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Can the traditional use of native plant species in rural communities in the Brazilian semi-arid region be affected by global warming?

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ABSTRACT

Extreme climate change events are capable of modifying the physiognomy of landscapes, impacting millions of people around the world. Consequently, the traditional knowledge of people residing in these regions about local natural resources may also be affected. To identify how the traditional use of native plant species can be influenced by a change in the availability of these species in a rural community in a semi-arid region, in a scenario of climatic extremes, we developed a Pressure Indicator for Use Preference (PIUP), seeking to identify the species under the greatest pressure of use. The study was carried out in the São Francisco Rural Community, in the Cabaceiras Municipality, in the semi-arid region of the Paraíba State, with 42 local informants. The species with the highest PIUP had their potential distribution for the year 2050 modeled using the HadGEM2-ES climate model under the RCP4.5 scenario, as an optimistic forecast, and the RCP8.5 scenario, as a pessimistic forecast. The construction of the models identified a potential increase in the coverage area of all analyzed species, with a greater territorial extension for the RCP8.5 scenario. *Myracrodoun urundeuva* M. Allemão, *Mimosa tenuiflora* (Willd.) Poir. and *Croton blanchetianus* Baill were the species with the lowest potential area growth for the year 2050. The high use of species, especially *M. urundeuva* M. Allemão, associated with reduced growth in a more arid environment is a worrying factor for the population structure of the species, as well as for rural communities that make representative use of the species.

Keywords: Local ecological knowledge, Native vegetation, Semiarid regions, Extreme weather variations, Species distribution modeling.

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SIGNIFICANCE STATEMENT

To understand how climate change events will affect the traditional use of native plants in the semi-arid region of northeastern Brazil, we developed an unprecedented index, the Pressure Indicator for Use Preference (PIUP), considering the usage characteristics indicated by the informants, the frequency of collection and the allocation of species into use categories. For species with the highest PIUP detected, we made modeling with potential distribution for the year 2050 using the HadGEM2-ES climate model under the RCP4.5 and RCP8.5 scenarios. We documented that: 1) There is a potential increase in the coverage area of all analyzed species; 2) *Myracrodoun urundeuva* M. Allemão, *Mimosa tenuiflora* (Willd.) Poir. and *Croton blanchetianus* Baill were the species with the lowest potential area growth for the year 2050; and 3) The high use of these species associated with reduced growth in a more arid environment is a concerning factor for the population structure and the persistence of these species.

INTRODUCTION

Traditional ecological knowledge (TEK) is defined as the relationship among knowledge, practices, beliefs and ethical values of different human groups and the ecosystem in which they are inserted (Berkes et al. 2000; Berkes and Turner 2006; Hunn 2007). The dynamism of TEK evolves on a temporal scale, that is, throughout people's life experience, which is transmitted over generations (Berkes and Turner 2006), in addition to reflecting the relationships of ownership and belonging developed by people (Ji et al. 2000). Several researchers and public policy makers increasingly recognize that TEK is a fundamental element not only for directing the sustainable use and management of species, habitats and ecosystems, but also for diverse aspects of human well-being (Pardo-de-Santayana and Macía 2015).

In the semi-arid region of Northeast Brazil, many studies have already investigated the knowledge of local farmers about different uses of plants, such as medicinal (e.g., Cartaxo et al. 2010; Coutinho et al. 2015; Zank et al. 2015; Reinaldo et al. 2020; Silva et al. 2020; Vandesmet et al. 2020; Ferreira et al. 2021) and fuel (e.g., Ramos et al. 2008a, b; Ramos and Albuquerque 2012; Lima et al. 2016a; Hora et al. 2021). Regarding native species, research has shown the use of products derived from native vegetation and the way in which these uses significantly contribute to maintaining the quality of life of people in this region (e.g., Lucena et al. 2007a, b).

According to the Ecological Apparency Hypothesis, for example, there is a relationship among uses of native species by human populations and the availability of these resources in their communities, as several studies have shown (e.g., Mutchnick and McCarthy 1997; Galeano 2000; La Torre-Cuadros and Islebe 2003; Lawrence et al. 2005; Cunha and Albuquerque 2006; Thomas et al. 2009; Jiménez-Escobar and Rangel-Ch 2012). In other words, the species most collected and used by people are typically those that are easiest to find in vegetation. This hypothesis was originally proposed by ecologists in order to explain the relationships among herbivorous animals and plants, in which large herbaceous and woody plants (the most visible ones) are more easily found and, therefore, more consumed (Feeny 1976; Rhoades and Cates 1976). Subsequently, in order to understand the dynamics of the use of natural resources by human populations, Phillips and Gentry (1993a, b), in two studies carried out with an indigenous population in the Peruvian Amazon, adapted this hypothesis to the field of ethnobotany, starting from the premise that people would have a pattern of behavior similar to that of herbivores, considering the search for plant resources in forest environments. However, studies carried out in seasonally dry tropical forests, such as the Caatinga, predominant in the semi-arid regions of Northeast Brazil (Silva et al. 2017), showed different results, showing that the pattern of use of plant resources in this environmental context may not follow fully the assumptions of the Ecological Apparency Hypothesis (e.g, Albuquerque et al. 2005; Guerra et al. 2012; Lucena et al. 2007a, 2007b, 2012; Ribeiro et al. 2014a, 2014b; Silva and Albuquerque 2005).

A logical necessity for the continuous use of a certain species in a rural community is its availability in an amount that equals or exceeds the demand for the resource intrinsic to each use or category of use, as reported by Lima et al. (2015), when evaluating the amount of native wood used in the construction of fences in a rural community. This availability, in turn, can be influenced by extreme weather events, phenomena capable of transforming a natural landscape (Collins et al. 2013), which can have serious consequences for cultural community livelihood strategies, especially those linked to the environment in a more basal way, such as collection and subsistence agriculture. These activities reveal significant vulnerability of some ecosystems and human systems to current climate change (Field et al. 2014).

The semi-arid region of Brazil is included in a climate characterization that can be compared to other dry regions on Planet Earth, for which temperature increases, dry periods and reduced precipitation are expected (Doblas-Reyes et al. 2021; Lee et al. 2021;

Marengo et al. 2020; Seneviratne et al. 2021). According to the publication of Working Group I for the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), a 1.5°C increase in global average temperature by the 2030s would imply warmer summer days with temperatures up to 3°C above current maximums in much of the Brazilian territory and, in the particular case of semi-arid regions, would cause a significant increase in the number of days with temperatures above 40°C (Doblas-Reyes et al. 2021; Lee et al. 2021). These changes are already perceived by local populations, who identify climate change and the way it has affected their daily activities, especially for communities that depend on the resources offered by forests for family sustenance, such as subsistence agriculture (Barkmann et al. 2017).

