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The use of firewood in protected forests: collection practices and analysis of legal restrictions to extractivism

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ABSTRACT

Restrictions to the collection of timber resources in protected areas have been scarcely studied. The aim of this study was to describe the practices of firewood collection in a protected forest and the perceptions of collectors, particularly with regard to their adjustment to the rules of the local management plan. The study involved 102 participants of a rural community adjacent to the Araripe National Forest and employed semi-structured interviews, free-listing and in-situ survey techniques for ethnobiological data collection. The volume of wood stored was measured and monitored using a modification of the weight survey technique. The residents used 69 plant species for firewood Most of the informants self-reported disagreement with the rules of the management plan, yet they tended to comply. Most interviewees felt that the rules of the management plan needed to be changed, especially those related to the day when firewood can be collected, fees charged and means of transportation. Management plans certainly represent a relevant strategy for the conservation of biodiversity, but they need continuous evaluation and adjustment to meet the needs of local human populations.

Keywords: conservation unit, dry forests, ethnobotany, forest extraction, human ecology, management plans

Introduction

The use of wood as fuel is a common practice worldwide, but especially in rural areas of underdeveloped and developing countries (Samant *et al.* 2000; Figuerôa *et al.* 2006; Madubansi & Shackleton 2007), where firewood is the main source of fuel for most low-income families (Brouwer & Falcão 2004). As a rule, firewood collected in such areas is green (wood with high moisture content) or dry (wood with low moisture content) and collected directly from native vegetation (Samant *et al.* 2000; Thapa & Chapman 2010; Ramos & Albuquerque 2012). As a form of destructive extractivism, the collection of green firewood leads to changes in the conservation status of the remaining vegetation by reducing the population size of the species used and posing a threat to local biodiversity (Tabuti 2003; McNally *et al.* 2011; Mustafa *et al.* 2011). Additionally, the extraction of dry firewood, despite often being considered a form of sustainable use of wood resources, can have environmental impacts (Shankar *et al.* 1998). In addition to reducing the amount of litterfall and influencing matter cycling, the extraction of dry firewood can also cause damage to seedlings due to trampling by collectors.

The problems associated with firewood collection are not only biological but also sociocultural. Reduced availability of firewood in forests or bans on collection leads extractivists to change their use and collection practices by replacing

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one resource with another or by exploiting other collection sites, thus increasing pressure on the biodiversity of natural habitats (Madubansi & Shackleton 2007).

Given the magnitude of this socio-environmental problem, public conservation measures have been implemented in several areas of the world (Velázquez *et al.* 2010; Mustafa *et al.* 2011), among which the establishment of protected areas stands out in Brazil. Also known as conservation units, these protected areas fall under two categories: (1) full-protection units, which aim to preserve nature, and thus no human interference whatsoever is allowed; and (2) sustainable-use units, which aim to link the conservation of nature with the sustainable use of its resources (SNUC 2002). The management plans of some protected areas restrict the access of the neighbouring communities to firewood by, for example, establishing a calendar for firewood collection or limits to the amount of dry firewood allowed per collector. Such is the case for the Araripe National Forest (FLONA), which was the site of the present study (IBAMA 2004). However, the success of restrictions aimed at the conservation of biological diversity, their implications for extractivism and peoples perceptions of management plans have been scarcely investigated, which hinders the assessment of the efficacy of such restrictions.

The establishment of management plans in conservation units might give rise to novel patterns of firewood use and collection (Madubansi & Shackleton 2007; McNally *et al.* 2011). Thus, restrictions imposed on extractivism do not seem sufficient to ensure the conservation of the biological diversity of forests. Besides being an important diagnostic tool for understanding the attitudes of individuals in the environment in which they are inserted, analysis of perceptions about this issue allows existing conflicts between populations and the rules established by management plans to be identified (see Garcia-Filho *et al.* 2016; DeFries *et al.* 2007).

Given this context, the present study sought to answer the following questions: (1) How is firewood collected and used? (2) What plant species are known, used and preferred by the community? (3) Is firewood actually collected only on days established by the management plan? (4) Do collectors extract firewood from the forest according to the amount and type established in the management plan? and (5) What are the perceptions of the collectors regarding the control/surveillance of firewood collection in the forest?

Materials and methods

Characterization of the study site

The study was conducted in the forest of FLONA-Araripe (07°11'42"S 39°36'33"W), which was the first conservation unit established for sustainable use in Brazil (IBAMA 2004). The site encompasses an area of 38,262.3261 hectares of the states of Pernambuco, Piauí and Ceará, with the largest part being in a region of Ceará known as 'Chapada do Araripe' (Araripe Plateau). The average temperature is 23 ºC, the average annual rainfall is 790.40 mm, and the rainy season lasts from January to May (IPECE 2012).

