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Factors that influence human behavior in fuelwood use and their implications for biocultural conservation

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ABSTRACT

A set of investigations has attempted to identify patterns in human resource use behavior to drive conservation strategies. However, it is still necessary to advance the understanding of the factors that influence human decision making in the use of resources. In this research, we assessed whether there are drivers of the differential consumption of plant resources. We also searched for socioeconomic predictors of firewood consumption. We adopted the use of fuelwood as research model in a rural settlement in northeastern Brazil. Resource availability was the main variable that directed the frequency of use of the species, and the number of people in the residences was the main predictor of the total firewood weight consumed monthly by the families. No variables predicted per *capita* monthly consumption. These findings can provide important insights for the elaboration of biocultural conservation strategies because they present the mechanisms that can direct the behavior in the use of certain resources and the greater consumption of firewood by certain families.

Keywords: Fuelwood; Evolutionary Ethnobiology; Human Behavioral Ecology; Social-Ecological Systems.

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SIGNIFICANCE STATEMENT

This study employs seeks to explain why certain natural resources are more used than others, as well as the factors that can predict the consumption of resources in a human community. For this purpose, our research model was the use of firewood. In theoretical terms, the understanding of these possible patterns of behavior and how they determine the use of resources represents a key aspect for explaining the processes of cultural evolution from an ethnobiological perspective. In practical terms, the results interpreted in the light of the Social-Ecological Theory of Maximization can provide important insights for the development of biocultural conservation strategies, as they present the mechanisms that can direct the behavior in the use of certain resources.

INTRODUCTION

It has been sought to understand the human behavioral bases associated with the selection and use of environmental resources (Albuquerque et al. 2015; Phillips and Gentry 1993). A set of studies shows evidence of patterns associated with the use of resources by various human groups, in which socioeconomic factors, such as age, income, schooling, among others (Medeiros et al. 2016; Rahut et al. 2016), and ecological factors such as the availability of resources in the environment (Phillips and Gentry 1993), can affect the consumption of certain plants by people (see Albuquerque et al. 2015).

Understanding these patterns has become increasingly urgent to favor biocultural conservation strategies. For example, the use of plants as fuel by human groups has been widely employed to meet the needs of various populations (Couture et al. 2012; Liu et al. 2003). This has generated impacts on biodiversity by pressing populations of plants that are highly targeted by human groups in this use (Liu et al. 2003; Samant et al. 2000). In this sense, research on use patterns can help in the selection of a group of people in a given human population that possess socioeconomic characteristics linked to a greater consumption of fuelwood, as well as to find the characteristics of the plants that are most in demand for consumption. These groups of people and plants may be targets of conservation strategies (see, for example, Martínez 2015). The development of strategies is important to minimize these impacts and support biocultural conservation.

In addition to the practical perspective aimed at biocultural conservation, there is a set of research theoretically advancing on the selection criteria of fuelwood species in different human groups. For example, the study of Top et al. (2004) investigated the consumption of fuelwood in three village groups that had different degrees of availability of forest areas. The authors observed that the groups with greater availability of forest areas presented a greater annual consumption of fuelwood and a smaller number of used species than the village groups located more distant from forest areas. In addition, the groups located more distant from the areas presented a higher proportion of people indicating that they do not have species preference in the fuel use. The authors explain that the greater number of species used in the more distant groups reflects a reduced availability of plants for fuel use, which may have led people not to focus on preferred species and use a greater wealth of plants to meet their demands (Top et al. 2004). This evidence suggests that the availability of the resource in the environment, affects fuelwood use by human groups.

In the case of preference for certain plants, studies also point out that people have different criteria to indicate a species as preferred for fuelwood purposes. The preference of the resource for this use is linked to a set of perceived characteristics, such as a longer duration of flames and embers, a greater ease of ignition and a lower production of smoke and sparks (see Ramos et al. 2008a,b; Tabuti et al. 2003). These characteristics are associated with a higher perceived quality of the resource. Thus, not only the availability but also the perceived characteristics related to the quality of the resource are important in the selection of plants in the fuel use (see Ramos et al. 2008a). Ramos et al. (2008b) showed that, for a rural community in northeastern Brazil, the most cited plants as preferred for fuelwood presented important physical characteristics (density and water content) in the use, indicating that the resource quality is associated with the preference of the resource as a fuel.

The evidence from the studies also indicates that the importance of quality in resource selection (in the case of preference) is linked to areas that offer greater availability of resources (Marufu et al. 1997; Top et al. 2004). In this case, in areas with greater scarcity of resources, people can select resources primarily considering the availability, not necessarily considering the resource quality. However, the work of Marquez-Reynoso et al. (2017) found that preference was not associated with the physical characteristics of resources (quality in fuel use), but rather with the proximity and availability of resources for the human groups living in areas that do not have a shortage of resources. This study, particularly, was conducted with human groups living near a protected area in Mexico and this may have affected the use of firewood in the communities due to restrictions of use in the area. It is possible that this explains the research findings, suggesting that several factors may influence the selection and use of fuelwood in different human groups.