Scientific evidence shows that the severity of a drought largely depends on the vulnerability of the socio-ecological system to risks arising from the climatic phenomenon, which, in turn, is related to factors such as vegetation composition, human activities and water supply. In short, droughts occurring in the same region may have different effects, even if similar in terms of intensity, duration and spatial scales (Cunha et al. 2019; Dai 2011). In the case of Northeast Brazil, the semiarid region concentrates the largest proportion of people living in poverty in the country, with many of them having subsistence agriculture as their main source of income (Campoli et al. 2020; Dantas et al. 2020). Thus, more frequent and severe droughts will inevitably imply increasing global economic and social losses, such as food, water and energy insecurity, since agriculture and the economies of arid and semi-arid regions are highly sensitive to climate variability (Dantas et al. 2020; Marengo et al. 2020; Ringler et al. 2008; Sivakumar et al. 2005; Trenberth 2011). In short, far beyond being a climatic phenomenon, extreme droughts have socioeconomic implications, capable of shaping culture, environment, politics and social structure, contributing to a reduced quality of living conditions of small producers (Finan and Nelson 2001; Lemos et al. 2002; Marengo 2009; Marengo et al. 2019, 2020, 2018).

Through the Species Distribution Model (SDM), it is possible to generate predictive maps that represent the distribution potential of one or more species in a given area, based on occurrence and/or abundance data, considering climatic variables as driving elements (Austin 2007; Davis et al. 2012; Elith and Leathwick 2009). In this sense, the Maximum Entropy (Maxent) modeling algorithm has been widely used to develop ecological niche models based on the evaluated environmental dimensions (Phillips et al. 2006, 2004). Maxent has been successfully used both for modeling the distribution of rare species (e.g., Qin et al. 2017), and those whose distribution is wider worldwide (e.g., Davis et al. 2012).

In this study, we seek to identify how the traditional use of native plant species can be influenced by a change in the availability of these species in a rural community in a semi-arid region, in a scenario of climatic extremes. To this end, we propose an index to identify the possible pressure that the preference for the use of certain native plant species used in a rural community in the Brazilian semiarid region. We then relate its result to the modeling of the current and future distribution of the main species used, through the Maxent algorithm.

MATERIAL AND METHODS

Study area

In the São Francisco Rural Community, located in the Cabaceiras Municipality, Paraíba State (coordinates 7°36'04.86"s and 36°26'17.48"w) (Figure 1), there are approximately 70 families distributed in sites equidistant to 1 km. (Arévalo-Marín et al. 2015). The municipality has an estimated population of 5,035 inhabitants, of which 55.6% live in rural areas, with a population density of 11.12 inhabitants per km2, according to data from the latest census carried out by the Brazilian Institute of Geography and Statistics (IBGE 2010). The local economy went from an economy solely based on subsistence agriculture (small corn, beans and animal husbandry plantations) to an income dependent on government benefits, such as old-age pensions and/or family allowances. (Lima et al. 2015, 2016b; Silva et al. 2014a).

According to the Koppen's classification, the climate of the region is semi-arid and hot (BSh), which is characterized by an average annual precipitation of 356 mm with irregular rainfall, concentrated in short periods, which makes the temperatures high throughout the year (Alvares et al. 2013; Santos et al. 2019). It is the driest region in Brazil (Alves et al. 2009), whose characteristics can be compared to other threatened regions of the planet by the effects of climate change (Collins et al. 2013). It is, therefore, an excellent scenario for our study.

Ethnobotanical data collection

The ethnobotanical data used in this study were obtained from semi-structured interviews (Albuquerque et al. 2014) applied individually to the heads of households, that is, people over 18 years of age (of both biological genders) who declared themselves responsible for the household income of each household visited. The visits took place from August 2016 to June 2017. Out of a total of 70 families (households

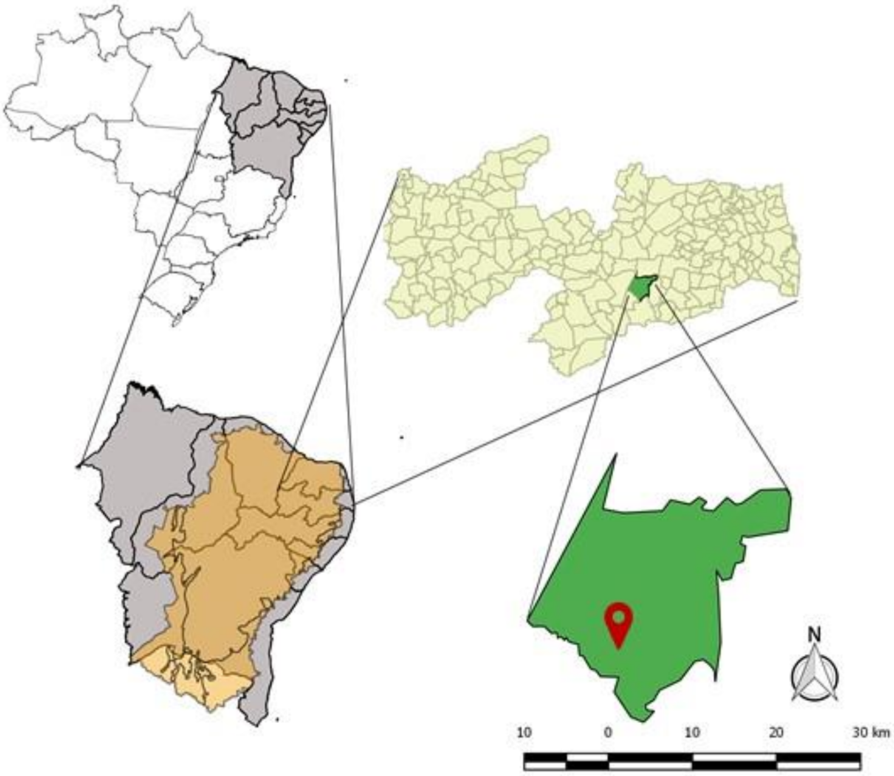

Figura 1. Map indicating the location of the São Francisco Community. a) Brazil, b) Northeast Brazil with emphasis on the semi-arid region, c) Paraíba State and d) Cabaceiras Municipality, with the Rural Community São Francisco location.

inhabited in the community), 42 heads of families proposed to participate in the research. Thus, informants who, after explaining the purpose of the research, chose not to participate or were not found in their homes after three attempts to visit were automatically excluded from the sample.

The interviews aimed to know the plant species most used by each family, allowing the identification of the use and frequency with which the species are used locally. In this study, we focused on woody plant species, such as shrubs and trees, as we understand that these are the life forms most susceptible to pressures of use (e.g., Albuquerque et al. 2005).