FLONA-Araripe comprises four types of vegetation (Ribeiro-Silva *et al.* 2012), which are distributed throughout its area: cerrado (savannah woodland, 48.53 %; cerradão, 27.49 %), tropical humid forest (22.47 %) and carrasco (deciduous shrubland; 1.51 %). Cerrado vegetation is predominant, has a density of approximately 5,220 trees per hectare and an average height of 4.6 m, with some of the tallest species being *Parkia platycephala* Benth., *Bowdichia virgilioides* Kunth and *Byrsonima* sp. (Costa *et al.* 2004). The species richness of the cerrado vegetation of FLONA-Araripe was estimated to be 43 shrub and tree species, with *Byrsonima sericea* DC. and *Qualea parviflora* Mart. standing out in terms of cover (Costa *et al.* 2007). A more recent study added another 38 tree and herbaceous species (Ribeiro-Silva *et al.* 2012).

The trees of FLONA-Araripe are used for several purposes. *Caryocar coriaceum* Wittm., *Himatanthus drasticus* (Mart.) Plumel and *Dimorphandra gardneriana* Tul. are the most widely used species although they are not abundant.

According to historical and archaeological findings, the Cariris Indians were one of the first ethnic groups to occupy the region where FLONA-Araripe is today, before the arrival of European settlers in the 17th century (Limaverde 2006). After numerous conflicts between these two groups, the Cariris were gradually expelled in the 19th century, at which point the settlers began to use the area of the forest for agriculture and livestock. The resulting economic development resulted in population growth, with several families living in the interior of the forest. FLONA-Araripe was created in 1946, with the initial challenge of removing the families living within the forest performing agricultural and livestock activities. Many of these removed families began to live in the vicinity of FLONA-Araripe, and contributed to the formation of several communities, including the community of Horizonte, the focus of the present research.

FLONA-Araripe management plan: restrictions to firewood collection

The FLONA-Araripe management plan is a legal instrument that establishes rules for the use of forest resources within the conservation unit, among other goals. One of the main uses of forest species by neighbouring communities is as firewood, mostly for cooking. According to the FLONA-Araripe management plan (IBAMA 2004), the neighbouring communities are only permitted to collect dry firewood and only on one day per week (Tuesdays). Only low-income families that cannot afford to buy gas for cooking are eligible to collect firewood, and to do so they must register with the administration department of

FLONA. According to the management plan, each family is permitted to collect one cubic meter of firewood per month, which the managers of FLONA-Araripe consider sufficient to meet the needs of a six-member family. Although the plan requires each registered family to pay BRL 3.20 (three Brazilian reis and twenty cents) per cubic meter of collected firewood to the administration department of FLONA-Araripe (IBAMA 2004), the current rate is BRL 2.00 (two Brazilian reis), which amounts to BRL 8.00 (eight Brazilian reis) per month. These rates were established to regulate firewood collection because it had previously been performed in an indiscriminate manner. The main collection sites at FLONA-Araripe are supervised every Tuesday, and occasionally on other days of the week, to ensure compliance with the management plan.

The management plan does not explain how the rules were established, and so it is not known whether those responsible determined the rules on a theoretical basis or if they incorporated dialogued with the communities of the region.

Selected rural community

The rural community of Horizonte, formerly known as Cacimbas, is located in the boundary zone (07°29'36.9"S 39°22'02.6"W) of the Área de Proteção Ambiental-Araripe (Araripe Environmental Protection Area) of the Araripe National Forest. It is approximately 15 km from the next closest town of Jardim in the state of Ceará (CE). Horizonte is one of the largest communities in the area with 1,120 residents (Lozano *et al.* 2014) of 284 families. The community was selected for this study because, according to the administration of FLONA-Araripe, its residents collect considerable amounts of firewood. The main source of income among residents of Horizonte is extraction of non-timber forest products. Other activities include subsistence agriculture, involving mainly beans, cassava and maize, and cattle farming, albeit on a smaller scale (IBAMA 2004).

There are 374 households in Horizonte; however, 114 are occupied only during the 'pequi' (*C. coriaceum*) and/or 'faveira' (*D. gardneriana*) harvest seasons, and are otherwise vacant. There are on average four residents per household, with a range of one to 12.

There is one health center in the community, where a physician provides care for residents once per week; one Catholic church, being the predominant religion in the area; one child day-care centre; and a municipal primary school — the city government provides transportation for youths who wish to attend secondary school in Jardim.

Legal issues and informant selection

The present study was approved by Sistema de Autorização e Informação em Biodiversidade (System of Authorizaiton and Information on Biodiversity; ICMBio/Sisbio no. 34925-1) and the human research ethics committee of the Universidade de Pernambuco (no. 19568113.7.0000.5207).

The first contact with the community involved visits to the 260 households that were inhabited at the time of the study. The objectives of the study were explained to the head of each household, who were then requested to consent to participation. Only 126 (48 %) agreed to participate and signed an informed consent form and another form giving authorisation for the use of images and statements in compliance with the ethical rules established by the Conselho Nacional de Saúde (National Health Council) (Resolution 510/2016).

Ethnobiological data collection

Semi-structured interviews (Albuquerque *et al.* 2014) were conducted with the heads of households, regardless of their age or gender, to characterize the use and collection of firewood for domestic use, and the perception that the Horizonte community has of the FLONA-Araripe management plan. Twenty-four (19.04 %) of the 126 households that agreed to participate in the study were excluded because they reported that they no longer use firewood at home. Therefore, the final sample comprised 102 interviewees.

