Distribution and future projections for *Schinopsis brasiliensis* Engler (Anacardiaceae) in the semi-arid region of Brazil

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Abstract. The advanced degradation and desertification processes, resulting from the anthropization of the semi-arid region of Brazil has led to an increasing need for research on the status of the occurrence of plant species. *Schinopsis brasiliensis* Engler, popularly known as "barauna", is recognized both for its exuberance and the use of its wood for different purposes. This species occurs in the Northeast and Midwest regions of Brazil and can be found in the Cerrado and Caatinga phytogeographic domains. This study aimed to analyze the local and regional distribution and abundance of *S. brasiliensis* in six municipalities in different regions of Paraíba State, as well as to perform the current and predictive modeling of the ecological niche of this species in the northeast region of Brazil, considering bioclimatic variables. On a state scale, this research was conducted in six rural communities, previously selected from studies already carried out by the Ethnobiology and Environmental Sciences Laboratory of the Federal University of Paraíba. On a regional scale, current and predictive modeling of the species' ecological

niche was used, considering bioclimatic variables, based on data obtained from the WorldClim database (www.worldclim.org). The data showed a heterogeneous distribution in the populations of *S. brasiliensis*. The high number of adult specimens may indicate low resource extraction. Climate change, in different scenarios, does not significantly affect the distribution of the study species in the Northeastern Region of Brazil.

Keywords: Availability; Climate change; Dry forests.

Resumo. ***Distribuição e projeções futuras de* Schinopsis brasiliensis *Engler (Anacardiaceae) na região semiárida do Brasil***. O avanço dos processos de degradação e desertificação, decorrentes da antropização da região semiárida do Brasil têm levado a uma necessidade crescente de pesquisas sobre o estado e ocorrência das espécies vegetais. A espécie *Schinopsis brasiliensis* Engler, popularmente conhecida como "baraúna", é reconhecida tanto pela exuberância quanto pelo uso de sua madeira para diversos fins. Esta espécie ocorre nas Regiões Nordeste e Centro-Oeste do Brasil, e pode ser encontrada nos domínios fitogeográficos do Cerrado e da Caatinga. Este estudo teve como objetivo analisar a distribuição local e regional, e a abundância de *S. brasiliensis* em seis municípios de diferentes regiões do Estado da Paraíba, bem como realizar a modelagem atual e preditiva do nicho ecológico desta espécie na Região Nordeste do Brasil, considerando variáveis bioclimáticas. Em escala estadual, esta pesquisa foi realizada em seis comunidades rurais, previamente selecionadas a partir de estudos já realizados pelo Laboratório de Etnobiologia e Ciências Ambientais da Universidade Federal da Paraíba. Em escala regional, foi utilizada a modelagem atual e preditiva do nicho ecológico da espécie, considerando variáveis bioclimáticas, com base em dados obtidos no banco de dados WorldClim (www.worldclim.org). Os dados mostraram uma distribuição heterogênea nas populações de S. brasiliensis. O alto número de espécimes adultos pode indicar baixa extração de recursos. As mudanças climáticas, em diferentes cenários, não afetam significativamente a distribuição da espécie em estudo na Região Nordeste do Brasil.

Palavras-chave: Disponibilidade; Mudanças climáticas; Florestas secas.

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Introduction

The Northeastern Region of Brazil has an area of approximately 1,554,292 km², which is covered by a semi-arid domain of about 877,317 km² (IBGE, 2011), occupying 56.44% of the region and accounting for 25 million people (MMA, 2009). This region comprises the Caatinga ecosystem (912.529 km²), which is inhabited by approximately

28.6 million people, mostly in the rural area, who relate to 3,150 species of plants found in this ecosystem (Silva et al., 2017).

Schinopsis brasiliensis Engler is one of these species, popularly known as "barauna", which stands out both for its exuberance and beauty and its numerous applications. This species occurs in the northeastern states of Brazil, except in Maranhão, as well as in the Midwest region, recorded in the Federal District, Goiás, Mato Grosso, and Mato Grosso do Sul and found in the Cerrado and Caatinga phytogeographic domains (Kiill et al. 2005, Luz et al., 2019).