The research was approved by the Ethics Committee for Research with Human Beings (CEP) of the Lauro Wanderley Hospital of the Federal University of Paraíba (CEP/HULW nº 297/11). All informants were previously informed about the research objectives and those who agreed to participate in this research signed the Free and Informed Consent Term, according to the National Health Council (Resolution No. 466/2012).

Pressure Index by Use Preference (PIUP) of the species

In order to assess the pressure of use of each useful plant species mentioned by the heads of households, we proposed an index, the Pressure Index by Use Preference (PIUP), which considers: a) the characteristics of use indicated by the informants; b) the frequency of collection; and c) the allocation of species into use categories. Thus, the index has the character of evaluating traditional ecological knowledge about plant species used for different purposes by human communities and, quantifying (1) the frequency of collection of each species, for each type of use (considering whether the extraction was weekly, monthly , sporadic or annual), taking into account the highest citation of registered use; (2) the type of human pressure that each use brought to the plant species (for example, if the extraction was total, partial, removal of branches and/or if the use was only of reproductive parts of the plant); (3) the number of people using each species and (4) total categories of use by species. The composition of reference values for non-numeric variables (frequency of collection and type of damage) was made by replacing values present within

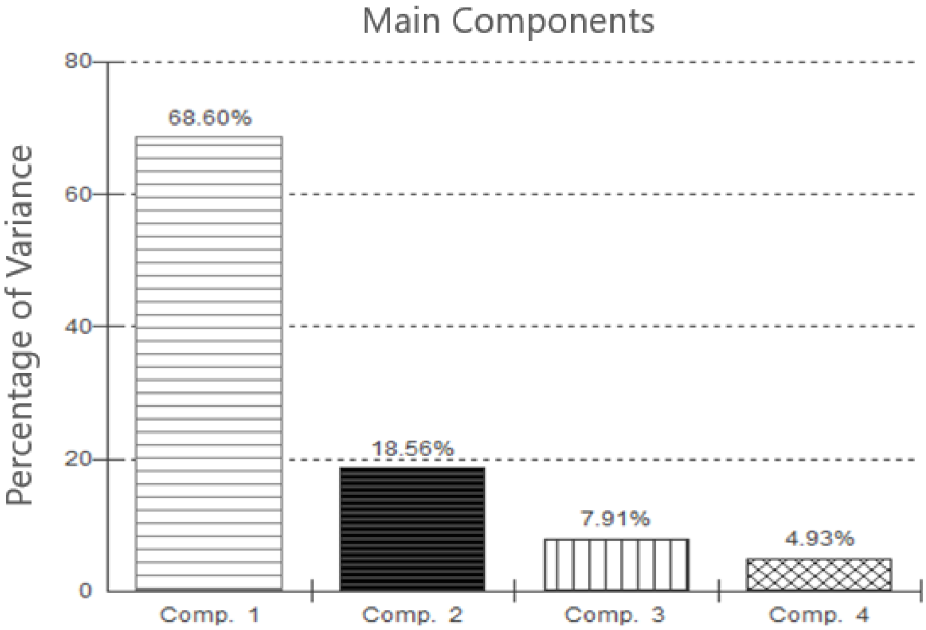

Figura 2. Percentage of variance of the main components evaluated to define the PIUP of plant species for the São Francisco Community, Cabaceiras Municipality, Paraíba State, Brazil.

a numerical ranking for the variables, with higher values being attributed to higher frequency and total damage, decreasing from 4 to 1. Thus, the highest recorded damage, which corresponds to the complete destruction of the plant, was assigned a score 4. On the other hand, the least severe damage, where only a small limited amount of a plant part (such as flowers or fruits, for example) was extracted, was assigned a score 1. Intermediate scores were assigned as follows: a score 3 represents collections that don't completely destroy the individual at the time of collection, but still pose a risk in the medium and/or long term (for example, collecting cascades that gradually lead to the plant's death). Score 2 represents collections that partially harm the individual, such as cutting parts of them or harvesting the entire seed and fruit bank, which hinders their development.

The choice of variables was guided by the assumption that a species suffers greater pressure when, for the main type of use cited for the plant, there is a need for total extraction of the individual. This pressure is heightened when we relate it to the frequency with which the plant is used locally and to the fact that it is used for multiple purposes. Thus, for the elaboration of the PIUP, we chose to relate the uses mentioned by the informants so that there was no overlapping of variables, represented from the following equation:

$$PIUP = a_1x_1 + a_2x_{2n} + ... + a_kx_{kn}$$

$$PIUP = \sum_{i=1}^{K} ?a_1x_?$$

Where: $x?$ is the value of the i-th variable observed for the n-th object ai is the weight of the i-th variable, the importance of each variable in the construction of the index, obtained in the Principal Component Analysis (PCA).

The weighting of variables was carried out as indicated by Kubrusly (2001), who uses the PCA model used in its classic form, so that each principal component is used as a weight in an index represented by the sum of the variables. After performing the PCA for the variables observed in the community, we obtained the following weights (ai) present in the principal components graph in Figure 2.

The weighting of the index components, using the PCA results, gave rise to the following formula:

PIUP = (Damage x 0.686 + Frequency x 0.185 + Number of users x 0.079 + Categories x 0.049) / 100

The analysis results in a classification of plant species according to human pressure, that is, frequency of local use. This choice was made even with knowledge of the theory proposed by Phillips and Gentry (1993a, b), and tested by Lucena et al. (2007b), Guerra et al. (2012) and Lima et al. (2016), among others, who propose a direct relationship between use and availability of resources in the vicinity of the community.

Species distribution

The identification of locally cited species was performed based on information from virtual herbaria, using the Species link data (Species Link 2018). The use of herbarium data to evaluate the distribution and abundance of species has already been tested, with successful results that support the repetition of the methodology (Buerki et al. 2015; Davis et al. 2012; Hart et al. 2014). Points of the community where the species were found were also included in the modeling.

Environmental variables

To reduce the multicollinearity among the 19 bioclimatic variables evaluated, those that had high correlation were eliminated from the analysis using Pearson's Correlation Coefficient r0.85 (Graham 2003). Among the pre-selected variables, 10 of them were included in the explanatory model applied to the seven most cited species locally (see Figure 3 and Table 1). However, among the cited species, the number of variables used varied from one use citation for *Myracrodruon urundeuva* M. Allemão and *Spondias tuberosa* Arruda to seven for the species *Sideroxylon obtusifolium* (Humb. ex Roem. & Schult.) T.D.Penn. The variables included diurnal average temperature range (Bio 2), temperature seasonality (Bio 4), maximum temperature of the hottest month (Bio 5), minimum temperature of the coldest month (Bio 6), annual temperature range (Bio 7), average temperature of the warmest quarter (Bio 8), precipitation of the driest month (Bio 14), precipitation of the driest quarter (Bio 16), precipitation of the warmest quarter (Bio 18) and, precipitation of the coldest quarter (Bio 19).