The interviews were performed in two stages. The first stage collected socioeconomic data (age, gender, educational level and income), then asked questions regarding the use and collection of firewood at FLONA-Araripe, such as the following: What is the best time of the year to collect firewood? Why? Who in your household is responsible for collecting firewood? How do you transport the firewood to your home? How many times on the same day do you collect firewood? On which days of the week do you collect firewood? Do you believe that it is becoming easier or more difficult to collect firewood? Why?

Among the 102 informants interviewed, 39 were females aged 21 to 81 years and 63 were males aged 19 to 84 years. Most household heads worked in agriculture (38.23 %) or were retired (37.25 %), with an average monthly income of BRL 849.24 ± 401.92. Another important source of income for the community is social welfare programs, such as 'Bolsa Família' (Family Allowance Programme). Most of the informants had never attended school (38.23 %) or had not finished primary education (29.41 %).

The second stage of the interview sought to collect data on the community's perception of the restrictions to firewood collection established in the management plan. For this the following questions were posed: What is your opinion of the rules established for firewood collection at FLONA? Do such rules fit your needs of firewood for domestic use? If they do not, what are the problematic issues? Do you comply with all the rules for firewood collection at FLONA? Do you use strategies for firewood

collection other than those permitted at FLONA? If you could, what changes would you make to the rules? Do you believe that firewood collection should continue? Why?

The free-listing technique was then used, whereby each informant lists all the species he or she knows to be used as firewood. The informants were asked to indicate on the lists which species they had used in the past or still use as firewood, and which species they preferred and why (Albuquerque *et al*. 2014).

The in-situ survey technique (Ramos *et al*. 2014) was used to confirm whether the species listed were actually used as firewood at home. Thus, only plants represented by stored firewood at the household at the time of the visit were classified as "used plants" and used to determine the richness of ethno-species. Next, each informant was asked the name of each used plant and the type of firewood collected (dry or green).

The volume (in cubic meters) of stacked wood at each household was determined (Ramos *et al*. 2014). Confirmation of the presence of ethno-species and the type of firewood (dry or green,) as well as the volume of stacked firewood, could only be performed in 98 of the 102 households because four had no stored firewood at the time of the visit.

The direct observation method (Albuquerque *et al*. 2014) was used during the period of fieldwork (eight visits lasting eight to 15 days) to establish whether the participating families only collected wood on the days they had reported in the interviews or if they collected on other days as well.

To perform appropriate taxonomic identification of all the ethno-species listed and found at the households (used plants), and to become acquainted with the collection sites at FLONA-Araripe, six guided tours (Albuquerque *et al*. 2014) were performed with the informants that were considered local experts because they had reported the greatest number of plants at FLONA-Araripe. During the tours the informants identified the collected ethno-species in loco and indicated the collection sites.

Fertile plant material of each ethno-species was collected and herborized for proper taxonomic identification, which was performed based on voucher specimens deposited at the herbaria Dárdano de Andrade Lima, Instituto de Pesquisas Agronômicas (Agronomic Research Institute; IPA) and Caririense Dárdano de Andrade Lima (HCDAL), in addition to expert advice and review of the specialized literature (APG 2009). The spelling of botanical names was checked at the websites Flora do Brasil Online (http://floradobrasil.jbrj.gov.br/2012/) and Tropicos (http://www.tropicos.org/). Voucher specimens of the collected plant material were included in the collection of the Herbarium Professor Vasconcelos Sobrinho, Universidade Federal Rural de Pernambuco (Federal Rural University of Pernambuco; PEUFR), and Herbarium HCDAL, Universidade Regional do Cariri (Regional University of Cariri; URCA).

Measurement of the firewood used and stored at households

To assess whether the use of firewood by the Horizonte community complied with the FLONA-Araripe management plan (i.e., one cubic meter of dry firewood per family per month), 25 households were randomly selected from the 102 that were included in the study. Daily firewood consumption was measured for eight consecutive days in two different periods, one corresponding to the dry season (November 2012) and the other to the rainy season (April 2013). The main criterion for selecting sampling periods in these months corresponding to the dry and rainy seasons was based on rainfall data made available by the Foundation of Meteorology and Water Resources of Ceará (FUNCEME). According these data, no rain was recorded at the municipality of Jardim in November 2012, which was rated by FUNCEME as the driest year in the past 10 years. In turn, April 2013 was among the months with the heaviest rainfall, with 44 mm. The opinions of the informants with regard to the beginning and end of each season in the region were also recorded.

The amount of firewood used was measured using a modification of the weight survey technique (Ramos *et al*. 2014), whereby each informant was requested to set aside a firewood stack deemed fit to meet the family demands for a 24-hour period. Four extra logs were added to each stack to ensure that families would use only the separated firewood and not the wood in stock.

The length, width, height and weight of the firewood stacks were assessed using a measuring tape and 40-kilogram digital scales. Measurements of the volume and weight of the firewood stack (initial volume and weight) and remaining firewood (final volume and weight) after a 24-hour period were performed for eight consecutive days. The volume (cubic meters) and weight (Kg) of firewood used per day was calculated as the difference between the initial and final values at each assessment. The average weekly and monthly volume and weight of firewood used per family in the Horizonte community were then calculated as recommended by Ramos *et al*. (2014). The results were used to establish whether the monthly volume of firewood permitted for collection by the FLONA-Araripe management plan was sufficient to meet the demands of the population.

