Use and extraction of medicinal plants by the Fulni-ô indians in northeastern Brazil – implications for local conservation

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Abstract – The aims of this study were: to characterize the knowledge and traditional uses of two important medicinal plants from northeastern Brazil, *Myracrodruon urundeuva* (aroeira) and *Sideroxylon obtusifolium* (quixaba); to quantitatively analyze the bark collection process of these two species, and; to evaluate the population structure of these species in the Ouricuri Forest, a native and sacred forest recognized as one of the collection sites of these resources. The study was conducted in the Fulni-ô Indigenous Land (IL) located in the municipality of Águas Belas, Pernambuco State. This study was part of an ethnobotanical survey in the Fulni-ô IL and formed one of the lines of action of the project "Studies for the Environmental and Cultural Sustainability of the Fulni-ô Medical System: Office of Medicinal Plant Care". In this study, 344 semi-structured interviews were carried out between November 2007 and March 2008 from a stratified random sample of the Fulni-ô population in the indian settlement (only including men and women over the age of 15). The interview script included specific questions regarding the interviewees' knowledge and use of aroeira and quixaba. To analyze the population structure and level of exploitation of aroeira and quixaba populations, we used two complementary techniques, 200-point quadrat sampling and walk-through sampling, in the Ouricuri Forest. Our data confirmed that aroeira is widely known by the Fulni-ô, while quixaba is known by fewer people in the community. Bark is the primary plant part used by the indigenous population. During the collection of aroeira, for example, tree size is used as a selective criterion. Neither species exhibits the reverse J-shaped population structure typical of stable populations. Few adult individuals are present, possibly due to selective logging targeted at such individuals. The two species studied here are also used for timber, increasing the pressure on their populations. Finally, despite the local scope of our findings, we briefly discuss their implications at both a local and a regional scale.
Additional key words: Biodiversity conservation, Caatinga, ethnobotany, semi-arid region, traditional botanical knowledge.

Resumo (Uso e extrativismo de plantas medicinais pelos índios Fulni-ô no Nordeste do Brasil: implicações para a conservação local) **–** Os objetivos deste estudo foram: caracterizar os conhecimentos e usos tradicionais de duas importantes espécies medicinais nativas do Nordeste do Brasil, *Myracrodruon urundeuva* (aroeira) e *Sideroxylon obtusifolium* (quixaba); analisar quantitativamente o processo de coleta de casca destas duas espécies; e avaliar a sua estrutura populacional na Mata do Ouricuri, remanescente de floresta nativa e sagrada, reconhecida como um dos locais de coleta destes recursos. O estudo foi realizado na Terra Indígena Fulni-ô (TIF), município de Águas Belas, Pernambuco. Este estudo fez parte de um levantamento etnobotânico na TIF, sendo uma das linhas de ação do projeto "Estudos para a Sustentabilidade Ambiental e Cultural do Sistema Médico Fulni-ô: Oficina de Manipulação de Plantas de Uso Medicinal". Neste estudo, 344 entrevistas semiestruturadas foram realizadas entre novembro de 2007 e março de 2008, utilizando-se uma amostra aleatória e estratificada da população indígena da Aldeia Sede (incluindo apenas homens e mulheres com mais de 15 anos de idade). O roteiro da entrevista considerou perguntas específicas sobre o conhecimento e uso dos parceiros da pesquisa em relação à aroeira e quixaba. Para analisar a estrutura populacional e o nível de extração nas populações destas espécies usamos duas técnicas complementares, a amostragem com 200 pontos quadrantes e o método do caminhamento, na mata do Ouricuri. Nossos dados sustentam que a aroeira é amplamente conhecida pelos Fulni-ô, enquanto o quixaba é identificada por poucas pessoas na comunidade. A casca é a principal parte da planta usada pela população indígena. Especificamente para a aroeira, o tamanho da árvore é utilizado como um critério seletivo. Nenhuma das duas espécies exibe a estrutura populacional em forma de J-invertido, típico de populações estáveis. Poucos indivíduos adultos foram amostrados, possivelmente devido à extração seletiva de madeira que foca tais indivíduos. As duas espécies aqui estudadas também são utilizadas para fins madeireiros, aumentando a pressão sobre suas populações. Finalmente, apesar do âmbito específico de

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Editor responsável: Marcelo Alves Ramos
Received: 18 Apr. 2011; accepted: 11 Aug. 2011.

nossos resultados, discutimos brevemente as suas implicações, tanto em nível local como em uma escala regional.
Palavras-chave adicionais: Caatinga, conhecimento botânico tradicional, conservação da biodiversidade, etnobotânica, Semiárido.

Tropical ecosystems provide a great wealth of plant that benefits human populations around the world, especially those that rely on the extraction and use of plant products. Many species, like those that provide non-timber forest products (NTFPs), are used as therapeutic resources in traditional medical systems (Soldati & Albuquerque 2008). The use of these plant products contributes to the prevention and cure of disease, particularly where biomedicine is inaccessible or prohibitively expensive (Zschocke et al. 2000). About three billion people worldwide depend on the use of medicinal plants collected directly from natural ecosystems (Kala 2000). However, little is known about the impact of medicinal plant resource extraction (Oliveira et al. 2007).

Ecological responses to NTFP use depend on many variables, including the life history of the plant species, the time of collection, the part collected, environmental factors, and cultural aspects of their use, such as the intensity, frequency and method of collection and preferred collection and handling practices (Peters 1994; Cunningham 2001; Pfab & Scholes 2004; Ticktin 2004; Ghimire et al. 2005). Given this complexity, studies that evaluate the process of medical resource extraction and its impact on resource populations are important in defining strategies for the conservation of biodiversity (Soldati & Albuquerque 2008).

Among Brazilian ecosystems, the *Caatinga* forest stands out for its high diversity of native and endemic species (Tabareli & Vicente 2002; Silva et al. 2004). Despite a large number of scientific studies in this ecosystem (see Albuquerque et al. 2010a), there are still some gaps in knowledge. The *Caatinga* supports diverse cultural groups, including indigenous populations, small-scale farmers, and *quilombolas* (communities descended from escaped African slaves), that are heavily dependent on plant resources (Araújo et al. 2007), including medicinal plants.