Even with the set of works that propose to explain the factors that affect the species selection, few investigations explore people's perceptions of firewood attributes to search for a larger set of intrinsic and ecological predictors.

In order to investigate these aspects of human behavior, with the purpose to propose new directions for future biocultural conservation strategies we the following hypotheses, using as a model the use of firewood in a human group in northeastern Brazil: (1) Perceived attributes of firewood species explain their differential use, and (2) household firewood consumption is explained by socioeconomic factors. The first hypothesis investigates the mechanisms that lead one species to be more used as firewood than another does. The second hypothesis seeks to understand what leads certain families in a given community to consume more firewood than others. The test of the two hypotheses provide important insights for the discussions related to biocultural conservation, with the identification of the mechanisms that regulate which species are used mostly and the factors that affect the consumption of resources in socioecological systems.

MATERIAL AND METHODS

Study site

The community selected for the field survey was the rural settlement Dom Hélder Câmara, which is located in the municipality of Murici, State of Alagoas, northeastern Brazil (Figure 1). The main economical activities of the municipality is the sugarcane agribusness (IBGE, 2012).

The creation of the Dom Hélder Câmara settlement results from a process of popular fight for land together with rural social movements. After the occupation of the area by farmer families, the negotiations for land owning began with the Instituto Nacional de Colonização e Reforma Agrária [National Institute of Colonization and Land Reform] - INCRA (PRA, 2007). The settlement was only officialized in the year 2000, two years after the occupations. It covers an area of 333.11 ha and it has 43 families. Most families used to live in other nearby communities of the same municipality or in other municipalities of the state of Alagoas. Agriculture is the main economic activity of the dwellers and the most important crops cultivated for both self-consumption and trade are manioc, beans, yam and maize (Costa et al., 2019).

The region is characterized by rainy tropical climate, with dry summer and rainy season in the fall/winter. The vegetation is classified as Open Ombrophylous Forest and Dense Ombrophylous Forest. One of the reasons for choosing this community is that it is located near the Murici Ecological Station (ESEC Murici), which represents one of the largest continuous fragments of Atlantic Forest in northeastern Brazil. Inside the Dom Helder Câmara Settlement, there are areas for the protection of native vegetation, called Legal Reserve (RL) and Permanent Preservation Areas (APP), following Brazilian law. RL areas add up to approximately 60.5 hectares, divided into three forest fragments, and APP areas add up to 14.9 hectares of riparian vegetation (Cruz and Silva, 2018). According to residents, the RL and APP areas are well maintained. The collection of firewood occurs in both these areas, as well as in the residents' own land plots and the forest fragments neighboring the Settlement. The collection does not take place within ESEC Murici. The use of firewood in a domestic environment is intended for food preparation. Therefore, it is a scenario of relevant socio-environmental importance, as it houses the biological diversity of ESCE Murici and the cultural diversity of the surrounding rural populations.

Legal aspects and permissions to carry out the research

Initially, the leaders of the rural settlement and the manager of the Murici Ecological Station were contacted at different times prior to the start of the research, so that they could express their interest in the research. Subsequently, in compliance with basis of article 10, paragraph 10.2, of Resolution no. 466/2012 of the National Health Council, the project was submitted to the ethics committee of the Federal University of Alagoas, under the registration number 089662/2016. The participants signed informed consent forms to authorize the use of participant information.

Data collection

Data collection was executed through semi-structured interviews with household heads from July to November 2016, period that included part of the rainy season (until September) and part of the dry season. All households in the settlement were visited, and the selected ones were those who residents allowed the participation in the survey, with a total of 43 residences, housing 204 people. Twenty men aged 20-85 years and 23 women aged 21-82 years were interviewed.

The interviews were divided into two stages: the first one aimed at obtaining socioeconomic information, such as name, gender, number of residents in the household, age, schooling, land tenure and income. At this stage, participants were also asked about the types of fuels used in the house and the duration of consumption of a liquefied petroleum gas (LPG) cylinder. They were invited to inform the days of the week of gas consumption and the days of consumption of firewood.