During the visits to perform the measurements and to confirm some of the data collected in the interviews, the 25 informants sampled in this stage were once again asked about the frequency of firewood collection, the day of the week they collected firewood at FLONA and the type of firewood (dry or green) they collected. The firewood stock at each household was observed and photographed every day to validate the information provided by the interviewed household heads.

Data analysis

The frequencies of the known, used and preferred species for firewood reported by the residents of the Horizonte community were calculated based on the ratio of informants who reported to know/use/prefer a given species to the total number of interviewed informants.

The perception of informants regarding (a) the influence of the management plan on local firewood-collection practices, (b) agreement with the rules and (c) negative features of the management plan, were subjected to descriptive analysis and expressed as percentages.

Differences between the proportions of informants who complied or did not with the management-plan rules regarding collection day, type of firewood (dry or green) and amount of firewood collected per family per month, were assessed using the chi-squared goodness-of-fit test. All analyses were performed using BioEstat 5.0 software (Ayres *et al.* 2007).

Results

Characterization of firewood use and collection

In the Horizonte community, all family members participate in firewood collection, but the actual collection is mainly performed by the household head (male or female) and the eldest children (10 to 19 years old). Six means are used to transport the firewood home: car, bicycle, animal-drawn vehicle, motorcycle, pack animal or head loading. Most of the interviewees (82.35 %) reported using bicycles.

FLONA-Araripe is the main source of firewood for the Horizonte community. Among the 102 interviewees, 79 (77.45 %) reported having collected firewood at FLONA-Araripe, while the remainder of the informants collect at other sites or do not collect firewood at all (but buy it instead). Among these 79 informants, 60 (75.94 %) do not collect firewood anywhere else, 13 (16.45 %) also collect firewood on private properties and five (6.32 %) also collect firewood from anthropogenic areas, whereas one purchases firewood. Among the 23 informants who reported that they do not collect firewood at FLONA-Araripe, four (17.39 %) collect on private properties, two (8.69 %) collect from anthropogenic areas, and 17 (73.91 %) purchase wood from third parties.

The residents of the Horizonte community collect firewood year round; however, most of the informants (80 %) reported a preference for collecting and storing firewood during the dry season for two main reasons: (1) greater availability of time for collection because it is a period when they are not performing agricultural work; and (2) collection and use are easier because the wood is dry, which facilitates lighting fires (53.54 % of informants) and is easier to carry home (18.18 %), plus the forest is more accessible (12.12 %) and log cutting is easier (10.10 %).

Firewood collection is most often performed once per day (72.94 % of informants) and usually in the morning. However, some families collect firewood twice per day (23.53 %), once in the morning and then once after lunch, or even three times per day, although with considerably lower frequency (3.53 %).

Most of the informants (92.15 %) reported that firewood collection has become more difficult due to three main reasons: (a) the increasing human population has resulted in the reduction of dry wood supply in the areas closest to the community, and thus residents must travel farther to collect firewood (83 % of informants); (b) the rules established in the management plan for firewood collection (16 %); and (c) health problems that prevent firewood collection, which was reported by a single informant (1 %).

Species known, preferred and used for firewood

A total of 98 ethno-species were mentioned by the informants as sources of firewood for domestic use, which corresponded to 69 species distributed across 65 genera and 31 families; four ethno-species could not be identified (Tab. 1).

Table 1. Species used as firewood in households in the rural community of Horizonte, municipality of Jardim, Ceará, Brazilian Northeast.

Scientific name	Local name	Life forms	Status	Frequencies (%)		
				Knowledge	Use	Preference
Anacardiaceae						
Anacardium occidentale L.	cajueiro	tree	native	14.70	5.10	0
Astronium fraxinifolium Schott	gonçalave	tree	native	1.96	0	0
Mangifera indica L.	mangueira	tree	exotic	5.88	4.08	0
Annonaceae						
Annona coriacea Mart.	ariticum	tree	native	0.98	0	0
Apocynaceae						
Hancornia speciosa Gomes	mangaba	tree	native	1.96	0	0
Himatanthus drasticus (Mart.) Plumel	janaguba	tree	native	2.94	2.04	0
Arecaceae						
Attalea speciosa Mart.	palmeira babaçu	tree	native	0.98	0	0
Cocos nucifera L.	coqueiro	tree	exotic	2.94	3.06	0
Bignoniaceae						

Table 1. Cont.