Modeling the species distribution

The ecological niche predictive map was made using the Maxent algorithm, present in the biomod2 package of the R software (Thuiller et al. 2021, 2012), using the HadGEM2-ES climate model under the RCP 4.5 and RCP8.5 scenarios (Chou et al. 2005, 2012), scenarios of greenhouse gas emission levels proposed by the IPCC whose projections are optimistic and pessimistic, respectively (IPCC 2014). Maxent has been used for presenting the best responses among the available algorithms to assess species distribution from data from herbaria (Elith and Graham 2009; Mateo et al. 2010; VanDerWal et al. 2009). This class of ecological niche model makes use of a correlative model of environmental conditions that utilizes the environmental needs of each species and predicts the possibility of registering the species in a specific area (Warren and Seifert 2011). The Operator's Operational Characteristics (AUC) function was used to evaluate the performance of the model. The AUC is considered an important index because it provides a single measure of general precision that does not depend on a specific threshold, and its values can vary from 0 to 1, so that a model with a higher AUC value indicates its better performance (Fielding and Bell 1997). In this study, we used version 3.5.3 of the R software (R Development Core Team 2019).

The resulting data from the Maxent prediction models were exported to QGIS (version 2.18). We followed the classification proposed by Yang et al. (2013) who characterized the habitats in five potential suitability classes: unsuitable habitat (0 – 0.2), poorly suited (0.2 – 0.4), suitable habitat (0.4 – 0.6), very suitable habitat (0.6 – 0.8) and extremely adequate (0.8 – 1).

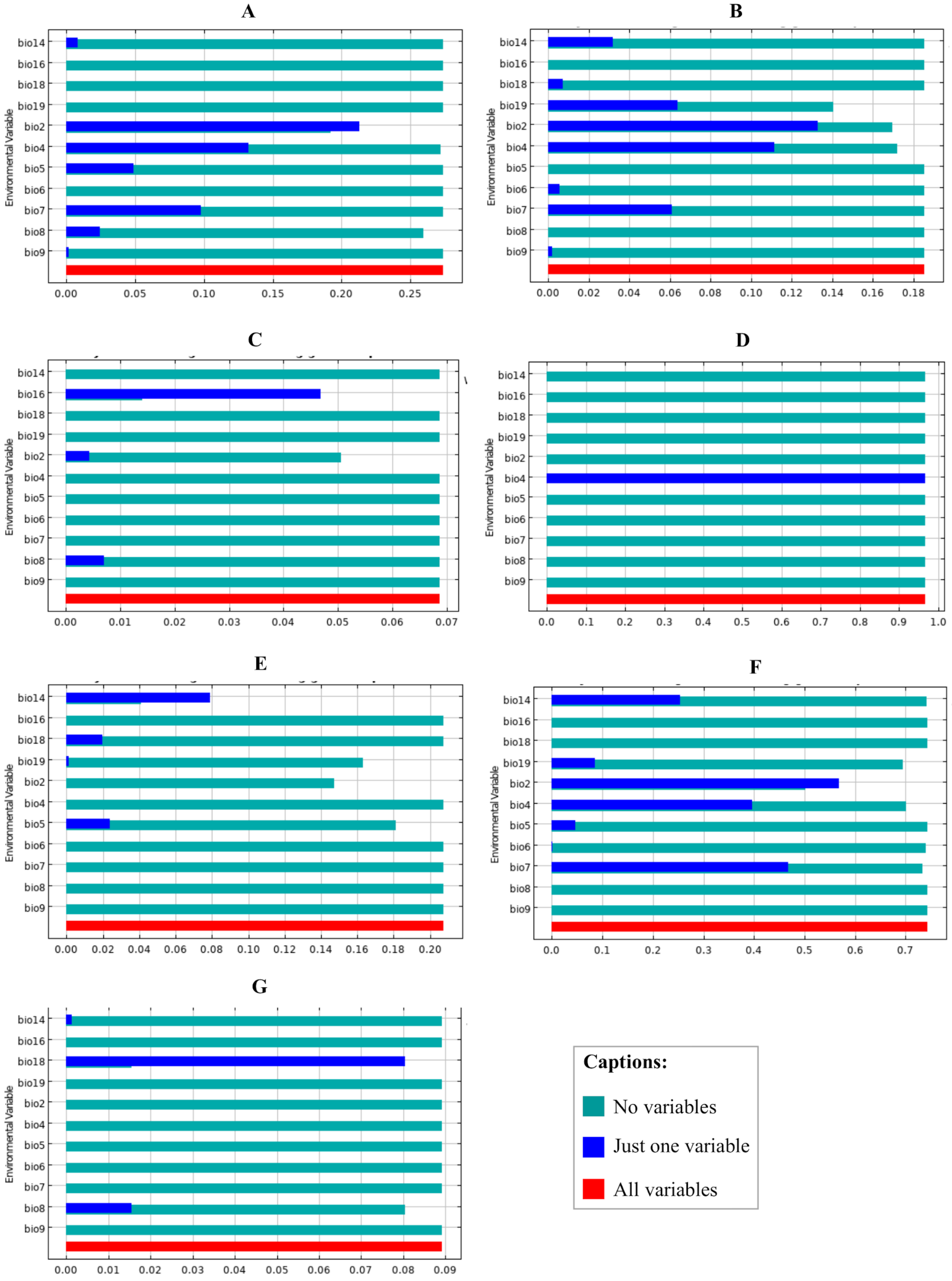

Figura 3. Jacknife test result to assess the relative importance of environmental variables for the seven most cited species locally. Each panel represents a specific species identified by the letters "A" to "G": A) *A. pyrifolium*; B) *C. blanchetianus*; C) *M. tenuiflora*; D) *M. urundeuva* Allemão; E) *P. pyramidalis* (Tul.) L.P.Queiroz; F) *S. obtusifolium* (Humb. ex Roem. & Schult.) T.D.Penn; and G) *S. tuberosa*.

Tabela 1. Environmental variables used in the study and their contribution percentages. The variables used are highlighted in bold. *A. pyrifolium* = A, *C. blanchetianus* = B, *M. tenuiflora* = C, *M. urundeuva* = D, *P. pyramidalis* = E, *S. tuberosa* = F, *S. obtusifolium* = G.