This study is part of an ethnobotanical survey in the Fulni-ô Indigenous Land (IL) conducted as part of the project "Studies for the Environmental and Cultural Sustainability of the Fulni-ô Medical System: Office of Medicinal Plant Care" (see Albuquerque et al. 2010b, 2011). This project was performed by the Associação Mista Cacique Procópio Sarapó (Mixed Association Cacique Procópio Sarapó – AMCPS), a Fulni-ô non-governmental organization, with funding and technical guidance from the Field of Indigenous Traditional Medicine/ Project VIGISUS II of the National Foundation for Health (FUNASA). The study was initiated in July 2007 and completed in December 2008.

The project employed an action-research design built on participation, multi-disciplinarity and inter-ethnicity. It comprised the following lines of action: anthropological action-research, ethnobotanical inventory, and pharmaceutical action linked to phytotherapy. Notably, the indigenous team contributed a key structural aspect of the project with regard to the participatory nature of the actions developed and the construction of intercultural dialogue.

The primary objective of the project was to strengthen scientific understanding and appreciation of the Fulni-ô medical system[1] and to ensure its cultural and environmental sustainability. In the ethnobotanical survey, one of the preliminary aims was to assess the possible impacts of the implementation of the Fulni-ô "Office for the Manipulation of Plants for Medicinal Use", built in 2003 as the result of a partnership between the Associação Mista Cacique Procópio Sarapó (Mixed Association Cacique Procópio Sarapó - AMCPS), the VIGISUS Project, the Department of Indigenous Health (DESAI), and the Special Indigenous Sanitary District of Pernambuco (DSEI-PE). The objective of this partnership was to facilitate the manufacture of "semi-artisanal phytotherapeutics" based on traditional knowledge as alternative therapeutic resources to meet the health needs of the Fulni-ô population. The activities developed as part of the project included the planting of a medicinal herb garden and the construction of a facility for the production of herbal medicines in the Manipulation Office.

In the garden, native and non-native plants are grown to ensure that the community has access to the raw materials used to prepare home remedies and to provide seedlings for reforestation of existing degraded areas in the IL. Thus, the garden contributes to the continuity of knowledge and traditional health care practices among the Fulni-ô. The garden is also meant to supply the herbal materials for the Fulni-ô Manipulation Office.

The present study examines the possible impacts of the exploitation of two tree species, *Myracrodruon urundeuva* Allemão (aroeira) and *Sideroxylon obtusifolium* (Humb. ex Roem. & Schult.) T.D.Penn. (quixaba), by Fulni-ô traditional medicine. These tree species were selected because they are culturally important (Silva et al. 2006) and because initial field observations found signs of extensive and intensive exploitation of their bark. In addition, aroeira

[1] In this paper, a medical system (Kleinman 1978) is defined as a symbolic system that covers basic concepts of health and illness, health care practices, practitioners, therapeutic resources, and therapeutic objectives and their evaluation. Notably, indigenous medical systems extend to all social aspects, establishing intrinsic relationships with the social organization, cosmology, and environment of the indigenous population.

is one of the most important plants in local medical systems in northeastern Brazil (Albuquerque et al. 2007a) and is considered an endangered species by the IBAMA (Brazilian Institute of Environment and Natural Resources). To address whether local populations of *M. urundeuva* and *S. obtusifolium* can support the demands of the Fulni-ô medical system and the Manipulation Office, we characterized the knowledge and traditional use of these two species, quantitatively analyzed the bark collection process, identified possible selection criteria, and evaluated the population structure of the two species in areas where they are collected.

Materials and Methods

Study area. The study was conducted in the Fulni-ô Indigenous Land located in the urban area of the municipality of Águas Belas (09º06'41"S and 37º07'23"W) (Figure 1A), 315 km from Recife, the capital of Pernambuco (CONDEPE / FIDEM 2006; IBGE 2007). The municipality was legally recognized in 1904 from the indigenous-land leasing process granted by the church in 1832 and currently has a population of approximately 35,374 inhabitants. The climate is semi-arid, hot, and humid (CONDEPE / FIDEM 2006), with an average temperature of 25°C and a rainfall index of 600 mm (IBGE 2007). The major economic activities are dairy farming, agriculture, goat and sheep production, poultry production and handicrafts (CONDEPE / FIDEM 2006). The Fulni-ô IL is located in a typical area of *Caatinga* vegetation, which is markedly xerophytic, deciduous, and thorny. The *Caatinga* ecosystem is characterized by a striking seasonal climate and exhibits diverse compositions and physiognomies throughout its range (Araújo et al. 2007).

The Fulni-ô ethnicity. According to the official historiography, the Fulni-ô were a nomadic people and were converted to the Catholic faith around 1685 by Capuchin missionaries (Diaz 1983). In the eighteenth century, Ipanema village was created, merging various ethnic groups in the region. The Fulni-ô were officially recognized by the Imperial Government at that time and received the lands that they inhabit to the present day. In 1832, part of this land was ceded to the Church of Nossa Senhora da Conceição de Águas Belas, which began to lease lots in the center of the old village, eventually forming the municipality of Águas Belas. Since then, conflicts over land ownership between the Fulni-ô and the inhabitants of Águas Belas have become increasingly intense.

The Fulni-ô are the only bilingual indigenous people in Pernambuco. They speak *yaathe*, a language belonging to the Macro-Jê linguistic group, and Portuguese. *Yaathe* is spoken daily within the community, especially by older members. The Fulni-ô concepts of time, space, and identity are marked by the Ouricuri ritual, which occurs annually between September and December. During this period, the population moves to the Ouricuri village (Figure 1B). Y*aathe* is spoken and taught especially during this ritual, which is an important means for the transmission of Fulni-ô cosmology, history, and traditional knowledge to younger generations. Only the Fulni-ô are allowed to learn *yaathe*, participate in the Ouricuri ritual, and access the cosmology and social organization of their culture, particularly the experiences related to clan divisions. These cultural features are protected by the symbolic boundary of secrecy established by the Fulni-ô.