The interviewees were asked about what most motivated them to choose a species to be used as firewood, having as possible answers: a) being more available or accessible; b) being of higher quality. This initial question allowed us to assess the interviewees' general understanding of the variables 'availability' and 'quality' before starting the second stage of the interviews. We used general terms, and we understand that several variables may influence people's perceptions of quality and availability. Peo-

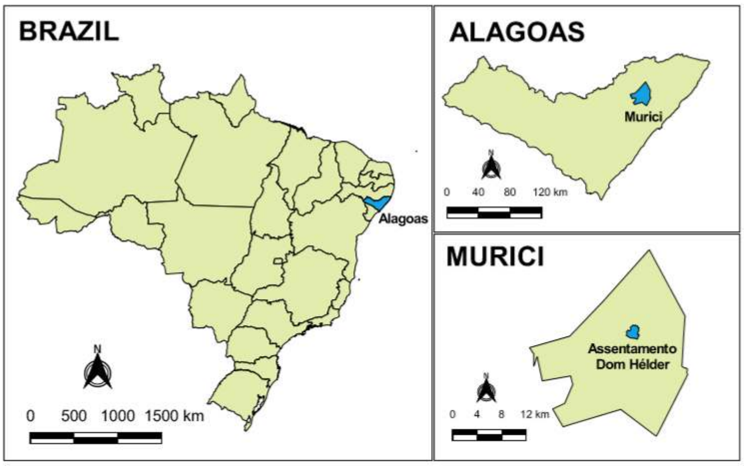

Figure 1. Location of the Dom Hélder Câmara Settlement in the municipality of Murici, state of Alagoas, Northeastern Brazil.

ple often consider in their availability judgments not only the total amount of a resource in a given area but also whether it is easily accessible, occurring near people's houses or paths (Gama et al. 2008). Therefore, we are aware that we are measuring a variable different from what would be accessed, for example, with community ecology methods.

Additionally, resources may be considered more available when it does not present legal (*e.g.*, property regime, protection laws) or biological characteristics (eg., spines, hardness) that hinder or prevent its collection. The understanding of "quality" was associated with the perception of a species for firewood as excellent, good, reasonable, bad, terrible, among other related qualifications expressed by the interviewee.

The second stage of the interviews was directed to 42 households that used firewood as a partial or integral energy source. Only one household in the settlement did not use firewood and for this reason it was not considered for the next stage of the research. In this stage, firstly, the "free list" technique (Albuquerque et al. 2014) was applied, in which each household head was invited to list the plants used for energy purposes. After listing the plants, the interviewee was asked to assign a score in a Likert scale from 1 to 5 for each plant used, in which 1 represented the best grade and 5 the worst, considering the following attributes adapted from the literature (Ramos et al., 2008b; Tabuti e Dhillion, 2003): frequency of use, wood quality, durability, ease of ignition, ash production, smoke production, smell and availability. Terms appropriate to the interviewees' understanding were used to explain the rating scales for each of the attributes. For example, for the attribute "wood quality", we asked respondents to define what they thought of the species for firewood on a scale from very bad to very good (assigning scores from 1 to 5), so that the answers were given based on their own perceptions and experiences of use.

At the end of the interviews, the "average day" methodology was applied (FAO 2003), and the participant was asked to show the amount of firewood normally used in one day and the amount was measured with a digital hand scale. To complement the data, we also adopted the technique of the guided tour (walk in the woods) (Albuquerque et al., 2014), which consisted in going to the field with the participant to collect botanical samples of the species mentioned in the interviews.

Sequentially, the collected samples were stored, containing relevant information and characteristics of the collection site and sent to the herbarium of the Institute of the Environment of Alagoas (MAC) to identify the species. The "plantminer.com" portal was assesed to review the scientific names and families according to the Flora do Brasil 2020 database. The origins (native or exotic) were defined according to the databases Flora do Brasil 2020 (Flora do Brasil, 2020). The scientific names of exotic species were reviewed by the Tropicos.org database.

Data analysis

We calculated the frequency of citation of each species, as the number of interviewees that use the species divided by the total number of interviewees.

In order to evaluate the first hypothesis (the species most used for firewood are those that present the most favorable cost-benefit relationship), we calculated the mean values for the attributes accessed according to people's perceptions. Since we were dealing with mean values, we excluded idiosyncratic information, so that plants that were cited by only one person were not considered for the statistical analysis. Such a procedure has been adopted in other studies on selection criteria (see, for example, Gomes et al. 2020). Therefore, a total of 26 species were included in the statistical analyses.

We considered the frequency of plant use (mean scores) as a dependent variable. This is a different measure from the above-cited frequency of citation. We only divided the scores of frequency of plant use by the number of interviewees who claimed to use a given species. In such a case, frequency of use has to be understood, for the purposes of this study, as how periodically the users of a given species consume it. The independent variables were general wood quality, durability, ease of ignition, smell, ash production, smoke production and availability.

The scores were inverted for all variables, so that the higher grades represented the best attributes (*e.g.* high durability, high availability, low ash content etc.). As our independent variables presented multicollinearity, we had to deal with variables with correlations (Spearman) higher than 0.8. That was the case for ash content and durability, which were highly correlated. In this case, we opted to calculate a mean score and create a single index for the variables. General quality was also highly correlated to both durability and ash content. For this reason, we excluded it from the model, as we found more important to investigate the role of detailed attributes.

