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CASE STUDY

Livelihood strategies and use of forest resources in a protected area in the Brazilian semiarid

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Abstract

Planning conservation strategies in semiarid regions is challenging since local populations are socially vulnerable and highly dependent on natural resources. Consequently, accessing the factors that develop knowledge and determine the use of forest products could aid in planning conservation actions or rethinking past strategies. We use an environmentally protected area in the Brazilian semiarid to describe the livelihood strategies of the local people and assess how socioeconomic variables affect the dependence on forest resources. We tested whether better conserved areas (with greater vegetation cover) have greater concentrations of useful species for local populations than less protected areas. Our findings demonstrate that families with retired or non-farming members have higher incomes. Additionally, men and elder people have greater knowledge about native medicinal plants, while people with lower household income have greater knowledge of native edible plants. Income and the number of residents in households do not explain the demand for wood forest products. Finally, the conservation levels of forest areas did not affect the number of useful species in the landscape. Local populations have a low socioeconomic dynamism, being highly dependent on natural resources, regardless of local variations in socioeconomic profiles. The variable of vegetation cover may not affect the distribution of useful species since it is only a proxy of total tree density and does not affect species composition. Finally, we recommend that creating fully protected areas in semiarid regions should be remodeled while prioritizing conservation units that allow the reconciliation of forest products' use and biodiversity conservation.

Keywords Ethnobotany · Human ecology · Conservation conflicts · Protected areas

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1 Introduction

In tropical regions, 820 million people live nearby forests or savanna areas, of which about 640 million are below the poverty line (Food and Agriculture Organization of the United Nations, 2018). Consequently, these populations are highly dependent on forest products for their livelihood. About 20% of the income generated by these populations comes from the extraction of natural products, such as food products, fuelwood, and forage (Vedeld et al., 2007). These poverty conditions and dependence on natural resources are exacerbated in arid and semiarid regions, where water scarcity hinders agricultural practice, usually affecting food security (Bird and Shepherd, 2003; Naschold, 2012; Wossen et al., 2014).

Ethnobiological literature has demonstrated that socioeconomic differences among households affect their dependence on forest products. Usually, lower-income families with members with lower education levels are more dependent on natural resources, including plants for food, medicinal and plants and plants with wood that can be used for fuelwood and for building houses and fences (Hegde and Enters, 2000; de Medeiros et al., 2012; Ramos et al., 2015; de Arruda et al., 2019). Furthermore, individual differences, such as age and gender, affect local ecological knowledge (LEK) (Soldati et al., 2015; Torres-Avilez et al., 2016), which may cause some individuals to be more dependent on natural products. It is likely that the effects of socioeconomic predictors over people with a dependence on forest products are exacerbated in semiarid regions because of the more strenuous conditions.

This high dependence on the forest may affect the strategies that the local people execute to collect resources. In humid tropical forests, local people usually prefer to use plant species from secondary forests nearby their settlements (Aguilar and Condit, 2001; Chazdon and Coe, 1999). The species from anthropogenic habitats are more familiar and may contain a greater diversity of pharmacologically active compounds than species found in old-growth forests (Voeks, 1996). In dry tropical forests, there is no unequivocal evidence about the preference of using species in anthropogenic areas, since conserved and degraded areas commonly have a similar number of useful species (Lucena et al., 2012; Soares et al., 2013). However, we believe forest areas nearby dry forests, where people are highly dependent on natural resources, may have a lower number of useful species because of their overexploitation.

In recent years, there has been increasing concern about the conservation of ecosystems in semiarid regions (Dryflor et al., 2016), which resulted in the creation of conservation units (see for example, Bernard & Melo, 2019). However, in some situations, the creation of conservation areas can affect the livelihoods of local populations, who must find new ways to survive (Cavalcanti et al., 2015). In addition, the ban on the use of natural resources can increase the socioeconomic vulnerability of some rural populations that depend on these resources, resulting in socio-environmental conflicts with environmental institutions (Baynham-Herd et al., 2018).

In addition, we carried out a case study, aiming to describe the livelihood strategies inserted in the Brazilian semiarid areas and adopted by local populations in a region in which a protected area has been created in a top-down approach. We also assessed how socioeconomic factors affect knowledge about plants for food and medicinal use, and whether household income and the number of residents in each household influence the demand for wood products from the forest. Regarding the distribution of useful species, we tested whether the conservation degree of different forest areas (estimated by the vegetation cover) affects the occurrence of these species.

2 Material and methods

2.1 Socio-environmental vulnerability in the Brazilian semiarid

The geographical area of the Brazilian semiarid region stretches over 1,262 municipalities in eight states in the Northeast (Alagoas, Bahia, Ceará, Paraíba, Pernambuco, Piauí, Rio Grande do Norte, and Sergipe) and the northern state of Minas Gerais (located in the southeastern region of Brazil), totaling an area of approximately 982.563 km^2 (Ministério da Integração Nacional, 2017). This region was delimited based on aridity indicators, such as annual rainfall lower or equal to 800 mm, Thornthwaite aridity index equal to or lower than 0.50, and a daily percentage of water deficit equal to or greater than 60%, considering every day of the year. According to the most recent demographic census (carried out in 2010), this region is inhabited by 22,598,318 people (Instituto Nacional do Semiárido, 2012).