Scientific name	Local name	Life forms	Status	Frequencies (%)		
				Knowledge	Use	Preference
Handroanthus impetiginosus (Mart. DC.) Mattos	pau d'arco	tree	native	0.98	0	0
Burseraceae						
Protium heptaphyllun (Aubl.) Marchand	amescla	tree	native	0.98	0	0
Cactaceae						
Pilosocereus pachycladus F.Ritter.	facheiro	arborescent	native	0.98	0	0.98
Caprifoliaceae						
Sambucus australis Cham. & Schltdl.	sabueiro	shrub	exotic	16.66	6.12	0.98
Caryocaraceae						
Caryocar coriaceum Wittm.	pequizeiro	tree	native	32.35	5.10	0
Celastraceae						
Maytenus distichophylla Mart.	bom nome, papagaio	tree	native	3.92	0	0
Connaraceae						
Connarus detersus Planch.	joão mole	shrub	native	0.98	0	0
Erythroxylaceae						
Erythroxylum stipulosum Plowman	carrasquinho	shrub	native	2.94	1.02	0
Euphorbiaceae						
Croton blanchetianus Baill.	marmeleiro	shrub	native	0.98	0	0
Croton campestris A.St.-Hil.	velame	shrub	native	0.98	0	0
Jatropha mollissima (Pohl) Baill.	pinhão brabo	shrub	native	0.98	1.02	0
Manihot esculenta Crantz	mandioca	shrub	native	1.96	1.02	0
Maprounea guianensis Aubl.	cascudo, casquinho	tree	native	19.61	2.04	0
Ricinus communis L.	mamona	shrub	exotic	1.96	2.04	0
Fabaceae						
Acosmium dasycarpum (Vogel) Yakovlev	pau pra tudo	tree	native	4.90	1.02	0
Albizia pedicellaris (DC.) L.Rico	amarelo	tree	native	60.78	13.26	1.96
Bowdichia virgilioides Kunth	sucupira	tree	native	17.65	3.06	0
Copaifera langsdorffii Desf.	copaíba, podóia	tree	native	25.49	4.08	1.96
Dimorphandra gardneriana Tul.	faveira	tree	native	68.63	15.31	1.96
Dioclea grandiflora Benth.	mucunã	climber	native	0.98	0	0
Enterolobium contortisiliquum (Vell.) Morong	tamburi	tree	native	0.98	0	0
Hymenaea courbaril L.	jatobá preto, jatobá de cavalo	tree	native	27.45	8.16	2.94
Hymenaea stignocarpa Mart. ex. Hayne	jatobá branco, jatobá de veado	tree	native	12.74	2.04	0
Libidibia ferrea (Mart. ex Tul.)	pau ferro	tree	native	0.98	0	0
Mimosa caesalpiniifolia Benth.	sabiá	tree	native	1.96	1.02	0
Senna martiana Benth	canafístula	tree	native	0.98	1.02	0
Parkia platycephala Benth.	visgueiro	tree	native	58.82	15.31	1.96
Poincianella pyramidalis (Tul.)	catingueira	shrub	native	0.98	0	0
Senna sp.	besourinh, flor de besouro	shrub	native	11.76	6.12	0.98
Stryphnodendron sp.	barbatimão	tree	native	3.92	0	0
Swartzia flaemingii Raddi	banha, banheira	shrub	native	30.39	15.31	0.98
Vatairea macrocarpa (Benth.) Ducke	amargoso	tree	native	1.96	2.04	0
Fabaceae 1	açoita cavalo	tree	native	2.94	1.02	0
Lauraceae						
Ocotea sp.	cheiroso	tree	native	45.10	21.43	5.88
Persea americana Mill.	abacate	tree	exotic	5.88	4.08	0
Lythraceae						
Lafoensia pacari A.St.-Hil.	lagartixeiro, romã braba	shrub	native	2.94	3.06	0
Malpighiaceae						
Byrsonima gardnerana A. Juss.	murici do carrasco	tree	native	19.61	4.08	2.94
Byrsonima sericea DC.	murici branco, murici da casca fina, murici vermelho, murici amarelo	tree	native	95.10	72.45	52.94
Byrsonima verbascifolia (L.) DC.	murici da casca grossa, murici preto, murici roxo	tree	native	85.29	40.82	52.94
Malpighia glabra L.	acerola	shrub	exotic	0.98	1.02	0

Table 1. Cont.

