailment category owed its name to the god of smallpox and earth, *Sakpata*. Although smallpox has long been eradicated, *Sakpata* diseases were considered as skin conditions with, what was often explained by our informants, a “mystical or bizarre” origin. Albeit sexually transmitted diseases (STDs) were also treated with herbal remedies, plants sold at the market were used in amulets that were believed to prevent them.

4. Discussion

We hypothesised that Ghana’s medicinal markets would be larger and more diverse than the Beninese ones. Beninese herbal

Table 2

Plant species found at Beninese herbal medicine markets in 2011 and 2012 with the highest sales frequency.

Species	Product	No. of uses	Frequency (%)	Threat status	Growth form	Domestication
<i>Sarcocephalus latifolius</i>	Roots	1	64		Tree	Wild
<i>Xylopi aethiopica</i>	Fruits	2	55	VU ^a	Tree	Wild, cultivated
<i>Pteleopsis suberosa</i>	Bark	3	55		Tree	Wild
<i>Schrebera arborea</i>	Fruits	2	55	EN ^a	Tree	Cultivated
<i>Aframomum melegueta</i>	Fruits	2	55		Herb	Domesticated
<i>Monodora myristica</i>	Seeds	4	50	EN ^a	Tree	Wild, cultivated
<i>Ocimum americanum</i>	Whole plant	3	50		Woody herb	Cultivated
<i>Chamaecrista mimosoides</i>	Whole plant	3	50		Woody herb	Wild
<i>Entada gigas</i>	Seeds	2	50		Woody climber	Wild
<i>Allium sp.</i>	Roots	2	45		Herb	Cultivated
<i>Abrus precatorius</i>	Seeds	1	45		Twinning herb	Wild
<i>Caesalpinia bonduc</i>	Seeds	3	45	EW ^a	Shrub	Cultivated
<i>Cymbopogon citratus</i>	Whole plant	1	45		Herb	Wild, cultivated
<i>Dicoma tomentosa</i>	Whole plant	1	40		Herb	Wild
<i>Lycopodiella cernua</i>	Whole plant	2	40		Herb	Wild
<i>Remirea maritima</i>	Whole plant	2	40		Herb	Wild
<i>Gladiolus dalenii</i>	Roots	2	40		Herb	Wild
<i>Senna siamea</i>	Leaves	1	40		Shrub	Wild, cultivated
<i>Lannea barteri</i>	Bark	2	36		Tree	Wild
<i>Picralima nitida</i>	Seeds	2	36		Tree	Wild
<i>Acridocarpus smeathmannii</i>	Roots	2	36	EN ^a	Tree	Wild
<i>Zanthoxylum zanthoxyloides</i>	Roots	1	32	VU ^a	Tree	Wild
<i>Tetrapleura tetraptera</i>	Fruits	2	32	VU ^a	Tree	Wild
<i>Aerva lanata</i>	Whole plant	1	32		Herb	Wild
<i>Garcinia kola</i>	Seeds	2	32	EW ^a	Tree	Cultivated
<i>Heterotis rotundifolia</i>	Whole plant	2	32		Herb	Wild
<i>Psychotria vogeliana</i>	Leaves	1	32		Shrub	Wild
<i>Khaya senegalensis</i>	Bark	2	32	EN ^a , VU ^b	Tree	Wild, cultivated
<i>Cucumis metuliferus</i>	Fruit	1	32		Scrambling herb	Domesticated
<i>Lagenaria breviflora</i>	Fruit	2	32		Scrambling herb	Domesticated
<i>Lagenaria siceraria</i>	Fruit	1	32		Scrambling herb	Domesticated
<i>Momordica charantia</i>	Fruit	1	32		Climbing herb	Cultivated
<i>Curcuma sp.</i>	Roots	1	32		Herb	Cultivated
<i>Ensette livingstonianum</i>	Seeds	1	27	CR ^a	Herb	Cultivated
<i>Mondia whitei</i>	Roots	3	27	VU ^a	Climbing herb	Wild

^a Adomou et al. (2011).^b IUCN Red List (<http://www.iucnredlist.org/>).**Table 3**

Plant species sold in the greatest bulk at Beninese herbal medicine markets in 2011 and 2012.