The Ouricuri village is surrounded by areas of *Caatinga* vegetation, forming one of the few fragments of native forest in the region (Figure 1C). Because basic sanitation and electricity are not available in this village, the demand for plant resources (medicinal and otherwise) increases considerably during the ritual, intensifying the pressure of utilization on these remnant forests (Figure 1E). In addition to the Ouricuri village, there are two other villages in the IL: the head village, where the vast majority of indigenous inhabitants live, and Xixiaklá. The Fulni-ô number 3,667 people in the head village, 122 in Xixiakhlá village, and 517 scattered across various locations and Brazilian states (FUNASA 2007).

The Ouricuri forest is not the only area where the Fulni-ô collect medicinal plants. There is a mountain within the Fulni-ô IL known as Serra do Comunaty (Mountain area). Due to its greater abundance of water, the mountain habitat exhibits floristic vegetation elements characteristic of more humid regions. However, this mountain is distant from the head village, and few indigenous inhabitants routinely explore this area. Therefore, the mountain area was not considered in this study.

Ethnobotanical inventory. To characterize the knowledge and local use of *M. urundeuva* and *S. obtusifolium*, we conducted 344 semi-structured interviews between November 2007 and March 2008 from a stratified-probability sample of the Fulni-ô population inhabiting the head village (including only men and women over the age of 15) (see details in Albuquerque et al. 2010b). The interviews included the following questions relating to the two focal species: What are the therapeutic attributes of the plant? What method of preparation, dosage and quantity are used? Where is the plant collected, and who collects it? To obtain a more realistic approximation of the impact of traditional medical-system activities, all survey collaborators who cited the focal species (228 for aroeira and 97 for quixaba) were asked whether they actually used this resources. According to Brazilian law, any research with indigenous peoples requires a prior authorization of the "Board of Management of Genetic Patrimony" (CGEN), except for one situation: when the study is conceived and requested by the indians themselves, as was the case of the present study.

Population structure and level of exploitation of *Myracrodruon urundeuva* and *Sideroxylon obtusifolium*. Populations of *M. urundeuva* and *S. obtusifolium* in the Ouricuri forest were sampled between August and September 2007 (Figure 1, C and D) using two complementary methodologies. First, four blocks of 50 point quadrats (Müller-Dombois & Ellenberg 1974) were marked, each containing ten 50-m transects located 10 m apart, making a total of 200 points. The four sites where the vegetation was sampled were selected based on input from the indigenous collaborators and members of the project team, considering the occurrence of higher collection rates and the permissibility of access by non-indigenous researchers (this forest is considered a sacred place, forbidden to non-indigenous people without permission). The inclusion criteria for sampling individual trees was a circumference at ground level (CGL) greater than or equal to 9.5 cm, which is the standard procedure in phytosociological studies in the *Caatinga* (Rodal et al. 1992). Additionally, we used walk-through sampling (Felfili et al. 2006), which involved walking throughout the area and sampling all individuals of the target species. Approximately ten hours of walk-through were recorded to locate individuals of each species. In addition to the CGL, we recorded the CBH (circumference at breast height) of all individuals sampled by the two methods (Figure 1D). CBH measurements were later converted to diameter at breast height values (DBH = CBH/π). The Diameter at Ground Level information for all individuals sampled and the point-quadrat and walk-through data were used to infer the population structures of *M. urundeuva* and *S. obtusifolium*. Specimens were collected and pressed for identification and deposited in the Professor Vasconcelos Sobrinho Herbarium (PEUFRP) of the Federal Rural University of Pernambuco under the accession numbers 49,434-49,444.

To quantify the removal of stem bark, we used an adaptation of the visual method described by Cunningham & Mbenkum (1993). Exploitation levels were scored in eight categories according to the percentage of bark collected up to 2 m above the soil: 0) no damage; 1) to 10% of bark removed; 2) 11–25%; 3) 26–50%; 4) 51–75%; 5) 76–99%; 6) girdling; and 7) entire bark removed (Lins Neto et al. 2008) (Figure 1, D and F).

Data analysis. The therapeutic uses of *M. urundeuva* and *S. obtusifolium* were categorized according to body systems, as in Albuquerque et al. (2007a). A chi-square test was used to verify whether the knowledge and effective use of the two species differed. To evaluate the sampling sites of the two species, we considered streets, yards, lakes, dams, and gardens in the head village to be anthropogenic areas. Tree diameters were binned into three-centimeter intervals to construct the population structure of each species. Finally, to detect possible selection criteria used in the collection process, we calculated the Spearman coefficient between the diameter at breast height (DBH) and the level of exploitation using the statistics package BioStat 5.0 (Ayres et al. 2005).

Results

Knowledge and traditional use of *Myracrodruon urundeuva* and *Sideroxylon obtusifolium*. Of the 344 collaborators who participated in the semi-structured interviews, 304 (88.37%) and 130 (37.79%) referenced aroeira and quixaba, respectively, as a medicinal resource. The collaborators reported 74 different therapeutic uses relating to 13 body systems for aroeira and 28 uses relating to 11 body systems for quixaba (Table 1). For aroeira, the following body systems had the greatest numbers of therapeutic indications (a measure of versatility): disorders of the genito-urinary system (DGS), with 16 indications; undefined disorders or pain (UAP), with 15 indications; and digestive system disorders (TSD), with 12 indications. In total number of citations, the UAP category stood out strongly, with 202 references. That number was almost twice the number of

Figure 1. Characterization of Fulni-ô Indigenous Land and the extraction of *Myracrodruon urundeuva* Allemão (aroeira) and *Sideroxylon obtusifolium* (Humb. ex Roem. & Schult.) T.D.Penn. (quixaba): **A-** Partial view of the Fulni-ô Indigenous Land; **B-** Ouricuri village; **C-** two Fulni-ô indians in the Ouricuri forest, smoking the typical "chanduca" pipe, during data collection; this picture also represents the vegetation structure of these fragments; **D-** team during the field collection, sampling one aroeira individual, which shows clear signs of bark extraction, **E-** Fulni-ô indian indicating a medicinal resource in the Ouricuri forest; **F-** quixaba individual, with strong evidence of bark extraction.