This species has already been used in the leather tanning industry because of the high content of tannins in the cell walls of its lignified tissues (bark and inner bark) (Kiill and Lima, 2011), which may have led to a decrease in its populations in semi-arid vegetation areas, contributing to its vulnerability condition.

According to ethnobotanical studies, *S. brasiliensis* is considered one of the most versatile plants in the semi-arid region of Brazil, recorded in the literature for different purposes in several categories of use, such as domestic constructions (door, window, beams, rafters, and slats), rural constructions (portress/gate, fence posts, and stakes), fuel (firewood and charcoal), technology (furniture and tool handles), and other timber and non-timber uses (Pereira et al., 2003; Trovão et al., 2004; Ferraz et al., 2006; Sousa, 2006; Lucena et al., 2008; Albuquerque et al., 2009; Lucena et al., 2012a,b; Alves et al., 2009; Silva et al., 2014).

Martins et al. (2003) found *S. brasiliensis* in uniform groups. Santana (2009), Mendes Júnior and Drumond (2009) evidenced a common occurrence of clusters in areas of Caatinga, where the abundance of this species appears clustered or with a tendency to form clusters. Mendes Júnior and Drumond (2009) explain this is a strategy of caatinga species to establish a large number of specimens in areas that have suffered some disturbance, even climatic. These authors emphasize that classification and studies recording few specimens in ecological surveys should be carefully analyzed.

However, in certain environments, the number of specimens has decreased. According to Calixto Júnior and Drumond (2014), a large part of the Caatinga has already suffered clear-cutting, which has caused a decrease in species diversity and the number of specimens in the last 30 years, including barauna. These authors also recorded the existence of a recovering population in fragments of Caatinga, and that when these areas were compared with other preserved areas, it was possible to observe both physiognomic and structural differences, evidencing these fragments have not yet reached a stage of ecological development similar to those in better conservation status.

The advanced degradation and desertification, as well as other environmental and anthropogenic changes, are other processes that affect the occurrence of *S. brasiliensis* in the semi-arid region of Brazil (Garda, 1996; Fernandes, 2002; Maia, 2004; Oyama and Nobre, 2004; MMA, 2008; COSTA et al., 2009). From this point of view, studies aimed at understanding the impacts of climatic events and changes in habitats on the distribution of plant species, such as the research by Butt and Gallagher (2018), have become more frequent and necessary so that more detailed and significant answers can be obtained.

Given the above, this study aimed to assess the local and regional distribution and abundance of *S. brasiliensis* in six municipalities in different regions of Paraíba, in addition to performing current and predictive modeling of the species' ecological niche in the northeast region of Brazil, considering bioclimatic variables.

Material and methods

Design for the State of Paraíba
Study area. This research was conducted in six rural communities in different areas of the semi-arid region of Paraíba, northeastern Brazil, as follow: São Francisco in