Species	Product	No. of uses	Market stock (kg/d)*	Threat status	Growth form	Domestication
<i>Dioclea reflexa</i>	Seeds	1	2788.84		Twinning herb	Cultivated
<i>Cola acuminata</i>	Fruits, seeds	3	2501.85		Tree	Wild
<i>Pavetta corymbosa</i>	Leaves	2	2194.27		Shrub	Wild
<i>Caesalpinia bonduc</i>	Roots, seeds, leaves	3	2171.15	EW ^{a,b}	Shrub	Cultivated
<i>Prosopis africana</i>	Leaves, wood	1	2163.15		Tree	Wild
<i>Cassytha filiformis</i>	Whole plant	2	1758.05		Parasitic herb	Wild
<i>Kedrostis foetidissima</i>	Whole plant	2	1691.46		Herb	Wild
<i>Annona senegalensis</i>	Leaves	1	1472.73		Tree	Wild, cultivated
<i>Anthocleista vogelii</i>	Roots	4	1266.24		Shrub	Wild, cultivated
<i>Ageratum conyzoides</i>	Whole plant	3	1231.75		Herb	Wild
<i>Raphia sp.</i>	Fibre	2	1203.06		Tree	Wild
<i>Leonotis nepetifolia</i>	Whole plant	1	1176.96		Herb	Wild, cultivated
<i>Uraria picta</i>	Whole plant, seed	2	1134.99		Herb	Wild
<i>Anacardium occidentale</i>	Bark	3	1131.50		Tree	Domesticated
<i>Pterocarpus erinaceus</i>	Bark	6	1096.89	EN ^{a,b}	Tree	Wild
<i>Sterculia setigera</i>	Leaves	1	1090.62		Tree	Wild

^a Adomou et al. (2011).^b IUCN Red list (<http://www.iucnredlist.org/>).

* Sum of stock of all plant products for each species.

medicine stalls were significantly more diverse than the Ghanaian ones in terms of species ($U=149.50$, $Z=-2.96$, $p=0.003$) and products ($U=151.00$, $Z=-2.93$, $p=0.003$). However, with an estimated annual volume of 951 t of plant material and a value of 7.8 million USD (Van Anel, et al., 2012), Ghana's herbal market was larger than Benin's.

The fact that Benin's vegetation type was not determinant to the diversity of its medicinal herb market vis-à-vis Ghana could find its explanation in the country's location in the Abidjan-Lagos Corridor. Cotonou, is the best performing port to reach land-locked neighbouring country Niger (Hall et al., 2011), and because of the absence of significant civil conflict, the country is an important

Table 4
Use percentage of medicinal plants sold in Beninese markets per ailment category.

Use	Number of species used	Percentage
Ritual		27
Love	25	
Good luck	20	
Protection against evil spirits	20	
Protection against <i>Tchakatou</i> (bewitchment)	10	
Initiation ceremonies (purification baths)	10	
Divination	7	
Protection against accidents	4	
Protection against enemies/ thieves	4	
Protection against STDs	1	
Women's health		21
Infertility	20	
Pregnancy	16	
Painful menstruation	17	
Breast milk production	11	
Vaginal cleanse	3	
Contraception	4	
Womb cleanse	3	
Cysts	4	
Malaria	22	16
Anaemia	29	
Fever	9	
Fatigue	1	
Jaundice	1	
Child care		15
Early walk	14	
<i>Atita</i> (redness and pimples in joints and stomach in infants)	14	
Teething	13	
Failure to thrive syndrome	5	
Closing fontanels	3	
Drying of navel cord	1	
Circumcision	2	
Other ^a	5	
Digestive disorders		5
Diarrhoea	16	
Constipation	4	
Respiratory diseases		4
Asthma	6	
Cough	8	
Skin diseases		5
<i>Sakpata</i> (rubeola, rubella, varicella)	10	
Rashes	3	
Wounds	2	
Hypertension	11	2
Sexually transmitted diseases (STDs)	5	1
Diabetes	4	1
Madness	3	1
Other	8	2
Total	378	100

^a Cited by informants as “for children's health”.

access point to the sea to Burkina Faso as well. These factors place Benin in privileged position at a crossroads of commerce amongst various phytosociological regions in West Africa.