As we dealt with a small sample and too many explanatory variables to fit a multiple regression model, we employed least absolute shrinkage and selection operator (lasso) regressions (Tibshirani 1996). This approach is especially useful for small samples and high dimensional data. We adopted the procedures described by Finch (2016) and searched for the most parsimonious model that also explains a substantial amount of variance in the dependent variable. The variables were standardized prior to the analyses. For this purpose, we used the R function 'scale' for the whole dataset. Therefore, the models were not standardized during the Lasso procedures. As a complementary analysis, we compared availability with wood quality to show which of these is the main criterion used by people to collect firewood. For this, a goodness-of-fit chi-square test was applied in order to compare the number of participants who claimed to select firewood based on availability with the number of participants who claimed to select firewood based on (general) quality.

In order to test the second hypothesis (household firewood consumption is explained by socioeconomic factors), a similar approach with lasso regressions was performed. The first model considered the monthly weight of wood consumed as a dependent variable. This variable was formed by multiplying the daily weight with the number of firewood consumption days in the month. The second model considered the monthly per capita consumption, which was obtained by dividing the previous variable by the number of residents in the household. Monthly consumption + 1 was log transformed (Log10) to fit a normal distribution. Monthly per capita consumption was square root transformed. The independent variables for both models were age of the family head (men or women that participated the interview), land tenure (binary variable – 0 for irregular and 1 for regular occupation), number of residents per household, family income (ordinal variable, coded according to the number of minimum wages), and participation in the flour house (binary variable – 0 for no participation and 1 for participation). The latter variable was included in the study because some residents also used firewood for flour production in a community house, which could increase the consumption of firewood in the residences of these household heads. Variables were also standardized prior to the analyses. These analyzes were also performed using the software R. We used the packages 'scales', 'glmnet', and 'lassopv'.

RESULTS

Socioeconomic characterization of participants

Based on the data obtained through the socioeconomic profile of the residents, it is observed that 204 people live in the settlement (111 male and 93 female dwellers). The predominant age group is concentrated between 25 and 64 years (35.3%), followed by children aged between zero to 14 years (33.8%) and young people and adults between 15 and 24 years old (23%). The register of residents over 64 corresponded to 7.8% of the local population. Regarding the level of education, the majority of the settlers (39%) have incomplete elementary education, followed by 22% of the interviewees who attended elementary school and 21% were not even literate. There were 8.8% of residents that have incomplete secondary education and only 3.9% have complete secondary education. Most of the male household heads interviewed (42%) studied only elementary education (incomplete). A similar situation was observed among the women responsible for the residence, of which 43% also studied until elementary school (incomplete).

It was possible to identify great diversity in the age group household heads in the community, with a minimum age of 20 years up to 72 years. As for the number of residents per household, there was also a considerable discrepancy in the community, ranging from 1 to 21 members. Most interviewees already had their land tenure regularized (76.74%), while 13.95% were still waiting for regularization and 9.3% declared they lived in regularized lands of family members (mostly daughters or sons that built a second house in the lot).

The monthly family income among the researched residencies ranged from zero (when they had no fixed income until the time of the research), up to R$ 3,520.00 (approximately U$ 700.00). The observed sources of income varied among farmers, rural workers, retailers, bricklayers and retirees/social benefits, according to Table 1.

General characteristics of firewood use

A total of 42 plants of firewood use were cited by their popular names, distributed among 21 families (Table 2). The families Anacardiaceae, Fabaceae, Myrtaceae and Moraceae were more prominent and together grouped about 34% of all species locally mentioned in the use of biofuel.

Among the 42 plants cited for firewood, 26 were mentioned by more than one interviewee. Five species were more noticeable in relation to their high frequencies of citations by the participants. These species were Murici (*Byrsonima sericea* DC.), cited by 78.57% of the participants, Sabiá (*Mimosa caesalpiniifolia* Benth.), cited by 54.76%, Caboatã (*Thyrsodium spruceanum* Benth), cited by 45.24%,Mangueira (*Mangifera indica* L.), cited by 28.57%, and Canzenze (*Stryphnodendron* sp.), cited by 26,19% of the participants. Of these, three are native to the region and two are exotic. The high frequency of use of these species suggests a great diffusion of the knowledge about them, so that they can be species very important to people as fuel.

M. caesalpiniifolia stood out in terms of the mean scores for frequency of use (Table 3. *Genipa Americana* L. stood out in terms of general quality, while *B. sericea* had the higher values for durability and (little) ash production, *Xylopia frutescens* aubl. for (little) smoke production and ease of ignition, *Vismia guianensis* (Aubl.) Choisy for smell, and *Himatanthus bracteatus* (A. DC) Woodson for (high) availability (Table 3). Most of the interviewees (97.67%) use firewood as fuel to cook in their homes in different degrees of intensity, that is, at least once a month, or every day (52.38% of participants). Of the total number of participants that use firewood, 16.28% have it as their sole source of fuel and 83.72% use mixed firewood associated with LPG. According to the participants who make mixed use, the use varies, mainly due to the type of meal being prepared, in which they choose to use firewood to prepare meals that require longer cooking time.