The Brazilian semiarid region is characterized by a high variation in both the intra and inter annual rainfall levels, with most of the annual rainfall concentrated between the months of February and May (Toni and Holanda, 2008). The projections for the climate of this region until the end of the twenty-first century, considering the climate changes resulting from global warming, ranging from an optimistic perspective of an increase in rainfall of up to 20% to more negative perspectives of a reduction of rainfall by about 50% (Krol and Bronstert, 2007; Marengo et al., 2009). Based on these negative scenarios, the decrease in rainfall may result in a water supply crisis. The rationale for this is that there would be a decrease in water storage capacity by the reservoirs, as well as increased water demand for industrial activities and irrigated agriculture (Krol and Bronstert, 2007).

Historically, the region has been marked by major drought events, which boosted migratory flows. Initially, this happened within the northeast region, and later, toward the north and southeast regions of the country. In the 1910s and 1930s, for example, large migratory flows toward the capital of the State of Ceará led the local government to take a harsh attitude an employ drastic measures by creating concentration camps to provide “shelter” to the *retirantes* (as used to be called those who migrated from the Brazilian semiarid) (Neves, 1995). These concentration camps, which came to “house” more than 100,000 people in total, had the political-hygienist purpose of preventing the *retirantes* from reaching the capital of the city, where the local elite did not welcome the arrival of this miserable population (Neves, 1995).

At the end of the nineteenth century, this intraregional migratory movement was greatly reduced, when new regions began to act as an attraction factor for immigrants. The beginning of the rubber cycle (material produced from the latex of the *Hevea brasiliensis* tree (Willd. Ex A.Juss.) Müll.Arg. in northern Brazil, mainly in the state of Amazonas, attracted approximately 250,000 Northeasterners, who acted as cheap labor in the region (Ferrari, 2005). From the 1920s onwards, migration flows toward the southeast region intensified, mainly toward the state of São Paulo. Initially, immigrants sought employment in coffee farming, replacing the workforce of foreign immigrants (Ferrari, 2005). From the 1950s, with the intensification of the industrialization process in São Paulo, this continues to be the focus of northeastern migration, due to the job offer in the urban area of the state (Ferrari, 2005). In total, it is estimated that approximately 3.6 million Northeasterners migrated to São Paulo (Melo and Fusco, 2019).

People who chose not to emigrate usually had to work in exploratory conditions for large landowners in the region, since subsistence agriculture was not sufficient to ensure the livelihood of their families (Neves, 1995). In the years of great droughts, part of the local population was assisted by religious entities or the Productive Work Fronts (*Frentes Produtivas de Trabalho*, in Portuguese), which involved employing the local population as cheap labor in public works, such as the construction of highways, dams, or centers for livestock rearing (Kenny, 2002). The region's politicians assisted local people in exchange for votes for future elections, in a political practice called clientelism (Nelson and Finan, 2009).

In the late 1970s, the first political instrument of social protection that reached the Brazilian semiarid region was the rural retirement, a mechanism that allows small farmers to retire, even if they have not contributed to social security (Bursztyn and Chacon, 2011). However, it was from the 2000s that the poorest households began to be included in social protection systems. In the early 2000s, the President Fernando Henrique Cardoso extended an income transfer program to the poorest households throughout the country, which had the attendance to school by children as a counterpart to reduce the intergenerational transmission of poverty (Bursztyn and Chacon, 2011). In 2003, President Luís Inácio Lula da Silva unified several federal assistance programs under the "Programa Fome Zero", which soon became the "Bolsa Família Program". These welfare initiatives have had positive effects in reducing poverty and extreme poverty in Brazil (Campoli et al., 2020).

However, some researchers argue that this social protection system can function as a new form of clientelism (Bursztyn and Chacon, 2011; Hevia, 2011; Bedran-Martins and Lemos, 2017). Although the objective of this system is to try to transform the social reality of households, it may actually strengthen the position of the poorest as subordinates and render them incapable of getting full citizenship. Consequently, out of gratitude to the politicians who provide these benefits or for fear of losing them, beneficiaries can become loyal to these politicians through voting (Licio et at., 2009; Bursztyn and Chacon, 2011).

However, this position is disputed among researchers. Other social researchers argue that the current welfare in Brazil can stimulate the exercise of citizenship through its counterparts, including school attendance by children (which helps prevent child labor) and the frequency of medical appointments (Pires and Jardim, 2014). For many assisted households, this was the first experience of receiving income and, consequently, entering the consumer market, which can be an important step toward the exercise of citizenship (Rego, 2008). Also, a qualitative study showed that since the advent of the Bolsa Família Program, women in rural regions feel more respected within their households because they are less dependent on their partners and contribute to household expenses (Suarez and Libardoni, 2007).

2.2 Study area

The Catimbau National Park is located in the state of Pernambuco, northeastern Brazil (8° 23′ 17″ and 8° 36′ 35″ S; 37° 11′ 00″–37° 33′ 32″ W) (Fundação Joaquim Nabuco, 2015) (Fig. 1). This park is located in a region with a warm semiarid climate (BSh according to the Köppen classification) (Alvares et al., 2013). There is a variation in rainfall within the park (from 480 to 1100 mm), which affects the structure of plant communities (Rito et al., 2017).