the municipality of Cabaceiras, Santa Rita in Congo, Pau d'Arco in Itaporanga, Coelho in Remígio, Várzea Alegre in São Mamede, and Capivara in Solânea, distributed between the Sertaneja Depression and the Borborema Plateau (Figure 1). These areas were selected from preliminary information obtained by researchers (Guerra et al., 2012; Leite et al., 2012; Lucena et al., 2012; Pedrosa et al., 2012; Sousa et al., 2012; Lucena et al., 2013; Lucena et al., 2014; Silva et al., 2014; Ribeiro et al., 2014) of the Ethnobiology and Environmental Sciences Laboratory (LECA/UFPB).
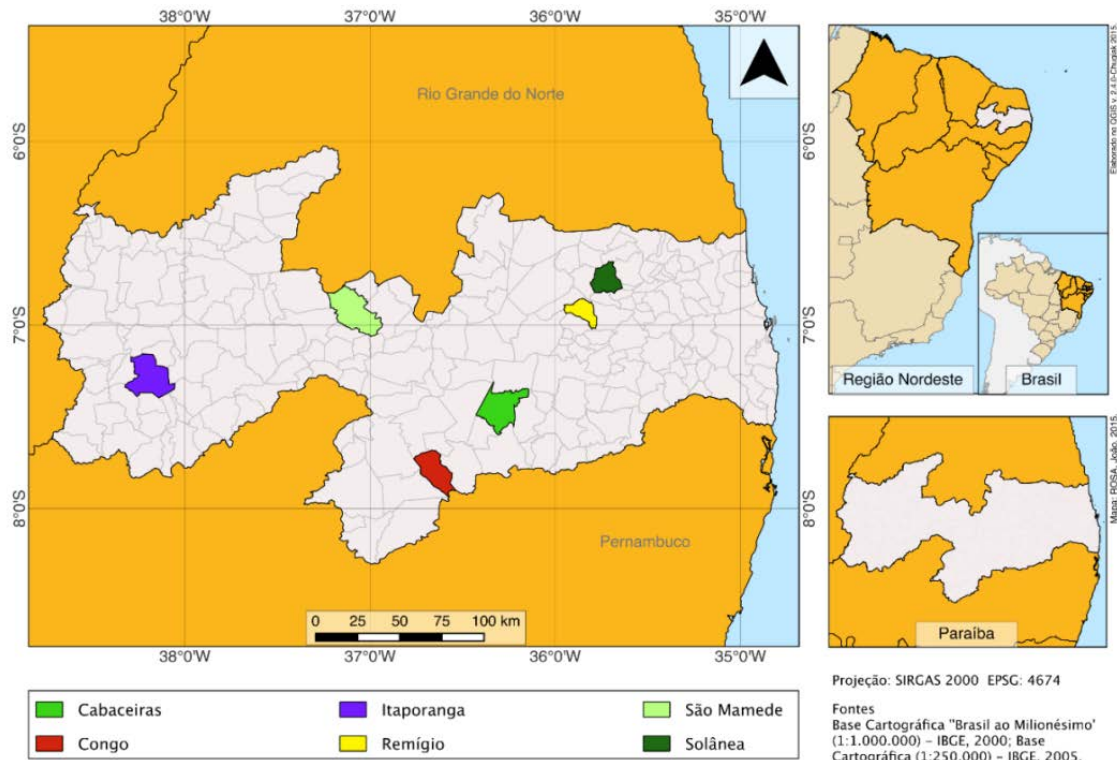

Figure 1. Geographic location of the municipalities of Cabaceiras, Congo, Itaporanga, Remígio, São Mamede, and Solânea (Paraíba, northeastern Brazil). Map by Ramon Souza.

The Municipality of Cabaceiras (7° 29' 20" S and 36° 17' 14" W) is located in the Borborema Mesoregion and Cariri Oriental Microregion, in the Borborema Plateau. It covers an area of 452,922 km², at 400 m altitude, with a "BSh" climate (semi-arid hot), mean annual temperature above 20 °C, and the lowest rainfall in Brazil, less than 300 mm per year (IBGE, 2010).

The Municipality of Congo (07° 47' 49" S and 36° 39' 36" W) is located in the Borborema Mesoregion and Cariri Ocidental Microregion, in the Borborema Plateau, covering an area of 333,471 km², at an altitude of 480 m. The climate in the region is semi-arid tropical, with summer rains ("Aw"), a mean temperature around 26ºC, and a mean annual rainfall above 400 mm (IBGE, 2010).

The Municipality of Itaporanga (7° 18' 14" S and 38° 09'00" W) is located in the Sertão Mesoregion and Piancó Valley Microregion, in the Sertaneja Depression, covering an area of 468,060 km², at an altitude of 191 m. The climate in the region is hot semi-arid

("Aw"), with a mean temperature above 23 C, short rainy season, high intensity and short duration rains, and mean annual rainfall above 500 mm (IBGE, 2010).