Table 1. Therapeutic uses of *Myracrodruon urundeuva* Allemão (aroeira) and *Sideroxylon obtusifolium* (Humb. ex Roem. & Schult.) TD Penn. (quixaba) by Fulni-ô, Águas Belas, Pernambuco, Brazil. BHD = blood and hematopoietic organs diseases; CSD = circulatory system disorders; DEG = diseases of the endocrine glands, nutrition and metabolism; DGS = disorders of the genito-urinary system, biliary; DMC = diseases of the musculoskeletal system and the connective tissue; DRS = disorders of the respiratory system; DSD = disorders of the digestive system; DSS = diseases of the skin and subcutaneous cellular tissue; IPD = infectious and parasitic diseases; IPO = injury, poisoning and other consequences of external causes; NSD = nervous system disorders; PCP = pregnancy, childbirth and puerperium; SD = sensory disorders; UAP = undefined alterations and pain.

	Corporeal systems	Uses	Citation (sum)	Therapeutic indication
Aroeira	DGS	17	71	Cystitis; vagina litching; vaginal discharge; female pain; feminine hygiene; ovarian infection; genital infection; urinary infection; female inflammation; genital inflammation; ovarian inflammation; uterine inflammation; gynecological problems; prostate problems; kidney problems; uterine problems;
	UAP	15	202	Antibiotic; antiseptic; colic; disease of women; headache; body aches; general aches; fever; personal hygiene; chronic inflammation; inflammation of internal organs; general inflammation; for all; disease prevention;
	DSD	12	29	Heartburn; dysentery; toothache; gastritis; inflammation of the tooth; clean the intestines; digestive problems; stomach problems; hepatic problems; intestinal problems; ulcers;
	IPO	7	106	Healing; depurative; injury; poisoning; stroke; burns; wound; healing; sprains;
	DRS	7	23	Throat disorders; expectorant; pharyngitis, influenza sore throat, hoarseness, cough;
	IPD	4	28	Acne; infections in general; intestinal infections; scabies;
	DSS	3	5	Itching; skin diseases; skin problems;
	PCP	3	9	Abortive; eliminate child labor in the rest; feminine hygiene postpartum;
	DGE	2	3	Tonsillitis, menstrual disturbance;
	BHD	1	1	Blood problems;
	SD	1	1	Cataract;
	CSD	1	2	Blood thinner
	NSD	1	1	Headache
Quixaba	UAP	6	46	Antibiotic; body ache; pain in general; inflammation of internal organs; inflammations in general; within the clean person;
	IPO	5	101	Healing; depurative; injury; bruising; blow;
	DRS	5	7	Lung afflictions; influenza; throat inflammation; respiratory problems in general; cough;
	DSD	3	5	Toothache; stomach problems; ulcers;
	DGS	3	3	Female inflammation; uterine inflammation; kidney problems;
	DEG	1	1	Menstrual disturbance;
	IPD	1	3	Infections in general;
	BHD	1	1	Blood problems;
	DMC	1	1	Back pain;
	PCP	1	1	Feminine hygiene postpartum;
	CSD	1	5	Blood thinner;

references to injury, poisoning, and other consequences of external causes (IPO). The body systems with the largest numbers of therapeutic indications for quixaba were UAP; injury, poisoning, and other external causes (IPO); and disorders of the respiratory system (DRS), with 6, 5 and 5 indications, respectively. Thus, no particular body system stood out for the latter species based on the number of indications (Table 1). However, when considering the total number of references rather than the reported uses, IPO stood out; this category received over twice as many references as all other body systems. The most frequent uses for aroeira were general inflammations (167 citations), injury (48), healing (44), general infections (25), and genital inflammation (19). The most frequent therapeutic indications for quixaba were contusions (77 citations), general inflammation (25), hematoma (14), and general pain (11).

Bark is the most frequently used plant part for both species. For aroeira, 286 collaborators (94.1%) used its bark, 13 collaborators (4.28%) used the bark and/or leaves, 1 collaborator (0.33%) used the bark and/or seeds, and 4 collaborators (1.32%) used the leaves. For quixaba, 128 (98.5%) collaborators used the bark. Only 1 collaborator (0.77%) reported using its bark and/or leaves and another one its bark and/or fruit. Stockpiling, especially of dry bark, is a common practice among the Fulni-ô; 115 survey collaborators (37.83%) stated that they stored aroeira at home, while 22 (16.92%) stored quixaba.

The Fulni-ô collect the two species in three locations: the Ouricuri forest, anthropogenic areas, and the Serra do Comunaty, a mountain distant from the head village where species typical of more humid regions grow. Most collaborators (286) stated that they collected aroeira from the Ouricuri forest, followed by anthropogenic areas (19 collaborators) and the Serra do Comunaty (7 collaborators). For quixaba, the situation was similar; the Ouricuri forest was the most frequent collection site (124 collaborators), followed by the Serra do Comunaty (7 collaborators) and anthropogenic areas (5 collaborators).

When questioned on their knowledge and effective use, 69 (30.26%) of 228 collaborators who reported the aroeira in interviews, stated that they effectively use this specie. These results indicate that *M. urundeuva* is both well known and frequently utilized within the Fulni-ô traditional medical system and suggest that the species may be subject to utilization pressure. For quixaba, 58 (59.79%) of 97 collaborators stated that they effectively use it. Importantly, while the aroeira is best known in the community in relation to quixaba (difference in the number of people who cited each of the species), the ratio of the number of people who actually use and the number of general service (by species) is greater for quixaba.

Population structure and bark collection of *Myracrodruon urundeuva* and *Sideroxylon obtusifolium*. The populations of both species did not exhibit a typical diameter distribution of populations capable of self-perpetuation (qualitative analysis). In the case of aroeira, 73 individuals were sampled, of which 58 (79.45%) were in the first eight diameter classes (from 0–2.99 up to 21.00–23.99 cm). Thus, almost 80% of aroeira individuals belong to the first one-third of the species' life stages, leaving a large gap in the later stages, especially between classes 48.00–50.99 cm and 72.00–74.99 cm (Figure 2). This situation may be the result of selective logging (although we did not evaluate logging pressure). Logging is biased toward adult individuals, which are larger and consequently possess greater volumes of wood and bark. Just as for aroeira, the vast majority of quixaba individuals belonged to young age groups (specifically, the first eight classes), they did not exhibit a negative exponential distribution. Again, many diameter classes lacked representatives. The first eight classes accounted for 110 (90.90%) of the 120 individuals sampled (Figure 3).