Fig. 1 Location of the study area, the Catimbau National Park, in the State of Pernambuco, Northeastern Brazil. The point indicates the capital of the State of Pernambuco (Recife)

The region's ecosystems belong to the Caatinga's domain, a seasonally dry tropical forest characterized by dense, thorny, and shrubby tree vegetation that grows in deep sandy soils (Fundação Joaquim Nabuco, 2015). The phanerogamic flora recorded in the park is composed of approximately 600 species, of which the families Fabaceae, Poaceae, Euphorbiaceae, Asteraceae, Convolvulaceae and Malvaceae present the greatest species richness (Athiê-Souza et al., 2019).

2.3 Socio-environmental scenario of the Catimbau National Park region

During the Portuguese conquest of the inland area of the state of Pernambuco (seventeenth century), the region of the Catimbau National Park was inhabited by people belonging to the Prakió ethnic group (also called Paratió) (Sampaio, 2011). At present inhabitants from part of the region identify with the Kapinawá indigenous ethnic group (Andrade, 2014; Sampaio, 2011). In the late 1990s, FUNAI (the official Brazilian State's indigenous institution) ratified a territory of about 12,400 ha south of the park as the Kapinawá indigenous territory. However, some of the communities that reside within the park are recognized as belonging to this ethnic group. Their need to claim their permanence in the region has resulted in conflicts with environmental enforcement institutions (Andrade, 2014; Sampaio, 2011).

The decree that instituted the Catimbau National Park does not allow the presence of human settlements within the park and, consequently, does not permit the direct use of natural resources (Brasil, 2000). The only officially permitted use of the landscape is ecotourism, an activity that is still underdeveloped locally. Despite having been instituted about two decades ago, the park does not yet have a management plan, and legal institutions are only starting to regularize land ownership. Thus, many residents were not compensated or did not have a judicial agreement aimed at expropriating the land.

We identified 10 communities within the park, three indigenous and seven non-indigenous communities. In total, 750 individuals reside in these communities, comprising 480 adults and 208 children. For this study, we sampled six of these communities, including the non-indigenous communities: Igrejinha, Breus, Muquém, Dor de Dente, Túnel, and Açude Velho (Fig. 2). These six communities total 325 inhabitants, about 200 adults and 125 children from 109 households. In total, we obtained complete socioeconomic data from 81 people (40.50% of the total sampled) from 68 households (62.38% of the total sampled).

2.4 Data collection

2.4.1 Ethical and legal aspects

We obtained research approval from the Research Ethics Committee with human beings at the Federal University of Alagoas prior to data collection (CAAE: 83182217.6.0000.5013). We informed all the research participants about the objectives of the study and we asked them to sign a free and informed consent form, following the recommendations of resolution number 510 of the National Health Council (Brazil, 2017).

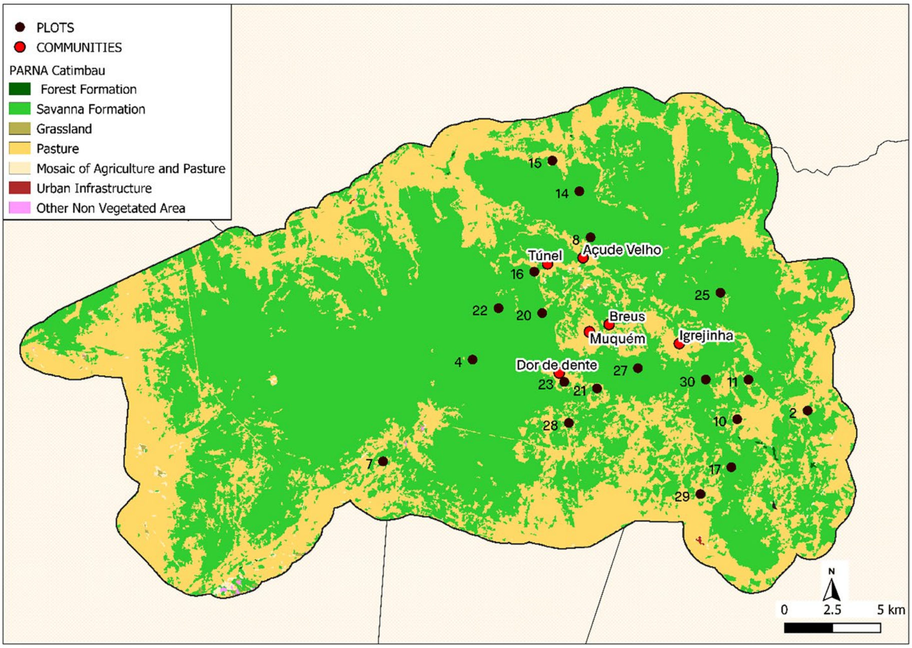

Fig. 2 Map of vegetation cover in the Catimbau National Park region, Northeastern Brazil. The black points represent the location of the plots where the vegetation was sampled, and the red points show the location of the six rural communities studied

2.4.2 Collection of socioeconomic data

From January 2017 to August 2018, researchers from the National Institute of Science and Technology: Ethnobiology, Bioprospecting and Nature Conservation (INCT—https://www.inctethnobio.com) carried out intensive data collection campaigns in the six communities mentioned above. Using structured interviews (e.g., Albuquerque et al., 2014), they collected the following information: sex, age, occupation, education level, monthly household income, number of residents in the residence, and number of goats (for households that practice extensive livestock). Schooling data were categorized into three levels: illiterate (individuals who did not have access to formal education), elementary school (those who did not start high school), and high school (those who have completed or initiated a high school degree). Occupation data were categorized into farming activities (farmers and ranchers), domestic activities (housewives and retirees), and liberal professionals (individuals who had a non-farming occupation). Although the artisans make their work from native trees, we chose to categorize them as liberal professionals because their income is based on the trade of these products. It could, therefore, be an alternative to farming.