			Contribution (%)						
Code	**Environmental variables**	**Unit**	***A***	***B***	***C***	***D***	***E***	***F***	***G***
Bio1	Average annual temperature	°C							
Bio2	**Monthly average amplitude (temp/min)**	°C	78.9	51	24.7		13.5		52.2
Bio3	Isothermality (Bio2/Bio7) (X100)	-							
Bio4	**Temperature seasonality (Standard Deviation x 100)**	C of V	3.6	22.7		100			2.8
Bio5	**Maximum temperature (warmest month)**	°C					13.9		3.5
Bio6	**Minimum temperature (coldest month)**	°C							1
Bio7	**Annual temperature range (Bio5-Bio6)**	°C							35.7
Bio8	**Average temperature (wettest quarter)**	°C	17.4						
Bio9	Average temperature (driest quarter)	°C							
Bio10	Average temperature (warmest quarter)	°C							
Bio11	Average temperature (coldest quarter)	°C							
Bio12	Annual precipitation	mm							
Bio13	Rainfall (wettest month)	mm							
Bio14	**Rainfall (driest month)**	mm					60.5		0.6
Bio15	Precipitation Seasonality (Coefficient of Variation)								
Bio16	**Precipitation (wettest quarter)**	mm			75.3				
Bio17	Rainfall (driest quarter)	mm							
Bio18	**Warmest quarter precipitation**	mm						100	
Bio19	**Coldest quarter precipitation**	mm	0.1	26.3			12.1		4.2

RESULTS

Plant species used locally

We recorded the use of 28 native plant species by local residents of the São Francisco Community (see Table 2), whose use was allocated into nine categories: food, fuel, construction, forage, medicine, veterinary, abortifacient poison, ornamentation and technology (e.g., elaboration of tools used in agriculture).

The species most used locally can be observed in the upper quartile of the analysis. The choice for the top quartile also considered the number of species used by informants, who cited an average of 8.1 different species per household. The species selected by our test were *M. urundeuva* M. Allemão, *S. obtusifolium* (Roem. & Schult.) T.D. Penn., *A. pyrifolium* Mart. & Zucc., *P. pyramidalis* [Tul.] L.P.Queiroz, *S. tuberosa* Arruda and *M. tenuiflora* (Willd.) Poir. The current distribution of species present in the top quartile of the PIUP is shown in Figure 4. The coverage area, in turn, can be seen in Table 3.

Species distribution modeling

Maxent models for the species provided results with an AUC value greater than 0.5 from a random model. The model that recorded the highest AUC was obtained for *S. obtusifolium* (Roem. & Schult.) T.D. Penn. (0.931), followed by *P. pyramidalis* [Tul.] L.P.Queiroz (0.849), *A. pyrifolium* Mart. & Zucc. (0.787), *S. tuberosa* Arruda (0.747), *M. tenuiflora* (Willd.) Poir. (0.742), *C. blanchetianus* Baill (0.715) and *M. urundeuva* M. Allemão (0.632). The average diurnal temperature range (Bio 2) was the variable that contributed with the largest number of species (five species), however, the variables seasonality of temperature (Bio 4) and precipitation of the warmest quarter (Bio 18) contributed only (100%) for modeling *M. urundeuva* M. Allemão and *S. tuberosa* Arruda, respectively (Figure 3, Table 1).

Species distribution potential for the year 2050

The potential distribution of all modeled species has increased in their area compared to the area currently recorded. For all models, the area increase was greater when subjected to a greater radioactive increment, in the RCP8.5 scenario. The model suggests that the distribution of species will expand in a direction that characterizes climate change predicted for the first half of the 21st century, both in the most conservative scenario (RCP4.5) and in the one that predicts a greater increase in radioactive forcing (RCP8.5). This is the most optimistic and most pessimistic scenario, respectively.

By looking at the area of greatest species suitability using RCP 4.5, we identified an average increase in potential distribution of 126% in its area compared to the current distribution. The species with the lowest expansion was *C. blanchetianus* Baill whose expected growth in the model was 10.2% of its area. The largest increase in area was registered for the species *A. pyrifolium* Mart. & Zucc. (248.29%). The analysis of the models that relate the current area with the less conservative scenario (RCP8.5) showed an average increase of 153.3% in the area of possible occurrence of the species. As recorded in RCP4.5, the species with the lowest expansion was *C. blanchetianus* Baill (‘23.5%) and the largest increase was recorded for *A. pyrifolium* Mart. & Zucc. (288.6%). When comparing RCP 4.5 with RCP8.5, an increase in the potential area of all species used locally was also observed, especially *S. obtusifolium* (Roem. & Schult.) T.D. Penn. and *S. tuberosa* Arruda, which recorded the largest increases in area in case of increased radioactive forcing (19.6% and 18.76%, respectively). The increase in the area of potential distribution of the species is recorded in Table 3 and Figure 4.