The Municipality of Remígio (06° 54' 10" S and 35° 50' 02" W) is in the Agreste Mesoregion and Curimataú Ocidental Microregion, in the Borborema Plateau. It covers an area of 180,897 km², at an altitude of 593 m, with a rainy tropical climate and dry summer ("Aw"), a mean temperature of 22 °C, and annual rainfall above 700 mm (IBGE, 2010).

The Municipality of São Mamede (6° 55' 37" S and 37° 05' 45" W) is in the Sertão Paraibano Mesoregion and Seridó Ocidental Microregion, in the Sertaneja Depression. This municipality covers an area of approximately 530,728 km², at an altitude of around 263 m, with a "BSh" climate (hot semi-arid), summer rains, mean annual temperature of 28 °C, and mean annual rainfall of 700 mm (IBGE, 2010).

The Municipality of Solânea (06° 46' 40" S and 35° 41' 49" W) is located in the Agreste Mesoregion and Curimataú Oriental Microregion, in the Borborema Plateau, covering an area of 232,096 km², at an altitude of 626 m. The climate in the region is rainy tropical with dry summer ("As"), mean annual temperature of around 25 °C, and mean annual rainfall above 800 mm (IBGE, 2010).

Data collection and analysis. The local distribution of *S. brasiliensis* in the communities was recorded and mapped using the guided tour technique, which consists of interviewing local specialists (Bailey, 1994; Albuquerque et al., 2010). The tour consisted of a 24-hour walk along the physical perimeter of the communities in the six municipalities, totaling 144 hours.

To draw a map of local geographic distribution in each community, all specimens found were identified and mapped by recording their geographic coordinates, using a Garmin Oregon® 400t GPS.

Subsequently, the data obtained in each municipality was organized in Microsoft Excel® spreadsheets, calculating (1) the total amplitude, (2) number of classes, by the distribution of Sturges (Logarithm Rule), and (3) the amplitude of classes, according to the following equations, respectively:

(1)

TA = total amplitude; MV = the largest perimeter; mv = the smallest perimeter.

(2)

NC = number of classes; N = number of sampled specimens;

(3)

AC = amplitude of classes; AT = total amplitude; NC = number of classes.

After obtaining these data, the amplitude of classes was used in each data set of each municipality, establishing the classes in centimeters, between the smallest and the largest perimeters, with the necessary adjustments, preventing the meeting of classes (Sturges, 1926). Distribution graphs were drawn to show the frequency (Y-axis) and classes (X-axis), as well as the standard error, in which the mean standard error was used to determine the precision with which the sample mean estimates the population mean.

For species identification, plant material was collected, processed in the field, and taken to the Ethnoecology Laboratory for treatment. The material (Registration No.

17.255) was later identified and deposited in the Herbarium "Jayme Coelho de Morais" (EAN) of the Federal University of Paraíba (Agrarian Sciences Center - Campus II).

For the spatial distribution, in addition to drawing a map, Pearson's correlation (r) and determination coefficient (R^2) were calculated for the number of specimens, mean height, and mean perimeter, for the species in all study communities.

Design for the Northeast Region

Species occurrence data collection. Occurrence areas of *Schinopsis brasiliensis* were obtained from the Global Biodiversity Information Facility-GBIF (https://www.gbif.org), iNaturalist (https://www.inaturalist.org) and Integrated Digitized Biocollections-*iDigBio* (https://www.idigbio.org), using the R software to search for occurrence data, adjust one point per cell of 1 km^2, and remove duplicates. This procedure was performed to obtain the species distribution in northeastern Brazil, resulting in 548 specimens.