2.4.3 Collection of data on knowledge of medicinal and edible plants

Alongside the collection of socio-economic data, the INCT researchers used the free listing technique (e.g., Albuquerque et al., 2014) to access people's knowledge about plants that is useful for medicinal and edible purposes. For non-wood forest products, we chose to use the knowledge as a proxy for dependence on these resources. For this work, we focus only on native species, most of which have been collected and identified. We performed the collection of botanical material using the walking in the woods technique (e.g., Albuquerque et al., 2014). All collected material was identified by taxonomists from the Agronomic Institute of Pernambuco (IPA).

2.4.4 Collection of data on household's demand for wood forest products

In this research phase, we accessed the use of wood forest products from 78 households from these six communities. However, only 33% of the heads of household signed the free and informed consent term, while the rest of the individuals declared their consent verbally, which is also acceptable according to article 5 of resolution number 510 of the National Health Council (Brazil, 2017).

We used two proxies to evaluate the demand for wood by households in the region: the firewood use and the wood used for building fences. To estimate the firewood use, we used the weight assessment technique (Ramos et al., 2015), in which the head of each household was asked to demonstrate, from his firewood pile, the amount of wood which he (she) usually uses in one day. With the help of a key informant (appointed as an expert on plants used as wood), we separated and weighted the wood selected by the household head.

To assess the wood used for building fences, we performed an adaptation of the in situ inventory technique (Gaugris and Rooyen, 2009; Nascimento et al., 2009). We identified different architectural fences in the region. Then, we adopted different sampling procedures for each one. We categorized local fences as follows: (1) closed fences—those of small diameter and quite juxtaposed stakes; (2) semi-open fences—those of small diameter and loosely juxtaposed stakes; (3) open fences—those of intermediate diameter stakes and spaced out; there are some large diameter stakes (called posts) used to secure the wires; (4) very open fences—those of intermediate diameter and arranged in a spaced way stakes, with some posts to secure the wires; and (5) fences made up entirely of posts that are widely spaced.

To estimate the wood volume used in the construction of the fences, in each fence we measured the height and diameter of each stake (e.g., Nascimento et al., 2009). For each of the four types of fences described above, we sampled stakes from different lengths and sampled a similar number of stakes between the different types of fences. For closed fences, we sampled 2 m; for semi-open ones, 4 m; for open ones, 50 m; for the very open fences, 70 m, and for the fences made up only of large diameter posts, 100 m. If the same fence had sections of different structural components, a sampling was carried out for each section. Subsequently, to extrapolate the volume of wood sampled to the entire perimeter of the fence, we covered each of the fences using the odometer function of a GPSMap 60CSx, with an accuracy of 5 m. Afterward, we collected and identified all the plant species used for wood, according to the methods described to the medicinal and edible plants.

2.4.5 Distribution of useful plants in the landscape

To access the distribution of useful flora in the landscape, we initially compiled all useful species collected by INCT Ethnobiology, Bioprospection and Nature Conservation from different studies carried out in the six communities studied (see Supplementary material). Regarding the ecological data, we used the data from Rito et al. (2017). These authors set 19 plots of 20 m × 50 m along gradients of rainfall and anthropogenic disturbances. We excluded from the data taxa that were not identified to the species level.

To quantify vegetation cover in the areas of the 19 plots, we used the forest cover map of the Catimbau National Park from 2017, generated from images available on the collaborative platform of the Annual Mapping Project for Land Use and Cover in Brazil (MapBiomas Project, 2020). These maps are produced from the classification of the reflectance bands, spectral, temporal, and texture indices by the Landsat satellites (with 30 m of spatial resolution). Subsequently, we calculated the total forest cover in a 1 km buffer from the center of the plots, using the QGIS 3.6.0 program (QGIS Development Team, 2020).

2.5 Data analysis

To meet our first objective of assessing variation between socioeconomic factors in the region, we tested whether there are differences in the proportion of men and women between the three classes of schooling, using a chi-square test. To test whether there are differences in the age range between people with different levels of education, we applied the Kruskal–Wallis test. Both analyses were performed with a sample of 81 people. To test the additive effect of certain characteristics related to the households' profile (presence of retired individuals, presence of individuals with a non-farming occupation, number of residents and size of the goat herd) on the variation of income in households, we used a generalized linear model (GLM), with Gaussian error distribution. To better adjust the model, we transformed the household income data into a logarithmic scale. The sample size for this analysis was 68 households.

To test whether socioeconomic variables can explain the variation in knowledge on medicinal plants native to the region, we performed a GLM with Gaussian error distribution. To have a better adjustment of the model, we transformed the data of the number of native medicinal plants known) into square root + 1. The predictor variables were sex, education level, age, household income, number of residents, and occupation. The sample size for this analysis was 77 respondents.