For the quantitative analysis of bark collection, of the 73 aroeira individuals sampled, 32 (43.84%) showed no signs of exploitation; 27 of these trees belonged to the first eight diameter classes (Figure 4). However, the majority of individuals analyzed (41 individuals; 56.16%) showed some level of bark damage. Damage levels ranged from 26 50% of bark removed, with 23 individuals exhibiting the latter damage level. The 18- to 20.99-cm diameter class included the largest number of individuals with signs of extraction (seven individuals), followed by the 12 –14.99-cm class (six individuals) and the 15–17.99-cm class (five individuals). Notably, three individuals had all their bark removed; these individuals belonged to the 15–17.99-cm, 21–23.99-cm, and 30–32.99-cm classes.

Among all quixaba individuals sampled (120 individuals), 101 (84.17%) showed no sign of exploitation (Figure 5), leaving 19 (15.83%) individuals with signs of extraction. This lower percentage of exploited individuals was apparently because most individuals of this species were young and might not attract the attention of collectors. Notably, quixaba individuals that showed some signs of extraction exhibited only three levels of damage (out of the seven possible), with most of the individuals exhibiting levels of damage from 26–50% of bark extracted (nine individuals), followed by 11–25% (eight individuals) and 51 –75% (two individuals). Individuals between 12 and 14.99 cm included the greatest number of individuals with signs of exploitation (four individuals), followed by 9–11.99 cm (three individuals) and of 15–17.99 cm and 21.00–23.99 cm (two individuals each). Among the six individuals in the area with larger diameters (> 45 cm), only three showed signs of exploitation: two individuals with 26–50% of their bark removed and one individual with 51–75% of its bark removed (Figure 4).

We found a significant correlation between the diameter at breast height (DBH) of the aroeira individuals and the level of exploitation ($rs = 0.5744$; $p < 0.0001$), suggesting that size is a criterion used by collectors during bark extraction. However, this correlation was not observed for quixaba ($rs = 0.158$; $p = 51.84$).

Discussion

Knowledge and medicinal use of *Myracrodruon urundeuva* and *Sideroxylon obtusifolium*. Data on the medicinal use of *M. urundeuva* indicate that this species is widely known by the Fulni-ô and plays a key role in their

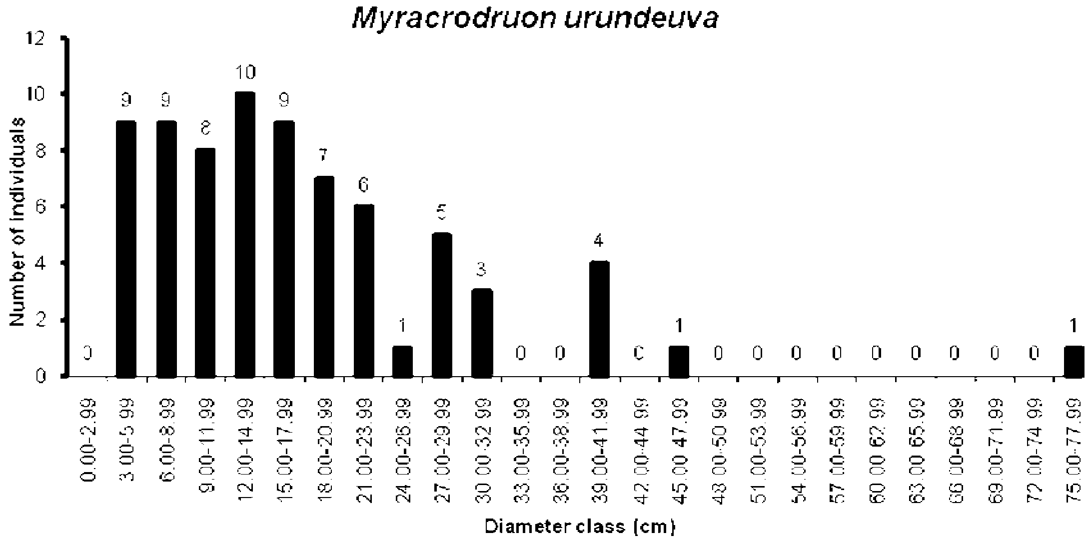

Figure 2. Diameter distribution of *Myracrodruon urundeuva* Allemão (aroeira; n = 73) in the Fulni-ô Indigenous Land, Águas Belas, Pernambuco, Brazil.

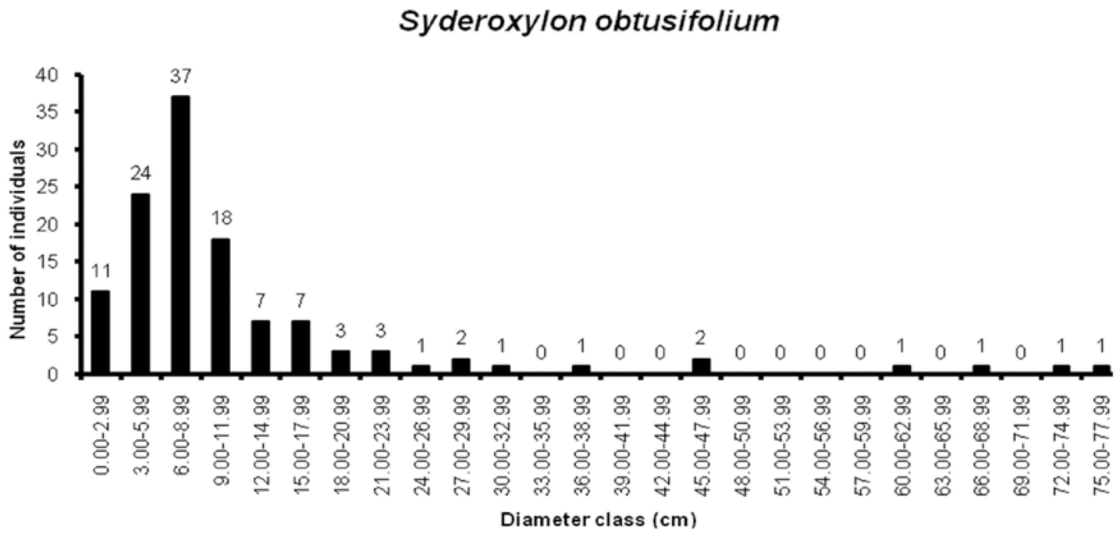

Figure 3. Diameter distribution of *Sideroxylon obtusifolium* (Humb. ex Roem. & Schult.) T.D.Penn. (quixaba; n = 120) in the Fulni-ô Indigenous Land, Águas Belas, Pernambuco, Brazil.

medical system. Several studies have shown similar results in different contexts, emphasizing the prominence of aroeira as a medical resource for human populations in the *Caatinga* (Albuquerque et al. 2007a). Lins Neto et al. (2008) have verified that this species is known to 81.63% of the informants in one rural community. Studying a rural community in the *Caatinga*, Albuquerque and Andrade (2002) have found that this species is well known locally, exhibiting high relative popularity (in other words, this species received a large number of references for utilization relative to the most-referenced species). Albuquerque et al. (2007a) have investigated the medicinal plants of the *Caatinga* and have concluded that aroeira is one of the ten plants with the greatest relative importance throughout the region.