Environmental variables. The database required for the modeling consisted of 19 bioclimatic (Hijmans et al., 2005) and 1 biophysical (elevation) variables, with a spatial resolution of 30 arc seconds (approximately 1 km^2), obtained from the WorldClim database (www.worldclim.org). The current climatic data correspond to the interpolated database for 1960-1990. The observation of representative scenarios of carbon dioxide concentrations (RCPs), optimistic (RCP4.5), and pessimistic (RCP8.5), derived from the HadGEM2-ES model, makes possible the formulation of a predictive niche map that demonstrates a possible species distribution until 2050 (mean forecast for 2041–2060). These were the most recent climate projections of the Global Circulation Models (GCMs) used in the fifth IPCC report (CMIP5).

To reduce multicollinearity, highly correlated variables (r ≥ 0.7 Pearson's correlation coefficient) were excluded (Graham, 2003). This decrease resulted in the inclusion of 8 predictor variables, as follow: mean annual temperature (Bio1), isothermalism (Bio3), annual thermal amplitude (Bio7), annual rainfall (Bio12), rainfall in the driest month (Bio14), rainfall seasonality (Bio15), rainfall in the warmest trimester (Bio18), and rainfall in the coldest trimester (Bio19).

The ecological niche modeling was performed in the R software using the MaxEnt algorithm (Phillips et al., 2006) in the dismo package (Hijmans et al., 2017). This algorithm worked better with small samples in comparison with other modeling methods (Pearson et al., 2007; Kumar and Stohlgren, 2009). The models of our research were run using the Bootstrap method for 100 repetitions, from which 75% and 25% of the data were selected for training and testing the model, respectively (Phillips, 2008). Using k-fold partitioning, 10,000 random background points were created. The Jackknife test was performed to determine the importance of the variables (Figure 2). The area under the curve (AUC), or ROC curve, was used to evaluate the model's performance. The AUC values range from 0-1 (Fielding and Bell, 1997). An AUC up to 0.50 indicates the model had no better performance in comparison with a random model, whereas 1.0 indicates perfect discrimination (SWETS, 1988).
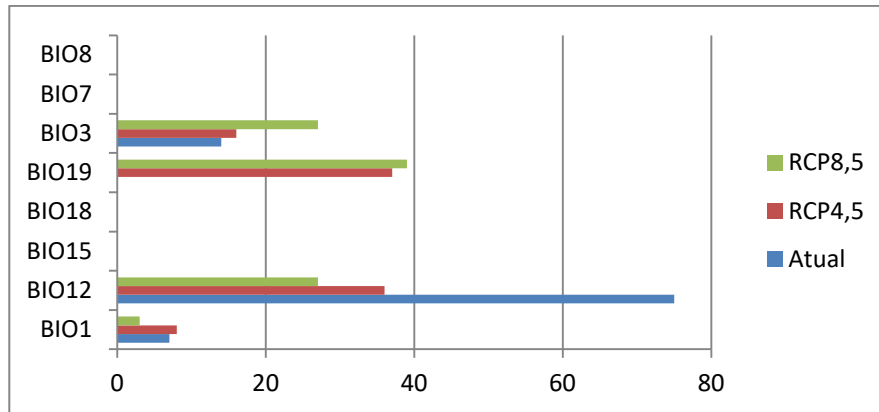
Figure 2. Evaluation of the relative importance of environmental variables using the Jackknife test.

For later exhibition and analysis, predicting the presence of species (0-1), variables were reclassified in the QGIS software, version 3.4 (QGIS Development Team, 2019), based on the classification proposed by Yang et al. (2013), into five potential classes: unsuitable habitat (0-0.2); barely suitable habitat (0.2-0.4); suitable habitat (0.4-0.6); highly suitable habitat (0.6-0.8); very highly suitable habitat (0.8-1.0). For each model, distribution area was calculated and binary values of presence (1) and absence (0) were obtained, using a cut-off threshold to maximizes the sum between sensitivity (true positives) and specificity (true negatives), according to the test data (MaxSS) (Jiménez-Valverde and Lobo, 2007; Liu et al., 2013).