On average ((Este Sinal é?) standard deviation) 179.8 223.3 kg of firewood are consumed monthly by the families interviewed, representing an average consumption of 2,157.6 2,679.9 kg of firewood per year for each family. The fact that the standard deviation was greater than the average indicates the existence of great variability among the consumption data.

Is differential firewood use explained by the species' attributes?

Our first hypothesis was confirmed, although not all the tested variables explained the species' frequency of use. The lasso regression with the optimal lambda (0.131) indicated that ignition, smoke and availability were predictors of the frequency of use (Table 4 4). Among them, the most important predictor (with higher standardized estimator) was availability, followed by smoke production and ease of ignition.

Regarding the availability of collecting species of plants used as firewood, it is noticed that of the 42 interviewees, 29 informed that they are guided by availability, while 13 are guided by quality and one did not respond. The difference between the values of availability and quality are significant ($chi-square = 6,095; p < 0.05$). Therefore, these finding reinforce that availability is the most important factor.

The role of socioeconomic factors in the consumption of firewood

Our second hypothesis was confirmed. The model for monthly firewood consumption ($lambda = 0.085$) indicated as predictors the number of residents, participation in the flour house and land tenure situation (Table 5). Therefore, houses with more residents, whose residents participate the flour house and whose land tenure situation is regular consume more firewood. However, participation in the flour house was not statistically significant. Number of residents was the most important predictor for this model.

The model for monthly per capita consumption (lambda=0.274) showed that none of the independent variables were good predictors ($lassocoefficient = 0$ and $p > 0.05$ for all variables).

Table 1. Profile of the sampled households of the settlement Dom Hélder Câmara, municipality of Murici - AL.

	Minimum	Maximum	Average	Deviation
Average age of household heads	20	72	52.7	14.4
Number of residentes	1	21	4.7	3.9
Montly family income (R$)	0	3520	1548.8	871.2

Table 2. Species cited as firewood by residents of the settlement Dom Hélder Câmara, in Murici-AL.

Family	**Species**	**Popular name**	**Origin**	**F.C. (%)**
Anacardiaceae	*Anacardium occidentale* L.	Caju	native	23.81
	Mangifera indica L.	Mangueira	exotic	28.57
	Schinus terebinthifolia Raddi	Aroeira	native	2.38
	Tapirira guianensis Aubl.	Cupiúba	native	23.81
	Thyrsodium spruceanum Benth.	Caboatã	native	45.24
Annonaceae	*Xylopia frutescens* Aubl.	Imbira vermelha	native	7.14
Apocynaceae	*Himatanthus bracteatus* (A. DC.) Woodson	Banana de papagaio	native	4.76
Araliaceae	*Schefflera morototoni* (Aubl.) Maguire et al.	Sabaquim	native	14.29
Arecaceae	*Cocos nucifera* L.	Coqueiro	exotic	2.38
Burseraceae	*Protium* sp.	Amescla	native	2.38
Cannabaceae	*Trema micrantha* (L.) Blume	Favinha	native	2.38
Cecropiaceae	*Cecropia* sp.	Embaúba	native	11.90
Combretaceae	*Terminalia catappa* L.	Amendoeira	exotic	2.38
Fabaceae	*Bowdichia virgilioides* Kunth	Sucupira	native	23.81
	Enterolobium timbouva Mart.	Tambor	native	23.81
	Inga sp.	Ingazeira	native	11.90
	Machaerium hirtum (Vell.) Stellfeld	Espinheiro	native	2.38
	Mimosa caesalpiniifolia Benth.	Sabiá	exotic	54.76
	Samanea tubulosa (Benth.) Barneby & J.W.Grimes	Bordão-de-velho	native	4.76
	Stryphnodendron sp.	Canzenze	native	26.19
Hypericaceae	*Vismia guianensis* (Aubl.) Choisy	Lacre	native	21.43
Lauraceae	*Ocotea glomerata* (Ness) Mez	Louro	native	16.67
Lecythidaceae	*Eschweilera ovata* (Cambess.) Mart. ex Miers	Imbiriba	native	16.67
	Lecythis pisonis Cambess.	Sapucaia	native	2.38
Malphigiaceae	*Byrsonima sericea* DC.	Murici	native	78.57
Melastomataceae	*Miconia hypoleuca* (Benth.) Triana	Carrasco	native	14.29
Moraceae	*Artocarpus heterophyllus* Lam.	Jaqueira	exotic	19.05
	Brosimum guianense (Aubl.) Huber	Quiri	native	2.38
	Brosimum sp.	Pau Cassaco	native	2.38
Myrtaceae	*Myrtus communis* L.	Murta	exotic	14.29
	Psidium firmum O.Berg	Araçá	native	9.52
	Psidium guajava L.	Goiabeira	exotic	26.19
	Syzygium cumini (L.) Skeels	Azeitona	exotic	21.43
Poaceae	*Bambusa vulgaris* Schrad. ex J.C.Wendl.	Bambu	exotic	2.38
Rubiaceae	*Genipa americana* L.	Jenipapo	native	4.76
Rutaceae	*Citrus × aurantium* L.	Laranjeira	exotic	9.52
Sapindaceae	*Talisia esculenta* (St. Hill.) Radlk	Pitomba	native	2.38
Indeterminate	*Indeterminate 1*	Capucaia	-	2.38
	Indeterminate 2	Mal vizinho	-	2.38
	Indeterminate 3	Mucuruba	-	2.38
	Indeterminate 4	Palmeira	-	2.38
	Indeterminate 5	Camará	-	2.38