Scientific name	Local name	Life forms	Status	Frequencies (%)		
				Knowledge	Use	Preference
Melastomataceae						
Miconia albicans (Sw.) Triana	candieiro	shrub	native	17.65	6.12	1.96
Meliaceae						
Cedrela odorata L.	cedro	tree	native	0.98	1.02	0
Myrtaceae						
Eucalyptus sp.	eucalipto	tree	exotic	12.74	4.08	0.98
Eugenia candolleana DC.	goiabinha	shrub	native	13.72	2.04	3.92
Myrcia jacobinensis Mattos	batinga	tree	native	3.92	0	0
Myrcia splendens (Sw.) DC.	murta	tree	native	0.98	1.02	0
Myrcia sp.	canela de veado	shrub	native	11.76	7.14	0.98
Psidium guajava L.	goiaba	tree	native	1.96	1.02	0
Psidium laruotteanum Cambess.	araçá preto, araçá vermelho	shrub	native	19.61	2.04	0
Psidium myrsinites DC.	araçá branco, araçá da casca fina	shrub	native	42.16	5.10	13.72
Olacaceae						
Ximenia americana L.	ameixa	tree	native	4.90	2.04	0
Punicaceae						
Punica granatum L.	romã	shrub	exotic	0.98	1.02	0
Rubiaceae						
Coffea arabica L.	café	shrub	exotic	6.86	6.12	0.98
Rutaceae						
Citrus sinensis (L.) Osbeck	laranja	tree	exotic	0.98	1.02	0
Zanthoxylum gardneri Engl.	laranjinha	shrub	native	3.92	2.04	0
Salicaceae						
Casearia grandiflora Cambess.	maria preta	shrub	native	19.61	8.16	0
Casearia sylvestris Sw.	café brabo	shrub	native	28.43	16.33	1.96
Sapindaceae						
Matayba guianensis Aubl.	pitomba braba, manga braba	tree	native	72.55	37.75	6.86
Magonia pubescens A.St.-Hil.	tinguí	tree	native	21.57	9.18	1.96
Serjania lethalis A.St.-Hil.	cipó, gibão	climber	native	1.96	0	0
Talisia esculenta (Cambess.) Radlk.	pitomba	tree	native	6.86	2.04	0
Sapotaceae						
Chrysophyllum arenarium Allemão	cajazinha	tree	native	35.29	13.26	0
Manilkara sp.	maçaranduba, murunduba	shrub, tree	native	2.94	0	0
Pouteria glomerata (Miq.) Radlk.	marmelada	tree	native	0.98	0	0
Simaroubaceae						
Simarouba amara Aubl.	craíba	tree	native	30.39	13.26	0
Solanaceae						
Solanum paniculatum L.	jurubeba	shrub	native	0.98	1.02	0
Verbenaceae						
Lantana camara L.	chumbinho	shrub	native	0.98	1.02	0
Vochysiaceae						
Qualea parviflora Mart.	pau piranha, pau terra	tree	native	46.08	23.47	1.96
Undetermined 1	estralador	tree	-	2.94	1.02	0
Undetermined 2	mané branco	shrub	-	2.94	2.04	0
Undetermined 3	nogueira	tree	-	0.98	1.02	0

Despite the richness of species belonging to the family Fabaceae (18), the species most widely used as firewood by the Horizonte community are *Byrsonima sericea* (95.09 %) and *B. verbascifolia* (85.29 %), members of the family Malpighiaceae, followed by *Matayba guianensis* (72.55 %) of family Sapindaceae and *Dimorphandra gardneriana* (68.63 %), *Albizia pedicellaris* (60.78 %) and *Parkia platycephala* (58.82 %) of family Fabaceae.

The richness of the firewood stocks at the households was 59 species (Tab. 1); the most frequently found species were also the best-known: B. sericea (72.45 %) and B. verbascifolia (40.82 %). Twenty-three species were mentioned as preferred for firewood for domestic use, among which B. sericea and B. verbascifolia stand out, being mentioned by 52.94 % of the informants each, followed by Psidium myrsinites (13.72 %) and M. guianensis (6.86 %) (Tab. 1).

Compliance of firewood collection with the FLONA-Araripe management plan

Most of the informants who collect firewood at FLONA-Araripe (85 %) reported that they do so only on Tuesdays, in compliance with the FLONA-Araripe management plan. The remainder of the interviewees reported that they collect firewood on any day of the week. There was a significant difference between the number of informants who reported that they only collect firewood on Tuesdays and those who did not ($\chi^2 = 39.20$; $p<0.001$), which shows that most of the residents of the Horizonte community comply with the restriction regarding days of collection. However, direct observation of the households showed that 28 % of the families collected firewood on other days of the week.

Among the 98 firewood stocks surveyed, 72.44 % (71 stocks) included wood collected at FLONA-Araripe, which confirms its role as the main source of firewood in the area. Green firewood was found at one household, while the other 97 contained only dry wood. The difference between the number of stocks with and without green firewood was significant ($\chi^2 = 67.05$; $p < 0.0001$), which indicates that the residents at the Horizonte community comply with the FLONA-Araripe management plan in this regard.

The average amount of firewood consumed per household per day was 4.22 kg (= 0.0335 cubic meters), corresponding to an average of 1.004 (± 0.47) cubic meters and 126.69 ± 55.52 kg per household per month. Therefore, the amount of firewood actually used tends to be withing the maximum established by the FLONA-Araripe management plan (one cubic meter per month). However, analysis of households on an individual basis showed that 40 % of them used more firewood collected at FLONA-Araripe than the permitted amount. Nevertheless, the difference between the number of households that comply with the limit indicated by the FLONA-Araripe management plan and those that do not was not significant ($\chi^2 = 1.00$; $p = 0.42$). This finding may be explained by factors such as the number of household residents and family income.

Perceptions of the rules of the management-plan for firewood collection at FLONA-Araripe

Most of the household heads (64.70 %) did not agree with the rules of the FLONA-Araripe management plan for firewood collection in the forest. Only 24.50 % of the households fully agreed with the all the rules, while 8.82 % reported that they agree with some rules but disagree with others. Among the remainder of the interviewees, one (0.98 %) refused to answer this item, and another (0.98 %) reported not that they were not aware of any rules regarding firewood collection.

Although a significant fraction of the informants reported that they did not agree with the regulations for firewood collection, when they were inquired as to whether they were able to meet their domestic requirements most of them (73.53 %) answered affirmatively, while only 24.51 % believed that the rules interfered with obtaining the firewood needed for domestic use at their household. The remainder of the informants (1.96 %) refused to answer this item.