To test whether socioeconomic variables could explain the variation in knowledge about native edible plants, we performed a GLM with Poisson error distribution. We used the same predictive variables as the model for medicinal plants. To test over-dispersion in the model, we applied the *dispersiontest* function of the *AER* package (Kleiber and Zeileis, 2008). The sample size for this analysis was 46 interviewees. This smaller sample size occurred because fewer people cited edible plants compared to medicinal plants.

To test whether household income and the number of residents in each household influence household demand for wood forest products (firewood and wood for building fences), we used GLM with Gaussian error distribution. To obtain a better fit of the models, we transformed the firewood usage data into square root + 1 (owing to the occurrence of some 0 values), and the wood usage data for building fences into log + 1. The sample size was 42 families for the model for firewood use, and 43 families for the model wood used for the building of fences. This smaller sample, if compared to the analyses referring to the determinants of household income, occurred because many of the interviewed household heads did not want to participate in the research phase relative to the use of wood products.

To test whether the vegetation cover affects the richness of useful species in the landscape, we performed mixed regressions using the *lme* function of the *nlme* package (Pinheiro et al., 2020), since this analysis allows defining variables with random and fixed effects within a model. In our study, we considered the species richness in the plots as a random variable. We carried out this analysis considering four different response variables: the total number of useful species, and the number of species useful for firewood, building fences, and for medicinal purposes. We transformed the data on species richness used as firewood and for building fences into a logarithmic scale to meet the assumption of normality of the model residues. Since few edible species were mentioned, we chose not to carry out analysis for this use.

For analyzes regarding knowledge about medicinal and food plants, we excluded data from species cited by less than three people, to exclude idiosyncratic information. In all analyses of generalized linear models, we selected the best model using the *MuMIn* package (Barton, 2019). Also, we access collinearity between the predictive variables of the models by the values of the variance inflation factor (VIF). In all models, the VIF values were < 5, indicating that there is no collinearity between the variables studied. We performed all analyzes in the R environment (R Core Team, 2020).

3 Results

3.1 Socioeconomic profile and livelihood strategies of the communities studied

Of the 81 people from whom we collected socioeconomic data, encompassing the six communities studied, 50.61% were women and 49.38% were men. The average age is 44.15 years (SD ± 16.95), and the average number of residents is 4.41 (SD ± 2.55). Regarding schooling, 48.15% had no access to formal education, 41.97% studied until the elementary school level, and 9.87% studied at least until the beginning of high school. There are no differences in the level of education in relation to sex ($\chi^2 = 4.62$; $p = 0.09$; df = 2). However, there are differences in the age range among people with different education levels

($\chi^2 = 33.56$; $p = 5.14e{-}08$; df = 2), since older people did not have access to formal education, although this scenario has changed in recent decades, with men and women having greater access to formal education.

Regarding occupation, 71.60% of respondents work in farming activities, 17.28% are engaged in domestic activities, and 11.11% work in non-farming activities. However, there are limitations in this categorization since the limits of these categories are not clear. For example, some women are engaged in both domestic activities and agriculture, and people who have non-farming activities may have small goat herds (this was determined through personal observations).

Some individuals from one of the communities that were studied (Igrejinha) have handcrafting as their main occupation and produce works of art from the trunks of the *Commiphora leptophloeos* tree (Mart.) J. B. Gillett. This kind of work generates irregular income, but some of these artisans have gained popularity nationwide, having their pieces exhibited at craft fairs, museums, and even in Brazilian soap operas. These artisans work in consortium with individuals who are reported to only use dead wood collected from the *C. leptophloeos* tree and report using only dead wood. However, this species has low densities in the local landscape (always less than 100 ind/ha).

The average household income is R$ 676.57 (US$ 206.27 in 2017 values), with a standard deviation of R$ 530.54 (US$ 161.75). The average per capita income is R$ 246.58 (US$ 75.18), with a standard deviation of R$ 305.63 (US$ 93.18). Therefore, 67.65% of local families live below the poverty line (with less than US$ 1.9 per person per day). In addition, based on the value of the basic food basket in the municipality of Recife (capital of Pernambuco), in December 2017 (R$ 332.15 or US$ 101.26), 29.41% of families were unable to buy one basic food basket. Our final model regarding the characteristics of families that influence household income shows that most of the variation in household income is due to the presence of retired individuals and individuals with non-farming occupations (AIC = 91.15; adjusted $R^2 = 0.64$; df = 65; $p = 1.83e{-}15$) (see Table 1). The number of residents and the size of goat herds do not influence household income. Despite that, farming practices can be important for food security. Some ranchers reported that they commercialize their herds in times of financial difficulties, using them as an emergency resource.