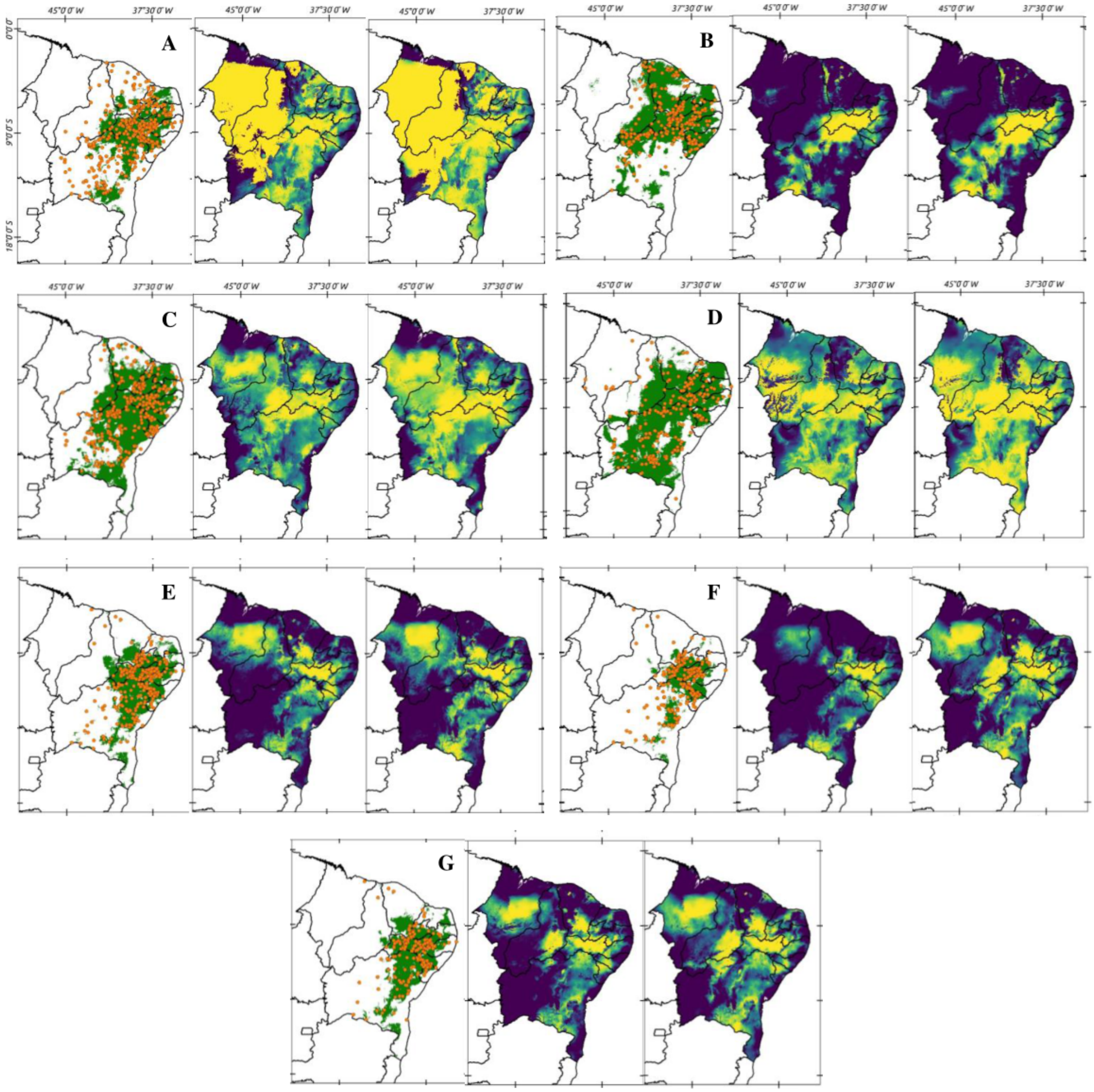

Figura 4. Distribution of plant species modeled from Maxent. Each of the lines brings three maps containing, from left to right, the current distribution of species, the optimistic scenario modeling (RCP 4.5) and the pessimistic scenario modeling (RCP 8.5), respectively, considering: A) *A. pyrifolium* Mart. & Zucc.; B) *C. blanchetianus Baill*; C) *M. tenuiflora* (Willd.) Poir; D) *M. urundeuva* M. Allemão; E) *P. pyramidalis* [Tul.] L.P.Queiroz; F) *S. obtusifolium* (Humb. ex Roem. & Schult.) T.D.Penn; and G) *S. tuberosa* Arruda.

Tabela 2. Plant species used in the São Francisco Rural Community. Use categories (captions): Food (Fd); Fuel (Fl); Construction (Ct); Forage (For); Medicinal (Med); Others (Out); Technology (Tec); Poison-abortive (Pa); and Veterinary (Vet). Real use identifies the number of informants/households where usage can be recorded. PIUP (Pressure Index by Use Preference) indicates the pressure by species use preference.

Taxonomic Family	**Scientific Name (Record Number)**	**Common Name (In Portuguese)**	**Use Categories**	**Real Use**	**PIUP**
Anacardiaceae	*Myracrodruon urundeuva* Allemão (17.632)	Aroeira	Ct, Fl, For, Med, Tec	33	0.30763
	Schinopsis brasiliensis Engl. (17.255)	Baraúna	Fl, Ct, For, Out, Vet	15	0.16913
	Spondias tuberosa (17.556)	Umbuzeiro	Fd, For, Med, Pa	26	0.23371
Apocynaceae	*Aspidosperma pyrifolium* (17.566)	Pereiro	Ct, Fl, Tec, For, Pa, Vet, Out	25	0.26664
Arecaceae	*Copernicia prunifera* (Miller) It.E.Moore (17.553)	Carnaúba	Tec	1	0.02336
Bignoniaceae	*Tabebuia aurea* (Silva Manso) Benth. Hook. F.ex. S. (17.641)	Craibeira	Ct, Tec, For, Out, Pa	16	0.17333
Burseraceae	*Commiphora leptophloeos* (Mart.) J. B. Gillet (17.642)	Umburana	Ct, Med, For, Tec, Fl, Vet	19	0.19311
Capparaceae	*Cynophalla flexuosa* (L.) J. Prese (17.583)	Feijão Brabo	For, Vet, Tec	6	0.07081
Celastraceae	*Maytenus rigida* Mart. (17.615)	Bom-Nome	Fl, Med, Tec, Vet	8	0.10207
Combretaceae	*Thiloa glaucocarpa* (Mart.) Eichler	João Mole	Vet	12	0.10841
Euphorbiaceae	*Cnidoscolus quercifolius* Phol. (17.581)	Favela	Med, For	2	0.03431
	Croton blanchetianus Baill (17.249)	Marmeleiro	Fl, Ct, For, Med, Tec, Out	20	0.22224
	Jatropha molissima (Pohl.) Baill. (17.578)	Pinhão Brabo	Med, Tec, Vet, For	14	0.14076
	Manihot dichotoma Ule (17.254)	Maniçoba	For, Pa, Out	5	0.06291
Fabaceae	*Anadenanthera colubrina* (Vell.) Brenan (17.630)	Angico	Fl, Tec, Ct, Pa, Med, Vet	14	0.17299
	Bauhinia cheilantha (Boing.) Steud. (17.648)	Mororó	Ct, Med, Fl, Vet, For	6	0.08246
	Erythrina velutina Willd (17.563)	Mulungú	Tec, Med, For, Out	6	0.07571
	Hymenaea courbaril L. (17.582)	Jatobá	Med, Ct, For	4	0.05501
	Libidibia ferrea (Mart. ex Tul.) L.P. Queiroz (17.639)	Jucá	Fl, For, Med, Tec, Ct, Out, Vet	11	0.13677
	Mimosa ophthalmocentra Mart ex. Benth. (17.236)	Jurema De Imbira	Ct, For	2	0.04117
	Mimosa tenuiflora (Willd.) Poir (17.626)	Jurema Preta	Fl, For, Ct, Med, Pa, Tec	21	0.22328
	Piptadenia stipulaceae (17.877)	Jurema Branca	For, Fl, Ct, Out	8	0.09151
	Poincianella pyramidalis (Tul.) L.P.Queiroz (17.234)	Catingueira	Fl, For, Med, Ct, Out	24	0.24894
Malvaceae	*Ceiba glaziovii* (Kuntze) K. Schum.	Barriguda	Out	2	0.02941
	Pseudobombax marginatum (A.ST.Hill) A.Robyns (17.562)	Imbiratã	Med, For, Vet	10	0.10241
Olacaceae	*Ximenia americana* L. (17.557)	Ameixa	Med	4	0.04521
Rhamnaceae	*Ziziphus joazeiro* Mart. (17.625)	Juazeiro	For, Med, Out, Fd, Fl	20	0.19121
Sapotaceae	*Sideroxylon obtusifolium* (Humb. ex Roem. & Schult.) T.D.Penn. (17.625)	Quixabeira	Med, For, Fd, Fl, Tec, Out	28	0.26802

DISCUSSION

The availability projections obtained in the scenarios presented in this study (Figure 4) suggest an increase in the distribution of the analyzed vegetation. This growth may represent a compromise of space, that is, the site may be harboring remnants of Caatinga composed of large vegetation and high seral stages. The ecological literature has shown how forest ecosystems can be resilient even after anthropic and/or natural actions (Jang et al. 2016; Sobrinho et al. 2016). For example, Jang et al. (2016) evaluated the impact of harvesting plant species of importance to human populations in the Montana region. The authors observed that, in the long term, the pressure of use of shrub species that, despite anthropic impact, the shrub biomass managed to recover approximately 40 years after pressure of local use and, possibly, this is related to the form of local management. This means, therefore, that the understanding of the relationship between the use of species, represented in this study through the use preference (PIUP) and the past and future distribution of certain vegetation, seems to contribute significantly to the development of management plans, which considers not only the preservation of the local ecosystem, but also the socio-cultural and economic needs of human groups whose source of sustenance is plant resources obtained from the forests surrounding the community where they live.