In addition to being well known, *M. urundeuva* exhibits great versatility; here, 73 uses related to 13 distinct body systems are attributed to it. In a study conducted in a major market in the state of Pernambuco, Albuquerque et al. (2007a) has recorded 33 medicinal uses for aroeira. Bearing in mind that markets can be understood as concentration points for popular knowledge, we conclude that the wealth of uses attributed to aroeira by the Fulni-ô is representative. The most frequent uses corresponded to the categories of general inflammation, wound healing, and general infection. The same indications have been highlighted by Albuquerque & Andrade (2002), Albuquerque et al. (2007a,b), and Lins Neto et al. (2008).

Quixaba appears to be known to Fulni-ô people, but it is not as broadly known as aroeira; fewer than 40% of

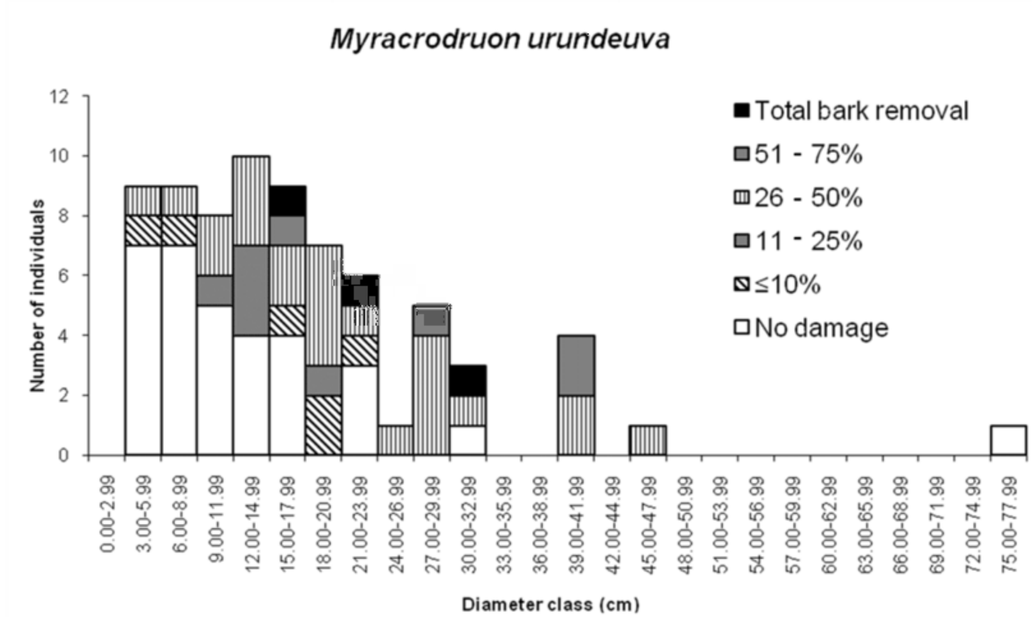

Figure 4. Distribution of bark damage by diameter class in *Myracrodruon urundeuva* Allemão (aroeira; n = 73) in the Fulni-ô Indigenous Land, Águas Belas, Pernambuco, Brazil.

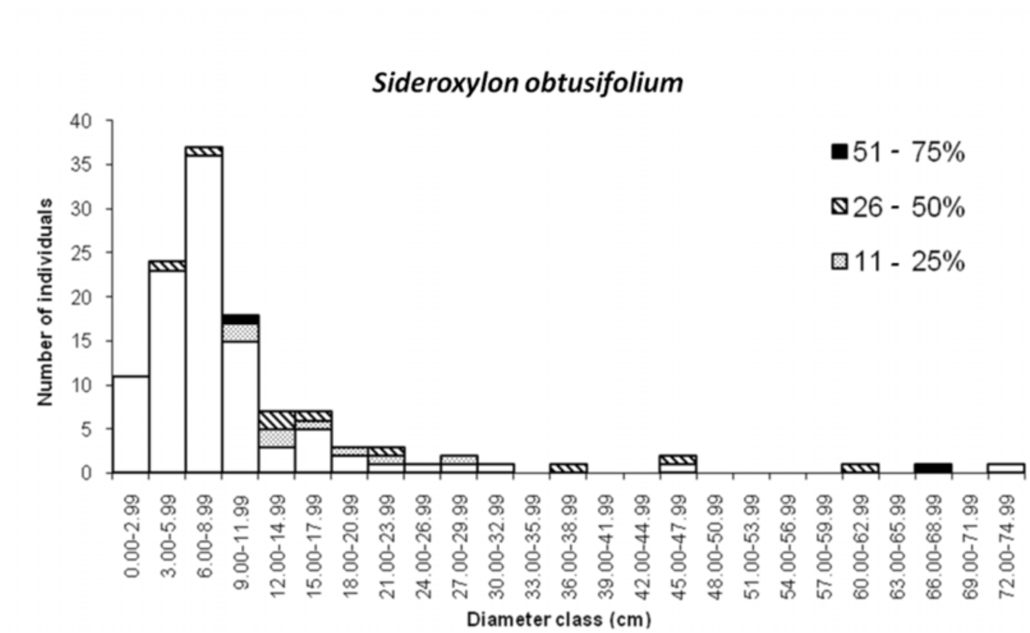

Figure 5. Distribution of bark damage by diameter class in *Sideroxylon obtusifolium* (Humb. ex Roem. & Schult.) T.D.Penn. (quixaba; n = 120) in the Fulni-ô Indigenous Land, Águas Belas, Pernambuco, Brazil.

collaborators reported knowledge of this species. In research conducted in the *Caatinga*, *S. obtusifolium* has been found to be one of the most-cited plants locally (Albuquerque & Andrade 2002; Almeida & Albuquerque 2002). Regardless of the distribution of knowledge, both quixaba and aroeira are versatile species with respect to both the richness of their uses and the diversity of body systems for which their therapeutic activities are recognized. Few studies that evaluate indigenous knowledge of *S. obtusifolium* are available in the literature. However, the use most often referenced by the Fulni-ô (the contusions category) has been emphasized in other studies (Albuquerque and Andrade 2002, Albuquerque et al. 2007a,b).