3.2 Effects of socioeconomic factors on knowledge and the use of forest products

The repertoire of native medicinal plants known to people in the communities studied is composed of 44 species. The most cited species are *Ximenia americana* L. (57.14% of respondents), *Sideroxylon obtusifolium* (Roem. & Schult.) T.D. Penn. (45.45%), *Pombalia arenaria* (Ule) Paula-Souza (36.36%), *Hymenaea courbaril* L. (36.36%), *Dysphania ambrosioides* (L.) Mosyakin & Clemants (35.06%) and *Myracrodruon urundeuva* Allemão

Table 1 Final model results to test the effects of household characteristics on the variation in household income

Independent variables	Estimate	SE	*t* value	*p* value
Intercept	5.83	0.07	87.03	< 2e−16
Families with a member in non-farming occupations	0.46	0.18	2.52	0.01*
Families with retired individuals	1.33	0.12	10.60	8.27e−16*

(35.06%) (see Supplementary material). These species (with the exception of *D. ambrosioides*, which is grown in gardens and backyards, and *P. arenaria*, which is herbaceous) appear to be rare in the studied landscape as they were not found in samplings from the vegetation. Our final model on the effects of socioeconomic variables on the knowledge of native medicinal plants demonstrated that age and sex explain approximately 1/3 of the variation in knowledge (AIC = 175.47; $R^2 = 0.30$; $p = 2.18e{-}06$) (Table 2).

Regarding the native edible plants, the repertoire known to people in the region consists of 12 species, of which the most cited are *Spondias tuberosa* Arruda (58.69% of respondents who cited food plants), Camboim (unidentified, 54.35%), and *Syagrus coronata* (Mart.) Bec (34.78%). The final model on the effect of socioeconomic variables on the knowledge of food plants indicates that people from families with lower income have the most knowledge (AIC = 205.93; Table 2). Moreover, men and individuals from smaller families likely have greater knowledge about edible plants, although these findings were above the significance threshold.

Concerning the use of wood forest products, we identified 62 used species in the six communities studied; 31 species used for firewood and 59 species used for building fences. The species most used for firewood are *Poincianella microphylla* (Mart. Ex G. Don) L.P. Queiroz, *Senegalia piauhiensis* (Benth.) Seigler & Ebinger and *Pityrocarpa moniliformis* (Benth.) Luckow & R.W. Jobson. The species most used for fences construction are *S. piauhiensis*, *Senegalia bahiensis* (Benth.) Seigler & Ebinger, *Poeppigia procera* C. Presl and *Prosopis juliflora* (Sw.) DC. In addition, we have found some of the important medicinal species in the survey for wood, such as *X. americana*, *M. urundeuva* and *C. leptophloeos*, which may raise concerns for their populations.

We observed that the household income and the number of residents in each household did not influence the demand for firewood (AIC = 113.44; adjusted $R^2 = -0.003$; $p = 0.36$; df = 40) nor for wood used for fence construction (AIC = 124.70; adjusted $R^2 = -0.01$; $p = 0.58$; df = 41) (see Table 2 for a description of the final models). After analyzing these findings, we wondered whether the *per capita* income would be the reason for the demand for these resources. Likewise, we found no effect of the *per capita* income on the

Table 2 Results of the final models referring to the effect of socioeconomic variables on the knowledge of native medicinal and edible plants, and on household demand for wood products, in six rural communities in the National Park of Catimbau, Northeast Brazil

	Estimate	SE	*t* value	*p* value
Number of medicinal plants known				
Intercept	2.18	0.26	8.33	3.09e−12
Age	0.02	0.005	3.93	0.0002*
Sex-women	− 0.55	0.17	− 3.23	0.002*
Number of edible plants known				
Intercept	2.16	0.18	12.04	< 2e−16
Household income	− 0.0004	0.0001	− 2.72	0.006*
Number of residents	− 0.05	0.02	− 1.90	0.06
Sex-women	− 0.24	0.13	− 1.82	0.07
Firewood use				
Intercept	2.95	0.25	11.89	1.05e−14
Household income	− 0.00022	0.00024	− 0.93	0.36
Wood use for building fences				
Intercept	1.54	0.31	4.89	1.59e−05
Number of residents	0.035	0.06	0.56	0.58

demand for firewood (adjusted $R^2 = -0.01$; $t = -0.76$; $p = 0.45$) and for fence construction (adjusted $R^2 = -0.02$; $t = -0.16$; $p = 0.87$). Considering only households that use firewood, the average biomass used per day is 7.94 kg (SD ± 5.06). And considering only households with fences, the average volume of wood used is 8.31 m^3 (SD ± 10.17).

3.3 Effect of the vegetation cover on the richness of useful species in the landscape

We found no effect of the vegetation cover (our proxy for conservation level) on the richness of useful species in general (AIC = 98.03; $t = 0.47$; $p = 0.65$), nor in the other uses, such as firewood (AIC = 28.21; $t = 1.80$; $p = 0.12$), building fences (AIC = 19.68; $t = 0.79$; $p = 0.45$), and medicinal (AIC = 78.15; $t = 0.55$; $p = 0.60$). Therefore, our findings indicate that there are a similar number of useful species in areas that present different conservation levels.

4 Discussion

4.1 A region of low socioeconomic dynamism and high dependence on welfare

Our findings demonstrate that the farming activities performed by the majority of the people in the communities surveyed seem to have a minor contribution to the income generation of households since the families with the highest income have retired individuals or individuals with a non-farming occupation. Due to these low incomes, most of these families are assisted by federal welfare programs, such as the "Bolsa Família Program," and are supported by non-governmental organizations. As we have already explained, some researchers see these assistance programs as a new form of clientelism (Bedran-Martins and Lemos, 2017; Bursztyn and Chacon, 2011). In our understanding, these forms of assistance are important because they contribute to the food security of families in the region.