This evidence shows the urgency in the need for methodological changes in studies aimed at evaluating disturbances caused by human populations on the environment, which has already been discussed by previous ethnobiological studies (e.g., Albuquerque et al. 2017), which criticize studies ecological aspects that do not include the importance of local vegetation for families living in the surroundings of a particular forest. According to these authors, there are limitations in many results presented by ecological studies that evaluated anthropogenic disturbances and suggest the theory of niche construction as an alternative for a better understanding of human influences on the environment. Regardless of the methodology used by scientists, it is impossible not to consider that people have shaped and will continue to change global biodiversity through short-term and long-term local activities (Albuquerque et al. 2018). Recognition of this contribution is essential for the contemporary understanding of the interactions that exist between vegetation of socioeconomic/cultural importance and ecosystems to predict future transformations.

Another important aspect that was considered was the bioclimatic structure of the study region, given that the world climate faces one of the greatest challenges for current and future society, especially in semi-arid areas of developing countries, which cover some of the human and ecosystems considered more sensitive to climate impacts (Doblas-Reyes et al. 2021; Lee et al. 2021; Seneviratne et al. 2021). The Semi-arid Region of Northeast Brazil, for example, has a vast climate diversity, which is why some areas tend to be hotter and drier than others (Dantas et al. 2020; Marengo et al. 2020), which may limit the local adaptation to the negative effects of the climate. Although it cannot be used as the only metric for evaluation, we can infer that the vegetation in this region has developed greater resistance and growth speed in order to survive. Thus, the growth of more resistant species can be seen when the potential expansion of the catchment area of all species modeled under the RCP8.5 scenario is observed, which predicts a higher radioactive forcing associated with modest rates of technological change and intensification of energy use that culminates in high emissions of greenhouse gases, and consequent increase in global temperature (Riahi et al. 2011).

The presence of the pioneer species *M. tenuiflora* (Willd.) Poir., *P. pyramidalis* (Tul.) L.P.Queiroz e *A. pyrifolium* Mart. & Zucc., associated with their potential increase in the availability of these species, may be an indication of environmental degradation, which may culminate in a process of local desertification. Souza et al. (2015a), for example, indicated the relative importance of species in non-desertified areas, indicating that the presence of pioneer species demonstrates that in this environment some type of vegetation change occurred and possibly is still occurring. The authors also recorded the contribution of these pioneer species in desertified areas as being higher than in non-desertified areas, depending on the level of environmental disturbance (Souza et al. 2015b). However, despite the identification of species that characterize a specific successional stage, in order to establish the indication of the sere in which the environment is found, a phytosociological assessment is necessary, in order to indicate the stage of development of the species and the verification of signs of cut, which may be delaying the growth of some specimen.

The smaller increase in potential area growth of *C. blanchetianus* Baill, a genus characteristic of early stages of succession and regeneration (Fabricante and Andrade 2007; Pereira Júnior et al. 2012) differs from what could be expected after recording the area growth of pioneer species. Although it was the species whose modeling identified the smallest area and presented the smallest PIUP in the first quartile, it has considerable use when related to the total number of species used in the São Francisco community. Thus, the relationship among the availability of the species known by human groups in the study community and its actual use is important to estimate the species conservation framework according to the different forms

Tabela 3. Variation in the potential distribution area of species influenced by different climate scenarios.

Species	**Current Area (km^2)**	**RCP4.5**	**RCP 8.5**
Aspidosperma pyrifolium	323,487	1,126,671	1,257,164
Croton blanchetianus	561,635	618,879	693,492
Mimosa tenuiflora	583,187	1,112,064	1,160,649
Myracrodruon urundeuva	695,900	1,288,992	1,365,435
Poincianella pyramidalis	348,848	848,053	902,746
Sideroxylon obtusifolium	178,933	408,676	488,763
Spondias tuberosa	315,024	888,539	1,055,256

of management used by local peoples, also based on the representation of socioeconomic/cultural and/or religious importance of a given plant resource in the community (Oliveira et al. 2015; Silva et al. 2014b).

The pioneer profile of *C. blanchetianus* Baill may be responsible for the high amount of the species verified by Lima et al. (2016), in a phytosociological study carried out in a degraded area of this community. On the other hand, it can be inferred that the greater use preference identified for *M. urundeuva* M. Allemão in this research, related to the quality of wood for the construction of durable structures for homes, appears to be related to the greater current distribution of the species among those recorded in the rank of the PIUP. With this, the modeling possibly pointed to *M. urundeuva* M. Allemão with one of the smallest increases in its availability for the year 2050, when compared to the other modeled species. While this can be explained by the collection of timber forest products, they are generally one of the most harmful to ecosystems since in most cases it leads to the immediate death of the target individuals (Albuquerque et al. 2018), it can be understood that further future analyzes should be carried out, since there is evidence that the extraction of plant species for the construction of fences and/or houses has a different dynamic, since people tend to use plants whose trunks have great resistance and durability and , consequently, the collection pressure tends to be lower (Oliveira and Hanazaki 2011). Thus, the replacement of wood used for these purposes tends to be carried out in the long term (Medeiros et al. 2011).

On the other hand, the fact that *M. urundeuva* M. Allemão presents a reduced growth in its potential distribution may indicate the need for conservation assessments and subsequent management plans for the species, which, according to Andrade et al. (2005), it is not adapted to colonize inhospitable environments for the species, without the necessary environmental characteristics to meet the needs of species that characterize a more advanced seral stage. The authors also registered the presence of *M. tenuiflora* (Willd.) Poir. only in an area with little anthropization. The species, together with *M. urundeuva* M. Allemão and *C. blanchetianus* Baill, were the species with the lowest growth expected for the year 2050 in both scenarios evaluated (RCP4.5 and RCP8.5). This reduction in growth for both species under the current climate scenario may suggest these species will become threatened which would likely result in the loss of knowledge on the local uses of these species, as well as the knowledge about the characteristics of these species for why they are selected for in local practices. Gottfried et al. (1999), for example, recorded a pattern of displacement of plant species in the European Alps due to the formation of a zone at the base of the mountains capable of sustaining only the establishment of pioneer species, and related this change to the warming of the local climate.