The particular collection rules most frequently criticized by the informants were the restriction of collection to a single day of the week (30.85 %) and the required fee of BRL 2.00 per collected bundle (30.84 %), despite the fact that the management plan actually states that the fee is BRL 3.20 per family per month. One further rule that received criticism was the imposed limit of one cubic meter of firewood per family per month (24.30 %), although the results of the present study revealed that this amount meets domestic requirements. The participants also criticised the need to use pack animals, bicycles or head loading for transportation (13.08 %). The least-criticised rule was the one establishing that only dry firewood might be collected (0.93 %).

According to the perceptions of the informants, 86.27 % felt that as a whole the community complies with the rules of the management plan, while only 11.76 % felt that it does not, while two participants (1.96 %) refused to state their opinion. The interviewees admitted to using strategies to evade the rules established in the management plan, such as collecting on the days and/or at sites with weaker surveillance (22.72 % of informants), while others reported collecting firewood at private properties (62.12 %) or purchasing wood (15.15 %) to meet the daily needs of their family.

According to the perceptions of the informants, the rules of the management plan ought to be changed to meet the needs of the community. A total of 12 changes were suggested: abolishment of the collection fee (31.72 % of informants); allow firewood collection every day of the week (18.62 %); allow firewood collecting two days per week (8.96 %); allow the use of motorcycles for transportation (7.56 %); increase the volume of the allowed firewood bundle (5.52 %); allow the use of animal-drawn vehicles for transportation (5.52 %); allow the use of cars for transportation (4.83 %); increase the number of inspectors (4.14 %); allow firewood collection three times per week (1.38 %); apply fines to rule transgressions (0.69 %); and only allow firewood collection every two weeks (0.69 %). Some of the informants (10.34 %) said they would not change anything.

All the interviewees stated that collection of firewood for domestic use at FLONA-Araripe should continue, mainly due to financial difficulties (86.36 % of informants). Other reasons for maintaining firewood collection were to reduce the amount of dry wood on the ground to help prevent fires (8.18 %); a dislike for gas cooking (2.73 %); the opinion that dry wood serves no other purpose (1.82 %); and to maintain the tradition (0.91 %).

Discussion

Characterisation of firewood use and collection

The fact that all family members participate in the collection of firewood in the Horizonte community shows that the distribution of this activity among family members differs from that reported for other regions, such as regions of Brazil, where firewood is collected mostly by males (Ramos *et al.* 2008; Sá-e-Silva *et al.* 2009), or regions of Africa, where in some communities women are primarily responsible for this task (Abbot & Lowore 1999). Although these features were not assessed in the present study, the collection profile identified at the Horizonte community might be related to social factors specific to this area. For example, unemployment, which compels household heads to move to urban centres, as found in the present study, requires increased engagement of other family members in activities related to subsistence. In a study conducted in Limpopo province, South Africa, Madubansi & Shackleton (2007) also found that unemployment, and the consequent relocation of household heads to urban centres, influenced the distribution of tasks related to subsistence among the local families.

The use of various means to transport firewood collected in forests has been reported by various studies conducted in many communities worldwide, including Vietnam, Brazil, Uganda and Malawi (Abbot & Homewood 1999; Nagothu 2001; Tabuti 2003; Ramos & Albuquerque 2012), although the most traditional, and still most widely used, method is head loading. One should bear in mind that the use of more efficient means of transportation is not systematically associated with a greater impact. In a study conducted with rural communities in Northeast Brazil, Ramos & Albuquerque (2012) found that the volume of firewood stock throughout the study period was greater at the homes of individuals who carried firewood by head loading.

The fact that bicycles were the main means of transportation at the Horizonte community does not necessarily indicate a preference for them. In fact, the use of bicycles is the most viable of the options allowed by the FLONA-Araripe management plan (bicycles, head loading or animal-drawn vehicles). Even when it requires pedalling for one or two hours to reach collection sites, the population still uses bicycles as a means of transportation because it is quicker and allows greater amounts of firewood to be transported than head loading.

In agreement with the data recorded at the Horizonte community, the literature indicates that forests close to communities are the ones most often used as sources of wood for fuel (Samant *et al.* 2000; Ramos *et al.* 2008). In regard to seasons, although most of the interviewees reported a preference for collecting firewood in the dry season, as other studies have also found (Abbot & Homewood 1999; Ramos *et al.* 2008; Ramos & Albuquerque 2012), firewood is indeed collected all year round. This finding is most likely due to the single day per week restriction placed on this activity, which hinders the formation of large stocks and compels collectors to visit the forest all year round.

Species known, preferred and used for firewood

The richness of plants known (68) and used (59) as firewood was high, which might reflect the plant diversity at FLONA-Araripe (47). Such high richness might also be due to variability in the criteria used for the selection of species. For example, in contrast to the present research, Cavalcanti *et al.* (2015) found lower richness for plants known (28) and used (14) as firewood for the production of 'pequi' (*Caryocar coriaceum*) oil in this very same community.