As we had expected, the majority of herbal medicine products in Benin was meant for use within a spiritual context (in Ghana this ailment category was only second in importance). However, the importance of traditional spiritual values (i.e. Vodoun) is even larger than the herbal market alone, as reflected by the large amounts of animals traded for this purpose (Djagoun and Gaubert, 2009; Djagoun et al., 2013).

Our quantitative market survey indicated that the annual value of Benin's medicinal plant market was at least 2.7 million USD in 2011.

This figure is small when compared to the economic value of cotton production, Benin's most important agricultural export, which in 2008 was about 620 million USD (CIA, 2013). Nonetheless, the importance of the plant trade in Benin cannot only be assessed with respect to its contribution to the GDP, as it is an important component of the livelihood strategies of vulnerable groups (Vodouhé et al., 2008). Moreover, our calculations should be seen as an underestimation as available medicinal plant export figures mostly lack volumes and values and we did not include several of the smaller markets in our survey. There were several plant species that, apart from being sold as remedies at medicinal plant markets, also served as food, condiments or colourants (the seeds of *Triticum* sp., *Amaranthus* sp., *Pennisetum* cf. *glaucum*, *Xylopia aethiopica*, *Monodora myristica*, *Aframomum melegueta*, *Piper guineense* and *Sesamum indicum*; the leaves of *Ocimum gratissimum* and *Sorghum bicolor*; the fruits of *Capsicum annum* and *Syzygium aromaticum*; and the bulbs of *Allium* spp). These products were sold in large quantities on general food stalls, and thus excluded from our survey.

In addition, plants that are officially exported from the country are shipped in small quantities to Italy and Guadeloupe. The largest exports comprise endangered species such as *Khaya senegalensis* (bark), *Kigelia africana* (fruits, of which 10 metric tons were exported between 2007 and 2010), *Rauvolfia vomitoria* (leaves), *Caesalpinia bonduc* (roots), and *Zanthoxylum zanthoxyloides* (roots). These data are only available because medicinal plants that leave the country as air shipments must go through a phytosanitary control, which is performed by the Phytosanitary Control Post at Cotonou's airport. However, there is no record as to whether these plants are cultivated by the exporting agents, bought directly from harvesters, self-collected, or purchased at the markets (C. Zinse, personal communication of May, 2013). Moreover, there is no record of the amount of plant material that leaves the country through other ports, although there is evidence that Beninese medicinal plants are sold in Ghana (Van Andel et al., 2012) and Gabon (A.M. Towns, personal communication of July, 2012).

Prices could be a misleading indicator of scarcity in the wild. As Botha et al. (2007) explained, it is difficult to estimate the scarcity of a species when collection is not done directly by one's self. Most of our informants did not collect the plants they sold themselves, and those who did only collected herbs and leaves. Thus, the rarity of bark, wood, and root products perceived by the vendors did not necessarily reflect scarcity in the wild, with the exception of the plant species with threat status in Benin. Many species were just occasionally commercialised (i.e. *Hydrocotyle bonarensis*) so they could be considered “hard to find” just because they were not frequently encountered at the market. Likewise, abundance at the market did not necessarily mean that a species was common in the wild. Some locally endangered species such as *Schrebera arborea* and *Monodora myristica*, had a high sales frequency and were sold at small quantities, but were not perceived as scarce by our informants. Moreover, far from reflecting scarcity, high prices were influenced by the size of their sales units. Some plants were sold in small quantities but are not endangered or perceived as rare (i.e. the seeds of *Cleistopholis patens*). This lack of consistency in the relationship between prices per sales units and per kilogram of medicinal plants has also been noted by other authors (Botha et al., 2007; Williams et al., 2007).