Three body systems account for a wide variety of uses of aroeira: disorders of the genito-urinary system (DGS), undefined diseases and conditions (UAP), and disorders of the digestive system (DSD). The same body systems also stand out when all species used in a local pharmacopoeia are considered. In other words, the pattern of body systems is repeated when considering all plants used in a medical system (Almeida & Albuquerque 2002). The most prominent body systems mentioned by the Fulni-ô have been highlighted in an ethnobotanical survey of the Caruaru Fair (animals and plants) (Almeida & Albuquerque 2002), one of the most important markets in Pernambuco state (northeastern Brazil). In the case of quixaba, we cannot state which body system is most prominent with regard to the number of therapeutic uses. However, when considering the utilization references of our collaborators, injury, poisoning, and other consequences of external causes (IPO) are the most salient.

For the two species analyzed in this study the Ouricuri Forest was reported as the most important collection site, being the difference in total citations too discrepant. The interviews and field experience have revealed that this forest is used in all months of the year, not only during the Ouricuri ritual. These results reinforces the importance of this resource area to receiving greater attention in relation to their conservation, since their role is fundamental to the practices of the local medical system and for the cultural perpetuation of Fulni-ô indians.

Finally, this study reinforces a pattern of utilization found in several studies (Araújo et al. 2007; Oliveira et al. 2007; Soldati & Albuquerque 2011): primary stem bark is preferentially used because it is a perennial resource. Albuquerque (2006) has argued that this pattern of utilization is an adaptation by the local population in the face of the Caatinga seasonal climate, allowing for greater security and safety in the resource collection.

Population structure and collection of *Myracrodruon urundeuva* and *Sideroxylon obtusifolium*. The diameter distributions of *M. urundeuva* and *S. obtusifolium* seem indicate that the two populations may not be capable of self-perpetuation because the distributions do not adequately fit the reverse J-shaped model, especially because they lack adult individuals. This distribution may be the result of a change in the reproductive process and in the recruitment dynamics of the species, directly due to the absence of adult individuals responsible for seed production (Hall & Bawa 1993). Analysis of the population structure suggests that the absence of individuals in mature, reproductive stages reflects selective logging targeting of larger individuals, which are used for timber.

However, few studies have evaluated the impacts of from bark collection (Ticktin 2004). Only three studies are available for the *Caatinga*. Monteiro et al. (2006a) have evaluated the diameter distribution of *Anadenanthera colubrina* (Vell.) Brenan, another important medicinal species, in two populations, one distant from and another one close to a rural community. These authors state that in the former population, there is no evidence for unsustainable collection; however, in the latter situation, continued exploitation may threaten the persistence of the resource in the environment. On the other hand, Soldati & Albuquerque (2011) has evaluated the exploitation of the same species in another rural community and have shown that bark removal does not compromise the exploited population, which is quite large, with very few individuals showing signs of extraction. Only Lins Neto et al. (2008) have evaluated the collection of *M. urundeuva* bark. These authors conclude that the collection of this resource by the rural community studied does not cause significant impact, mainly because there is no strong market demand.

Our conclusions for the Fulni-ô situation are somewhat limited. Within the context of the Fulni-ô IL, which is characterized by strong landscape conversion and therefore a lack of other native vegetation, our methods do not allow for the categorical assessment of the impacts of bark collection on the traditional medical system because comparisons with populations that have not been subjected to any form of extraction are impossible. The two focal species in this study provide timber-related uses, increasing the pressure on their populations; however, we did not evaluate how timber extraction contributes or will contribute to sustainable resource use. This multiple-use practice is common among local communities in the Caatinga (Lucena et al. 2007); the effects of extractive practices on plant populations can be influenced by both the demand for local medicinal utilization and the use of this species for timber.

Given the context of fragmentation and alteration of the local landscape, the small size of the Ouricuri forest, the potential impacts of bark collection, the presence of clear signs of exploitation in both species, the fact 26–50% of a tree's bark is usually extracted, and the high utilization pressure on aroeira, we conclude that the extraction of *M. urundeuva* bark for therapeutic purposes by the Fulni-ô can compromise the local populations. On the other hand, the collection of quixaba bark seems unlikely to compromise the local population of this species. However, the population structure of this species, which exhibits relatively few mature adult specimens, suggests that continued indiscriminate and unsustainable extraction practices might deplete this resource. It is important to discuss here that the difference between the extraction signals in these two species is due to the difference in the richness of uses and body systems cited in the interviews. By treating a greater variety of diseases the aroeira is potentially collected more frequently, which generates major impacts on their populations.

Our results suggest that aroeira is a species in need of immediate conservation measures, such as encouraging the use of equivalent species in the local medical system, thus reducing the extraction pressure on a single species; replacing the use of bark with other plant parts whose collection is less damaging, such as leaves; and replenishment of the species in the Ouricuri forest and elsewhere in the Fulni-ô IL. These strategies could be presented to and discussed with the community extracting the resource to adjust to local realities. Such conservation measures should respect the specificity of the traditional medical system while keeping in mind its cultural sustainability.

The presence of the Medicinal Plants Manipulation Office may affect local aroeira and quixaba populations. This Office is designed to produce semi-artisanal phytotherapeutics from locally known species cultivated in the garden or collected in adjacent forest fragments (Souza 2006). The discussion presented here is based on the fact that the intensity and frequency of collection of natural resources negatively influence the impacts of resource extraction (Bitariho et al. 2006; Guedj et al. 2007). Thus, the increased demand for *M. urundeuva* and *S. obtusifolium* bark to supply the activities of the Office might compromise local populations of these species by intensifying the pressure of their utilization.