Indeed, the most popular and frequently preferred plants within the body of knowledge of a given social group are, as a rule, more favorable for effective use (Ramos *et al.* 2008; Sá-e-Silva *et al.* 2009), as found in the present study. The species actually selected for use represent a more limited group of plants within the body of knowledge of each informant. Tacher *et al.* (2002) and Ramos *et al.* (2008) observed that the use of a wide diversity of species has significant implications for conservation because it reduces the risk of pressure on particular groups of plants. That fact notwithstanding, conservation is not systematically successful because the use of a given plant might be associated with several factors, such as its availability in the forest and the physical properties of the wood (Pote *et al.* 2006; Sá-e-Silva *et al.* 2009; Ramos & Albuquerque 2012), particularly its calorific power. Few species, especially *B. sericeae* and *B. verbascifolia*, were the source of most of the firewood collected by the Horizonte community; these species were also the most widely known, used and preferred by collectors. According to Medeiros *et al.* (2011), the use of a small number of species might cause greater imbalance in the conservation of biodiversity, especially when the availability of such species in nature is poor. Even it these species were to exhibit satisfactory availability in the forest, given that they are preferred and widely used, it is recommended that they be consider a priority in the formulation of strategies for the management of forest wood resources.

Compliance of firewood collection with the FLONA-Araripe management plan

The pattern of firewood collection exhibited by most of the residents of Horizonte complied with the restrictions established by the FLONA-Araripe management plan, especially regarding the day allowed for collection and the type of firewood (dry or green). Although the average amount of firewood collected was slightly above the permitted limit, the amount was quite close to that recommended in the

management plan. These findings represent a relevant contribution to the on-going discussion of the effectiveness that management plans play in conservation units; such plans are often considered unfeasible due to their inadequacy in practical terms, lack of appropriate surveillance and management of the protected areas, or failure to promote the conservation of biodiversity, which is one of their main functions (Ervin 2003; Hockings 2003; Lima *et al.* 2005).

Although the data from the present study data indicates that the behavior of collectors complied with the rules of the conservation unit, their disagreement with such rules points to the need to increase local participation in decisions regarding the use of regional forest resources. It is noteworthy that although the community did participate in the development of the FLONA-Araripe management plan (IBAMA 2004), the analysis of the data regarding the perceptions of informants indicates a need to make changes in the regulations when considering the current lifestyle of, and the appropriation of natural resources to, the community. Colchester (2000) emphasized the need to revise the current model for protected areas, which is widely used at the global level, and recommends the implementation of more radical strategies for resource conservation that stimulate participatory processes.

Some considerations are in order regarding the collection practices exhibited by the residents at the Horizonte community. First, the residents' alleged compliance with the one-day only rule might not correspond to the actual situation because the interviewees might have not provided completely true information to avoid exposing themselves as transgressors of local legislation. Therefore, in addition to methods based on interviews, future research should also monitor collection sites on different days of the week and over a longer period of time to effectively establish whether collection is exclusively performed on Tuesdays.

The population of the Horizonte community was found to be in greatest compliance with the management-plan rule restricting collection to dry firewood. Indeed, according to the literature, dry wood resources are most indicated for use as fuel because wood is lighter, making transportation to households easier, and more fuel efficient, when it is dry (Almeeruddy-Thomas *et al.* 2004; Bhatt *et al.* 2004). However, it is not possible to assert that all the families of the informants actually collect only dry wood. Visits to the forest during the period of participant observation revealed that full trees are cut and left in the forest to dry for future collection.

The amount of firewood collected at the Horizonte community is the one feature of the management plan that deserves the closest attention of FLONA-Araripe managers given that a significant part of the population (40%) was found to collect over the allowed limit. The rates of domestic consumption of firewood are acknowledged as highly variable in the literature and might vary as a function of the socioeconomic characteristics of families, such as size and monthly income, and of geographical and climate factors, such as elevation, temperature, rainfall and season of the year, among others (Samant *et al.* 2000; Bhatt & Sachan 2004; Ramos & Albuquerque 2012). Thus, the amount of firewood allowed by the management plan for collection should be revised taking the socioeconomic profile of the families of the Horizonte community into consideration while simultaneously ensuring the conservation of forest resources. When the actual needs of a population are not met, the risk of the development and implementation of strategies to transgress the rules increases, such as collection on non-allowed days and harvesting of green firewood for drying in the forest, among others. Such behaviours put the very aim of the management plan in jeopardy because they lower the conservation status of the forest and increase the vulnerability of at-risk of species.

Conclusions

The results of the present study show that plans developed for the management of protected areas in Brazil are far from representing a finished task. The management plans for conservation units should be dynamic and include a continued learning and maturation process that allows for revisions of procedures and technical guidelines to make the plans more relevant to the reality of different areas. It is also noteworthy that over time plans, including restrictions of use and collection of a resource, might favour the development of a local conservation cultural, as the suggestions for even more restrictive measures, such as collection only every two weeks, made by some of the informants in the present study seem to indicate. In addition, it is important to emphasize that existing conflicts between social and environmental interests can be minimized if, in the construction of conservation measures, the human populations directly affected are heard and included in every discussion of the process.

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