In Benin there is a legal restriction for the collection and commercialisation of endangered species. Article 84 of the law of forests of Benin stipulates punishments up to ca. 1000 USD and two months of jail for the exploitation of protected plant species. However, we lack the evidence to state that these measures effectively discourage harvesters from collecting the endangered species we encountered during our market visits. Finally, there is a substantial number of species whose perceived rarity has been

reported by Djègo et al. (2011) and were encountered only once during our survey (e.g. *Acmella uliginosa*, *Bryophyllum pinnatum*, *Cissampelos mucronata*, *Commiphora africana*, *Ficus thonningii*, *Milletia thonningii*, *Parkia biglobosa*, *Pseudocedrela kotschy*, and *Pterocarpus santalinoides*). Although none of these plants were perceived as rare by the market vendors interviewed in our survey, the fact that their scarcity was reported elsewhere merits consideration when revising local lists of threatened species.

The fact that during our market survey we encountered only 75% of the total plant products and species recorded during our entire field stay raises the question: has our sampling effort been sufficient to cover the entire floristic diversity of the Beninese markets? In 1989, 530 plant species with medicinal uses were recorded in Benin (Adjanohoun et al., 1989). In 2013, only 20 species had been added to this figure in the PROTA database (<http://www.prota4u.org/>). During our market survey we covered around 50% of this total medicinal plant diversity. Over a period of three months, Legba (2010) recorded a total of 205 species (and 217 products) sold at the Calavi market, while the CENPREBAF market survey (1999) registered 338 species found in 81 markets, but neither referred to making botanical collections nor specified the duration of fieldwork.

Vodouhé et al. (2008) sustained that during the rainy season medicinal plants became scarce in the Beninese markets because farmers, who they identified as the most numerous of commercial collectors, were not active during this period because of agricultural activities. We started our survey at the end of the long rainy season (April–July) and finished during the short dry season (August–September). Although we surveyed one more market in January, we did not find new species. A fieldwork stay of an entire year would have been desirable, however, our budget and time schedule limited the period of our stay in Benin. Further market research should focus on plant availability during the long dry season (December–March).

The importance of collecting comprehensive herbarium vouchers and the potential of DNA barcoding for ethnobotanical research has been stressed by Veldman et al. (2013). Our results from the DNA analysis and wood anatomical identification for those specimens that lacked other diagnostic features were not completely satisfactory. In spite of its relatively large size, descriptions in the InsideWood database do not represent all woody plants and are supported by a few samples only, thus they not always reflect the full variability of a species (InsideWood, 2004–onwards). Nine of the samples that were sent to the laboratory for DNA barcoding yielded unlikely results, as their sequencing “matched” that of species that did not occur in Benin or even West Africa (e.g. *Schima superba*, *Pongamia pinnata*, and *Digitalis lutea*). The task of rigorously actualising these databases remains a challenge that can be bridged by completing botanical collections, as much as possible, not only with vernacular names, uses, woods, barks, and roots, but also with DNA samples.

5. Conclusions

In our study we found that 50% of the total medicinal flora in Benin was commercialised in its markets. A volume of approximately 655 metric tons worth 2.7 million USD is offered for sale annually. These figures are below the estimated volume and value recorded for the herbal market in Benin’s much larger neighbour Ghana, but the floristic diversity of both markets is comparable. Nonetheless, our results suggest that the domestic medicinal plant market in Benin is of substantial economic importance. Traditional spiritual beliefs seem to be a major driving force behind the trade in herbal medicine. As it has been previously stated, medicinal plants are a resource of societal, economic, and cultural

importance for the Beninese people. Therefore, our conclusions are presented with the intention to inform decisions pertaining culturally appropriate development interventions and, eventually, to contribute to the conservation of valuable medicinal plant species.

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Appendix A. Supplementary materials

Supplementary data associated with this article can be found in the online version at <http://dx.doi.org/10.1016/j.jep.2013.12.019>.

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