DISCUSSION

Our results show that the use of plants as fuels is explained by plant species' attributes. However, the findings still indicate that, although several factors are related to this use, availability is more important in relation to the others. This suggests that the most commonly used resources are those that offer lower collection costs associated with their availability. Considering that the statistical model also indi-

Table 3. Average scores of the species cited as firewood by residents of the settlement Dom Hélder Câmara, in Murici-AL. Included species were cited by more than one interviewee. (Q=Quality, I=Ignition, D=Durability, Smell=S, Ash=A, Smoke=Sm, Availability=Av)

Species	**Frequency of use**	**Attributes**						
		Q	**I**	**D**	**S**	**A**	**Sm**	**Av**
Anacardium occidentale L.	3.30	2.70	3.10	2.90	4.00	2.40	2.90	3.90
Artocarpus heterophyllus Lam.	3.13	3.75	3.75	3.38	4.13	3.80	3.13	4.50
Bowdichia virgilioides Kunth	2.90	4.30	3.60	4.20	4.20	4.10	4.10	3.00
Byrsonima sericea DC.	4.00	4.45	3.61	4.67	4.18	4.40	4.09	3.58
Cecropia sp.	2.20	2.00	3.40	1.20	3.00	1.80	1.60	4.20
Citrus × aurantium L.	2.75	3.25	3.00	2.75	4.00	2.30	3.50	3.75
Enterolobium timbouva Mart.	3.60	3.00	4.10	2.40	3.50	2.30	2.90	4.00
Eschweilera ovata (Cambess.) Mart. ex Miers	3.00	3.86	3.29	3.29	3.71	3.70	2.86	3.71
Genipa americana L.	1.00	5.00	3.00	4.50	4.00	4.00	3.00	3.00
Himatanthus bracteatus (A. DC) Woodson	3.00	2.00	2.00	2.00	1.00	2.00	1.00	5.00
Inga sp.	2.80	2.40	3.40	2.40	4.00	1.80	1.80	2.20
Mangifera indica L.	2.92	2.58	2.92	2.08	2.92	2.50	2.50	4.17
Miconia hypoleuca (Benth.) Triana	3.83	3.83	4.17	3.33	4.17	2.30	2.83	4.67
Mimosa caesalpiniifolia Benth.	4.57	4.52	4.30	4.57	4.22	4.00	4.26	4.61
Myrtus communis L.	4.00	4.00	3.50	4.00	3.83	3.80	3.67	3.83
Ocotea glomerata (Ness) Mez	3.14	2.86	3.86	2.71	3.86	3.00	2.43	3.86
Psidium firmum O.Berg	2.75	3.75	3.50	4.00	4.25	4.00	4.00	3.75
Psidium guajava L.	3.73	3.64	4.00	3.45	4.09	3.80	3.64	3.91
Samanea tubulosa (Benth.) Barneby & J.W.Grimes	2.00	1.00	2.00	1.50	4.00	2.50	2.00	3.00
Schefflera morototoni (Aubl.) Maguire et al.	2.67	3.17	4.83	2.67	4.00	2.00	3.00	4.17
Stryphnodendron sp.	2.64	4.36	4.55	3.45	4.00	3.50	3.00	2.82
Syzygium cumini (L.) Skeels	3.56	3.33	3.22	3.33	4.22	2.90	3.22	3.33
Tapirira guianensis Aubl.	4.00	3.30	4.60	2.50	3.80	3.10	2.50	4.40
Thyrsodium spruceanum Benth.	3.26	4.16	4.42	4.53	4.11	3.90	3.89	2.68
Vismia guianensis (Aubl.) Choisy	3.78	3.67	3.22	3.67	4.33	2.70	3.33	4.22
Xylopia frutescens Aubl.	4.00	4.00	5.00	2.00	3.67	3.30	4.67	4.00

cated resource quality factors (ignition and ash production) as predictors, we can suggest that people direct consumption to plants that are highly available, but not any species of high availability. These must have some quality to allow their use as fuel. This could indicate that the use of firewood in the studied human group tends to be a generalist behavior, in which the search for resources is mainly directed to those that are available, but not necessarily, because they are of higher quality (see Albuquerque et al. 2015).