Finally, the impacts of resource exploitation depend on the forms of extraction (Peters 1994; Pfab & Scholes 2004) and selection criteria used. Borges-Filho & Felfili (2003) have evaluated the collection of *Stryphnodendron adstringens* (Mart.) Coville bark and found no correlation between the level of exploitation and the size of individuals. These authors conclude that haphazard exploitation without selection criteria compromises the species locally, especially young individuals. Lins Neto et al. (2008) have made a similar conclusion concerning aroeira in the Caatinga ecosystem; there is no evidence of selection criteria for the collection of aroeira bark because there is no confirmed correlation between damage levels and diameter classes at breast or ground level. These results suggest that collection is indiscriminate and not based on the size of the individual. However, the exploitation data collected in the present study indicate that the size of aroeira individuals is correlated with bark extraction; that is, the larger the diameter at breast level, the greater the quantity exploited. Thus, aroeira collection in the Fulni-ô IL follows a selection criterion, thus sparing the younger individuals. The same correlation is not observed for quixaba.

Implications for conservation at the local and regional levels. Some conservation professionals believe that when a local population has used a resource for a long time, its use is sustainable (Bitariho et al. 2006). This concept, which is not founded on any real data, may be totally mistaken. Godoy & Bawa (1993) argued that sustainable use can only be verified by direct measurements of related variables, such as use pressure and resource availability. In the specific case of the *Caatinga*, especially in the region studied, we do not have any information that would enable us to evaluate sustainable use with confidence.

Rigorous evaluations of the sustainability of an extractivist practice rely on knowledge of the local floristic composition (Peters 1994) and of the ecological characteristics of the resource (Lawrence et al. 1995) in addition to external characteristics, such as the risk of use and the nature and intensity of collection (Peters 1994; Dzerefos & Witkowski 2001). Gaou & Ticktin (2007) stated that other characteristics, such as multiple uses of species and spatial and temporal variations, can influence the patterns of collection and their impacts. All of these factors, which are necessary to consider for a more accurate assessment, are complex, with some requiring considerable time to understand.

Although our results appear to apply only at a local level, in particular to the Fulni-ô people, they present implications at different scales. Both species studied enjoy considerable prominence in popular medical practices in northeastern Brazil (Monteiro et al. 2006b; Albuquerque et al. 2007a,b), and at least one of them, *Myracrodruon urundeuva*, has sparked the interest of the pharmaceutical industry. Despite the importance of this species, we have little information on its current distribution, population size, ecology, and genetic variability. Such information is essential for appropriate management and use programs for these species. *Myracrodruon urundeuva*, for example, is on the Brazilian list of endangered species, not only as a result of its medicinal use, but also due to other associated uses, especially for timber (Lucena et al. 2007). Thus, compromising a given *M. urundeuva* population, even within local boundaries, has serious implications for the understanding and maintenance of the species because to the best of our knowledge, there is currently no information on genetic variability of this species. Even simple information, such as the capacity for regeneration after the extraction of stem bark, is still scarce. There is only one study that investigated the bark regeneration after extraction events in the Caatinga (Monteiro et al. 2010), and *M. urundeuva* the target species in this study. The data presented by Monteiro et al. (2010) indicate that the aroeira has great regenerative processes after injury, but damage levels studied by this author was father smaller than the levels found by this research.

The same considerations are relevant at the regional level, but with a number of complicating factors. Santos et al. (2007) found that *M. urundeuva* has a high incidence in different areas of the *Caatinga*. However, its populations are not numerous. In contrast, the distribution of *S. obtusifolium* is more restricted and generally associated with smaller populations (Santos et al. 2007). The population recorded in our study area is significantly larger than that documented in many phytosociological studies in northeastern Brazil (Santos et al. 2007). The aforementioned arguments can also be applied at a regional scale, considering that these plants supply both informal (Albuquerque et al. 2007b) and formal economies and that we are completely unaware of their supply chains and of how much of their main associated product (stem bark) is taken from our native forests, given a complete lack of official data on the subject.

Another factor to consider is the sharp decline suffered by the *Caatinga* vegetation due to numerous processes of human origin (Araujo et al. 2007). This accelerated decreasing trend in native vegetation at a regional level, which is associated with the inappropriate use of land and native resources, can have severe implications. Because there is evidence that the diversity of useful plants in the *Caatinga* is a function of general diversity (Santos et al. 2007), these processes compromise the future existence of plants of great medical, biological, ecological, social, and cultural importance. Additionally, many of the medicinal plants used in the Brazilian pharmaceutical industry result exclusively from extractivism, reinforcing what we discuss above (Melo et al. 2009).

Despite the scenario presented, our data are insufficient to identify more robust measures and conclusions. The analyses offered here are preliminary and do not consider information about the quantities exploited, the frequency of collection and the response of each species to bark extraction. From one perspective, this lack of information presents an opportunity to alert the Fulni-ô indigenous people to the need to conserve not only the biological wealth of the region, recognized by the medicinal uses of native plants, but also the natural vegetative communities found there. Furthermore, from another perspective, our findings have local and regional implications for the conservation of populations of these species.

Acknowledgements

Many thanks are owed to the Fulni-ô people for their support and enthusiasm for the project; to the anthropologist Luciane Ouriques Ferreira, Manager of the Area of Traditional Indigenous Medicine, VIGISUS II/ FUNASA Project; to Sr. José Francisco de Sá (Xyce), Project coordinator and traditional knowledge holder; to Sr. Gláucio Machado (Txhleká), traditional knowledge holder; to Sr. Luiz Carlos Frederico da Silva, President of the Associação Mista Cacique Procópio Sarapó (AMCPS); to the following members of the indigenous team: Ubiram Leite Machado, Surama Correia Darcca, Tanawá Correia Darcca, Jussiara Veríssimo, Nerivaldo Alves dos Santos e João Veríssimo Machado, Almirair Cunha Pontes and Tairam de Leite de Sá; Maria Eliane Barreto da Silva, Project pharmacist Fabíola W. Zibetti, Project lawyer; Dr. Cláudio Fortes Garcia Lorenzo, Project physician.

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