These governmental cash transfer programs are found to be effective in reducing poverty and extreme poverty in Brazil (Campoli et al., 2020). Studies carried out in the Brazilian semiarid region show that these programs may have contributed to an improvement in material aspects of the quality of life (income, education level, and access to health services), although they are not sufficient to reduce the socioeconomic vulnerability of small farmers (Bedran-Martins and Lemos, 2017; Bedran-Martins et al., 2018). During drought events, small farmers in semiarid regions lose their production and need to spend more on food and water, which may force them into debt (Bedran-Martins et al., 2018). This can push them back to the condition of extreme poverty, resulting in a phenomenon named poverty trap (Maru et al., 2012; see also Specht et al., 2019).

According to poverty trap models, there are socioeconomic thresholds that need to be crossed in for families to overcome poverty (Naschold, 2012). In the long run, some of the factors that contribute to overcoming these thresholds are the right to land tenure (which is usually a prerequisite for granting bank credits or access to crop insurance), the increase in the level of education, the formation of cooperatives, and the diversification of activities that generate income (Naschold, 2012). Therefore, although assistance programs are important, it is essential to fight not only the symptoms of socioeconomic vulnerabilities but also their structural causes (Nelson and Finan, 2009). It is necessary that the old (and still current) ways of making policies be replaced by participatory management, investments in infrastructure, and investment in human capital, generating diversification of economic activities (Nelson and Finan, 2009). Specht et al. (2019) stated, considering our area of study as a starting point for reflection, "that the future of dry forests, characterized worldwide by the presence of low-income populations, will be largely dependent on conservation strategies that address poverty alleviation and human well-being".

We propose that the local handicrafts produced from the timber of *C. leptophloeos* may be an unsustainable activity from an economic perspective since this activity focuses on the use of a single species that has low density in the region (see Rito et al., 2017). Therefore, we strongly recommend recovery (or increase) strategies to be implemented to increase the abundance of this species. A more efficient alternative would probably be to plant with techniques that guarantee faster growth, such as layering or grafting.

To our understanding, the designation of an environmentally protected area in a region with this socioeconomic profile may have two kinds of consequences, depending on the direction of the management applied in the area. In the first scenario, people can be compensated and evicted from their properties and forced to abandon the landscape with which they have emotional and historical ties. They would have to attempt living for subsistence in an unfamiliar manner. In this scenario, the flora and fauna could recover without direct human interference.

In the second scenario, the park could be recategorized for a type of designation that allows the maintenance of families and the sustainable use of natural resources. In this case, the management plan for the conservation area needs to be prepared not only from an environmental perspective but also from a political and social perspective (e.g., Albuquerque et al., 2019, 2021). It is necessary that political managers, together with the local populations, think about alternatives for income generation and means of subsistence that are compatible with the conservation of local biodiversity. For example, the study area has great potential for socio-environmental tourism, which is under-explored, due to the lack of infrastructure and social organization.

4.2 Men as the holders of knowledge about native medicinal plants

Most of the socioeconomic variables that we assessed did not affect knowledge about native medicinal plants, except for sex and age. Most of the ethnobotanical literature shows that variables such as income (de Almeida et al., 2010; Karunamoorthi and Tsehaye, 2012), occupation (da Silva et al., 2011; Pérez-Nicolás et al., 2017), and education (Quinlan and Quinlan, 2007; Srithi et al., 2009) affect the number of plants known for medicinal use. The effect of socioeconomic variables may also vary in relation to the type of use to which a species is subjected, as well as its general use, as occurs in the use of palm trees (Paniagua-Zambrana et al., 2014). Moreover, as different studies use different methods of data collection, the interpretation of the results on the effect of socioeconomic variables should consider these different aspects (e.g., Zambrana et al., 2018).

In general, these factors imply some abandonment degree or a decrease in traditional knowledge, since people with higher education levels, non-farming occupations, or higher income would have less dependence on natural resources (Hegde and Enters, 2000; Lacuna-Richman, 2002). However, in the studied scenario, although there are differences in people's socioeconomic profiles, these differences probably do not imply lower dependence on natural resources. For example, although there are many retired individuals in our sample, these people may have higher health care expenses (e.g., Rowland and Lyons, 1996), and might be more frequent targets of financial scams and abuse (e.g., Tueth, 2000), a situation that we have seen in some families (personal observation).

The effect of gender on knowledge about medicinal plants has been studied for a long time in ethnobiological literature, and a recent study indicates that its effect varies at different scales (Torres-Avilez et al., 2016). These authors demonstrated that, globally, there is no difference in knowledge about medicinal plants between men and women. However, on a continental and national scale, the differences become clear. In Brazil, for example, there is evidence that women have more knowledge about medicinal plants than men (Torres-Avilez et al., 2016). These differences in regional scales are probably associated with differences in social roles and the division of tasks between genders (Torres-Avilez et al., 2016), since in rural communities in northeastern Brazil, women are normally responsible for primary family health care (Vidal, 2013; Voeks, 2007).