Several papers have shown the importance of the availability and use of fuel resources in different human groups (Gonçalves et al. 2016; Maldonado et al. 2013; Top et al. 2004). Top et al. (2004), for example, compared three human groups with different plant availability for fuel use and observed that the group with the lowest availability of resources used more species because they did not focus the collection on a few preferred plants. These studies, including the results of the present research, provide evidence for the "Apparency" Hypothesis (AH), which

Table 4. Standardized Model Coefficients for the predictors of firewood species' mean use frequency by a rural settlement in NE Brazil.

Variable	Lasso
Ease of ignition	0.167+
Durability/Ash production	NA
Smoke production	0.253+
Smell	NA
Availability	0.313+

NA=Variable not selected for inclusion in the final model
+Statistically significant at alfa=0.05

Table 5. Standardized Model Coefficients for the predictors of monthly firewood consumption by a rural settlement in NE Brazil.

Variable	Lasso
Number of residents	0.460+
Participation in the flour house	0.006
Family monthly income	NA
Land tenure situation	0.233+
Age	NA

NA=Variable not selected for inclusion in the final model
+Statistically significant at alfa=0.05

has been proposed to explain the role of resource availability in its cultural importance and use by human populations (see Phillips and Gentry 1993).

The idea of Apparency and our findings are in agreement with the explanation proposed by the Social-Ecological Theory of Maximization, which indicates that social-ecological systems are constructed and organized through cognitive and behavioral mechanisms that contribute to the survival of human groups, maximizing benefits and lowering costs in human interactions with different environments (Albuquerque et al. 2019). Particularly, our findings are related to one of the models presented in the Theory, entitled *Model of Maximum Environmental Performance*, which proposes that the entry and the differential use of resources for a given use are explained by the returns based in the cost and benefit balance considering different variables, so that the best known and most used resources are those that give the greatest returns, with a decrease in cost-related factors and maximization of benefits (Albuquerque et al. 2019). This can be observed in our findings, when people reduce collection costs by using the most available species and increase benefits by applying quality criteria. Considering that our results corroborate this scenario of maximization, it is important that future efforts of biocultural conservation consider the factors related to the human perception that can inform on the relations of cost and benefit in the consumption of resources. If the same maximization logic occurs for other types of use, then we can understand some of the mechanisms behind the human decisions associated with plant uses, which will help predict behaviors and make biocultural conservation decisions.

Based on this information, we believe that conservation strategies should initially focus on native species with a low average score for availability and a high average score for frequency of use (*e.g., B. sericea, T. spruceanum, B. virgilioides, L. pisonis* and *Stryphnodendron* sp.) In such cases, we recommend the development of silvicultural actions focusing on these species, with the collection of seeds, production of seedlings, and propagation in energetic forests in the properties and forest areas of the settlement. Besides, the private stocks of the exotic species *M. caesalpiniifolia* should be maintained, especially in the properties' fences. The use of this species, which has outstanding firewood attributes according to the interviewees' perception, can reduce the use-pressure on native species.

Another punctual finding which may have implications for biocultural conservation is the fact that some species have high quality scores, high to intermediate availability and yet a low frequency of use. *G. americana* is an outstanding example, since it presented the highest score for general quality, with an intermediate availability score, but it was the species with the lowest value for frequency of use. *G. americana* fruit is widely consumed in the settlement and often commercialized in nearby markets. Therefore, it is possible that a high importance for a more specialized use protects species against firewood use. However, this hypothesis should be tested with proper research designs.

Availability is not always related to the use of resources in human groups, as some studies have not verified this tendency in medicinal use (Gonçalves et al. 2016; Lucena et al. 2012). For medicinal use, the quality of the resource, and not necessarily the availability, has been an important factor for the selection of plants (Saslis-Lagoudakis et al. 2012). In this sense, depending on the category of use, cost-benefit relationships can be directed to different optimization points. For some use categories quality may become a very important factor (in the medicinal case), while for others, the availability may be a more important factor (as in the present study case for fuel use) (see Albuquerque et al. 2015 for a similar discussion). In this case, the use of fuelwood present a generalist strategy because the woody plants can be replaced by another to generate heat and fire, instead, the medicinal resource is more specific, where a plant may not be replaced because it does not have the same effect (see, for example, Gonçalves et al. 2016 for a brief discussion on the different requirements involved in these two types of uses.