The reduction of areas conducive to climax species is similar to that expected for species such as *M. urundeuva* M. Allemão, *S. obtusifolium* (Humb. ex Roem. & Schult.) T.D. Penn. and *S. tuberosa* Arruda and may be related to the small proportional increase in area of the last two species. In turn, the variation in the potential availability of *P. pyramidalis* (Tul.) L.P.Queiroz, in which there is an estimated increase for the year 2050, suggests that the use of the species is directed as options for maintaining the use of native species, from a management plan in order to obtain recovery of species with higher frequency of use and lower local availability. It is necessary to emphasize that there is a need for studies on the soil structure of the community, as there is an observation of a variation in the susceptibility of the region to maintain the current phytosociological structure. However, the functional structure of this modeling does not allow for identifying which areas are undergoing changes or if any region is recovering while another is being more degraded, as well as it does not allow for the inclusion of data on soil, thus requiring a later evaluation. Given that there is interspecific competition, geographic barriers and human activity when modeling the distribution of plant species of importance to human populations, whose expected distribution may differ from what may be observed in nature (Qin et al. 2017).

The results present in the modeled scenarios are based on the association between bioclimatic information and the location of the species obtained from georeferencing, considering that the distribution of plant species in the surroundings of the rural community was also influenced by the pressure of use. In this way, we suggest that better-designed management plans, which allow the maintenance of the forest structure and reduce the socioeconomic/cultural damages of rural communities, should consider the variation of species availability during the century and relate these data to information on preference and frequency of species use.

We believe that the construction of plans for the management and protection of native vegetation in dry areas, such as the semi-arid region of the Paraíba State, Brazil, involves the identification of environmental problems caused both by different management techniques and by the use of land for extensive livestock. Bearing in mind that the latter is historically characteristic of semi-arid areas and its use on a large scale is a modifying element of the floristic composition of the herbaceous and arboreal-shrubby strata (Alves et al. 2009), with interference in plant diversity and structure (Souza et al. 2015a). Therefore, in the process of analyzing the distribution of useful species in a locality, it is necessary to recognize the importance of local forests and their components for the human populations that live in their surroundings, since people will continue to modify local landscapes. Furthermore, the large effect of natural climate impacts and anthropogenic intensification on Planet Earth must be considered.

FINAL CONSIDERATIONS

In general, the history of rural populations living in semi-arid regions of developing countries is related to the use of resources obtained from forests for family survival, which has led both people and the ecosystem around the community to experience greater vulnerability to the current climate impacts framework (e.g., Magalhães et al. 2021). However, reports by these peoples about plant resources of socioeconomic/cultural importance is a useful tool to assess the conservation status of plant species known and used locally.

The increase in the potential area in which the species modeled in this study could be found by the year 2050 indicates an increase in the Brazilian Semiarid Region, as indicated by the predictions found in the Assessment Reports of the Intergovernmental Panel on Climate Change (e.g., IPCC 2014; Lee et al. 2021). By analyzing these data punctually, taking a rural community as a point of observation, we can understand how the patterns of climate change expected for the globe can affect small human groups, which may even be unaware of the origins of these changes.

Informants from the São Francisco Community showed preferences for species whose availability should increase in the community's collection zones, which could be beneficial for the maintenance of the local social and cultural structure. However, the increase identified in the modeling may be an indicator of the worsening of environmental extremes, such as droughts and a possible process of desertification, which would imply a reduction in the availability of available water resources for the maintenance of subsistence activities of rural communities, such as agriculture. and subsistence livestock, and the presence of species from seral stages closer to the climax.

The modeling done with Maxent allowed us to infer the shape of the distributions of useful species for the São Francisco community at a regional level. Despite the spatial amplitude obtained from the modeling, it was possible to predict future changes in the reality of the community, especially after comparing the distribution of species expected for the year 2050 with the past phytosociological data presented by Lima et al. (2016). The use of distribution modeling has therefore proved to be a useful tool for aiding conservation status estimates of plant species that are historically important to human groups living in rural environments. Such a tool may be able to assess how the activities characteristic of the semiarid region can be maintained. In addition, the information derived from these analyzes are necessary complements for the basis of a management plan that has at its core the sociocultural structure of human communities.

Likewise, the results provided important evidence on the scenario for ethnobiological and ecological research presented by Albuquerque et al. (2017), on the importance of more effective methods to predict the future of ecosystems considering humans as niche builders (niche construction theory). Thus, this research brought new data using a semi-arid area as a scenario, an environment highly vulnerable to the adverse effects of climate change (Doblas-Reyes et al. 2021; Lee et al. 2021; Seneviratne et al. 2021), based on mathematical modeling focusing not only on the local ecosystem, but also considering the knowledge and real use of plant species of importance to a human group.

On the other hand, the study suggests the need for further studies to test the same methodology in regions with different climatic profiles, considering the conservation and proper management of plant and/or animal resources in a realistic context, that is, always considering the anthropic and natural impacts in the context of the reality studied. In this sense, we also suggest carrying out investigations with the same methodological proposal as the present study, with a more focused focus on Landscape and Population Ecology, seeking to evaluate the effect of use pressure on useful plants in altering landscapes; in the relationship between availability and use of resources by community populations (see Lima et al. 2016b); and on the biomass of collected plant parts, also focusing on the life history of the plants in focus.

Finally, when we developed and proposed the PIUP, our proposal was to estimate preference over use pressure in useful species. However, we did not consider important variables such as differences in lifestyle, plant life history strategies, type of organ(s) harvested and demographic parameters in general, which could direct our response in different ways. Thus, although we emphasize the relevance of the PIUP as an index for general assessment of preference on the pressure of use in useful plants in the Caatinga, we believe that, as it is a newly developed proposal, it is certainly still subject to tests and revisions that consider the aforementioned assumptions. Thus, we will have a methodology whose estimate is more robust within its proposal.

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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 declare that they have no conflicts of interest.

CONTRIBUTION STATEMENT

Conceptualization: JRFL, RH, RWB, RFPL.
Data curation: JRFL.
Formal analysis: JRFL, TKNC.
Investigation: JRFL, TKNC, RFPL.
Methodology: JRFL, RH, RWB, RFPL.
Visualization: JRFL, TKNC, RSS, HFM, RCSO.
Writing – original draft: JRFL.
Writing – review & editing: JRFL, TKNC, RSS, RH, RWB, HFM, RCSO, RFPL.

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