However, our findings showed that men have more knowledge (cited plants) than women. It is possible that this finding is associated with our scope since we focus only on native species. It is possible that men are more knowledgeable about native medicinal plants because they usually access forest areas more than women (Caniago and Stephen, 1998). Another explanation refers to the difficulty in collecting some plants, since several of the important medicinal species appear to be rare locally. Thus, although women play the role of family health care providers, men seem to be responsible for collecting these resources.

Finally, greater knowledge about medicinal plants among older individuals is common in the ethnobotanical literature (da Silva et al., 2019; Doyle et al., 2017). This is related to the process of cultural transmission of knowledge. Usually, people learn about medicinal plants from their parents or other older individuals in general, such as in-laws or grandparents (Soldati et al., 2015). In any case, these differences in knowledge related to gender or age may have little implications in terms of local dependence on natural resources. Therefore, families in the studied region seem to be equally dependent on medicinal plants for health care.

4.3 Household members with lower income have more knowledge about native edible plants

In the Brazilian semiarid region, the consumption of some native edible plants has historically been associated with times of great drought. In these situations, part of the local population resorted to these foods to supply their nutritional needs (do Nascimento, 2012, 2013). Some of these plants, in particular legumes, need to undergo laborious processes to eliminate toxic compounds, so that they can be eaten (do Nascimento et al., 2012). Thus, by referring to these times of great poverty, in some locates, there is currently a social stigma regarding the consumption of native edible plants, which has led to a decline in consumption (Cruz et al., 2013, 2014).

Moreover, since the introduction of the "Bolsa Família Program," the eating habits of families in the Brazilian semiarid region have changed. An increase in the consumption of ultra-processed foods (canned goods, sausage, instant noodles) and foods rich in refined carbohydrates (sweets, bread, cake, pasta, chocolate, yogurt) has been observed to result in childhood obesity, which is a new problem in the region (Pires and Jardim, 2014; Saldiva et al., 2010). Our findings may be explained by the possibility that only very low-income people still have a degree of dependence on native edible plants and, therefore, have more knowledge about these resources.

4.4 Household income and size do not affect demand for wood forest products

In contrast to the literature on the use of wood forest products for subsistence purposes (Arabatzis and Malesios, 2011; Brouwer and Falcão, 2004; de Arruda et al., 2019; Hernández-Garduño et al., 2017; Jin et al., 2019; Kim et al., 2017; Marufu et al., 1997; Moeen et al., 2016; Ramos et al., 2015), we found no effect of income and household size on the use of these resources. These findings could probably also be explained by the proposition that the variation found locally in socioeconomic factors is not sufficient to result in less dependence on natural resources.

It is possible that the households of the communities studied are devising different strategies to ensure their subsistence. For example, some of the households with incomes starting at R$ 500.00 (USD 95.00) have abandoned or reduced the use of firewood, while others make greater use of it. Thus, our findings seem to corroborate the hypothesis of de Medeiros et al. (2012) that the relationship between socioeconomic factors and the demand for wood is affected by the different choices that households make to save money. Some low-income households may decrease their firewood use but increase the wood they use for construction (for example, see Medeiros et al., 2012). We also emphasize that, in recent years, the price of cooking gas has increased considerably in Brazil, resulting in an increase in the percentage of households that use firewood throughout the country (IBGE—Brazilian Institute of Geography and Statistics, 2018). Furthermore, since the communities studied are far from an urban center, the use of cooking gas is even less accessible because it requires paying for transportation to the community.

4.5 The most conserved areas have no greater richness of useful species

Our proxy for the conservation level in the forest areas (the vegetation cover), did not affect the richness of useful species in the landscape. Thus, our findings demonstrate that if we consider areas with similar species richness, the variation in vegetation cover does not affect the number of useful species. In the study area, vegetation cover is weakly associated with the total density of trees, but it has no effect on the total biomass of the vegetation on the species' composition (Rito et al., 2017). Thus, it is likely that what remains under the label of vegetation cover may be a variation in the total density of the vegetation dominated by few species.

There is some evidence that the collection of wood resources (one of the most detrimental extractivist practices) has a low effect on the abundance of dominant species in the Caatinga, which have regrowth mechanisms that enable their populations to recover (Sampaio et al., 1998; Milliken et al., 2018). Thus, it is possible that the areas with the highest vegetation cover are dominated by the same species, but with greater absolute densities, as found in our study area (Rito et al., 2017).

5 Final considerations

Our findings show that socioeconomic factors have little impact on knowledge and demand for forest products in a protected area in the Brazilian semiarid region. In particular, increasing income does not reduce people's dependence on natural resources. It is, therefore important to reconsider strategies for designating protected areas in semiarid regions with a history of human occupation. The historical low socioeconomic dynamism of families living in these regions can result in socio-environmental conflicts, as people need to use resources, and may feel uncomfortable in an illegal situation. In addition, the ban on the use of resources and subsistence practices (agriculture and livestock) may further accentuate the socio-economic vulnerability of people, who often may not be able to get jobs in urban areas. Therefore, we suggest that planning conservation strategies in semi-arid regions should be done with three axes in mind: strategies that allow people to deal with the droughts, the conservation of biodiversity, and the generation of income for local populations.

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Availability of data and materials All the data are available in supplementary material.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethics statement The study was carried out in accordance with the recommendations of the resolution number 510 of the National Health Council. All the respondents gave informed consent for the anonymous use of the data gathered for research purposes.

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