The importance of availability can still be supported by another finding of the present study, the demonstration that the number of people living in the houses influenced the consumption of firewood in the residences. This indicates that the larger the number of people in a given household, the greater the family's demand for firewood consumption, which makes the availability of the resource important for meeting the needs of large family households. Some papers have also suggested this relationship (see Bhatt et al. 2016; Kumar and Sharma 2009). In this case, plants that present a relatively quality in fuel use but are highly available tend to serve these families, and the relationship between firewood consumption and plant availability increases. From a practical point of view, it is important to consider that the most available plants can be more targeted by people, especially when they belong to homes with large families. On the one hand, this may favor biocultural conservation by the fact that more available resources tend to be less vulnerable than lesser available resources, decreasing the chances of local extinctions due to fuel use. However, on the other hand, further monitoring of the situation of these more available resources is necessary to understand how they respond to extraction activities over time.

It is also possible that an initially very available species has its population greatly reduced due to human management. To worsen the situation, studies have suggested that people do not always notice these changes immediately, that is, changes in the landscape (e.g. reduced availability of a species) may remain unnoticed by certain generations or by a period of time (Hanazaki et al. 2013). In this way, the present management may be influenced by the perception of a past scenario - which could cause a species to continue being overexploited, even though it is no longer available as it used to be in the past.

However, it is likely that, in contexts of generalist use of firewood, people simply collect what is in their way (while avoiding species of very low quality). Thus, the probability of a species being selected in a collection event would increase according to its natural availability (Albuquerque et al. 2015), which would prevent a previously available and now declining species from being the main collection target. This seems to be the case in the context of this community.

Although the number of residents was the socioeconomic predictor that best explained the monthly consumption of firewood, the variable "situation of land tenure" was also significant. This may indicate that families holding land ownership have higher availability / accessibility to resources, allowing them a higher monthly consumption. A similar logic can explain the permanence of the variable "participation in the flour house" in the model, even if not significantly. It is likely that families participating in the flour house have a larger stock of firewood in their homes, to meet both domestic use and use in the production of the flour house. Higher stored can lead to higher monthly consumption in those homes, which would also be indirectly linked to an idea of availability.

When considering the per capita monthly consumption, there were no significant relationships between socioeconomic factors and the consumption of local firewood. What draws attention to this finding is the fact that income did not affect consumption, as it did not affect family monthly consumption. This relationship has been observed in a set of studies in other regions, which indicates an inversely proportional relationship between household income and firewood consumption (Bhatt and Sachan 2004; Brouwer and Falcão 2004). The main explanation suggested in the literature is that households with higher incomes may opt for alternatives in fuel use, such as Liquefied Petroleum Gas (LPG), and thus reduce the consumption of firewood (see Bhatt and Sachan 2004; Cai and Jiang 2010; Medeiros et al. 2015).

However, in some contexts, income does not explain the consumption of firewood in the same human group. For example, the work of Cai and Jiang (2010), evaluating the consumption of firewood of four communities located near natural reserves in China, observed that the total consumption of firewood in the houses was not related to the economic situation of the families in each community.

In our study, the lack of predictive power of income on wood consumption, although not in line with most of the literature, has plausible justifications. Although in different socio-environmental scenarios there is a tendency for the greater purchasing power lead people to acquire alternative resources, it is necessary to consider that, not always the alternative resource to be acquired will be something to replace the firewood. Medeiros et al. (2011), for example, when studying the factors that interfere with the use of wood in a rural community in northeastern Brazil, observed that income is much more important to explain the general consumption of wood than to explain the consumption of each wood use individually (including fuel use). Thus, while some people with differentiated incomes may choose to spend financial resources buying LPG, others may direct that extra value to obtain masonry material to replace wood construction.

Thus, it is possible that in the settlement studied here, even those with higher purchasing power opt to keep the use of firewood, directing their additional income to meet other demands or needs. Thus, it would be necessary to extend the research to other categories of plant use, in order to identify whether income can be an explanatory factor of consumption for them.

CONCLUSION

The present research demonstrates that people's behavior in the use of firewood is influence by species' perceived attributes. However, the perceived availability was the factor that strongly directed the consumption of firewood in the studied group. In addition, our data show that the number of people residing in the residences was the most important socioeconomic factor that explained the local consumption of firewood. In this case, if the same logic guided by availability is present in other human groups (with a generalist pattern), and the consumption of these resources focuses on larger families, conservation efforts should favor strategies directed to families with a large number of people and the use of species with high environmental availability. However, it is necessary to develop future studies that seek to replicate this approach in other regions. These studies can even add other firewood attributes such as wood hardness and the flavor they leave in the cooked foods. They can also consider other socioeconomic predictors, such as the average age of family chiefs (and not only the age of the respondent), and the average instruction of family chiefs.

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DATA AVAILABILITY

The data used to support the findings of this study are available from the corresponding author upon reasonable request.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

CONTRIBUTION STATEMENT

Conceived of the presented idea: RRVS, PMM Carried out the field work: RSC. Carried out the data analysis: PMM, RRVS, RSC. Wrote the first draft of the manuscript: RSC. Review and final write of the manuscript RRVS, PMM, WSFJ, RSC. Supervision: RRVS, PMM.

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