Results and discussion

Spatial distribution in regions of Paraíba

After completing the 144 hours of guided tour in the six study communities, 624 specimens of *S. brasiliensis* were recorded (Table 1). No specimen was found in Várzea Alegre (São Mamede).

Sixty-four specimens were recorded in São Francisco (Figure 3), with a minimum height of 3 m and a maximum height of 18 m. All plants were grouped into classes, the smallest of 25 cm and the largest of 233 cm. The majority (64.06%) were grouped into two perimeter classes with ranging from 55 cm to 114 cm, showing a possible adult population. No plant with a perimeter < 25 cm was recorded, which may indicate the absence of young specimens and seedling recruitment, soon leading to the existence of an old population, which will be more susceptible to anthropogenic activities and local extinction process.

Based on the coefficients of variation [CV (%)], height, and perimeter, it can be suggested that the species has a heterogeneous pattern, indicating the presence of specimens in various classes, which can be a good finding, considering the ecological succession process, which may indicate a recovery process of *S. brasiliensis* and recruitment of its young specimens.

The determination of these parameters with the number of specimens is very important since several characteristics of the target vegetation can be inferred, such as management and preservation and conservation intensities (Alcoforado-Filho et al., 2003; Herrera et al., 2009; Longhi et al., 2013). Based on this importance presented by the aforementioned literature, the data obtained in our study are useful and relevant for future actions aimed at the management and conservation of this important species in the semi-arid region of Brazil.

Table 1. Total number of specimens of *Schinopsis brasiliensis* Engler, recorded during a guided tour in six rural communities in the semi-arid region of Paraíba, northeastern Brazil, and their mean height ± standard deviation (m), mean perimeter ± standard deviation (cm), and respective coefficients of variation [CV (%)].

Município	Comunidade	Indivíduos	Altura média (m)	C.V. (%)	Perímetro médio (cm)	C.V. (%)
Cabaceiras	São Francisco	64	10,63±2,96	27,84	99,23±37,28	37,56
Congo	Santa Rita	243	9,73±3,12	32,06	72,52±46,34	63,89
Itaporanga	Pau d'Arco	43	5,87±2,89	49,23	31,90±17,21	53,94
Remígio	Coelho	116	11,34±3,49	30,77	103,45±52,14	50,40
São Mamede	Várzea Alegre	-	-	-	-	-
Solânea	Capivara	158	9,46±4,11	43,44	61,41±43,48	70,80

From the information on the distribution, height, and perimeter of the specimens, Pearson's correlation between such variables can be shown to explain some correlations between the populations of *S. brasiliensis* in the study communities (Table 2).

Table 2. Pearson's correlation for the number of specimens of *Schinopsis brasiliensis* Engler, and their mean height and mean perimeter in six communities in the semi-arid region of Paraíba, northeastern Brazil.

	Número de Indivíduos	Altura média (m)	Perímetro médio (m)
Indivíduos registrados	-	0,65	0,50
Altura média (m)		-	0,95
Perímetro médio (m)			-

The number of specimens positively related to both mean height and mean perimeter with coefficients of determination of $R^2 = 41.93\%$ and $R^2 = 24.81\%$, respectively, indicating that, although it is a mean correlation, in some cases, probably most of the specimens of a population have greater height and diameter.

The mean height also positively correlated with the mean perimeter, with a coefficient of determination $R^2 = 90.69$, showing that, for being a high correlation, when the mean height increases, the mean perimeter also increases and thus, possibly, the perimeter and the height tend to be proportional in relatively old populations. Similar parameters are found in other species, which, after primary growth ceases, tend to develop only their secondary growth, causing height to be proportional in adult specimens (Lima et al., 2015).

The local distribution maps of *S. brasiliensis* with its classification into perimeter classes are shown in Figures 4 and 5.

Silva et al. (2014) conducted a phytosociological study in the same region and communities by allocating plots; however, they recorded no specimen of *S. brasiliensis*. Based on our research and that by Silva et al. (2014), it is possible to suggest studies aimed at mapping a specific species. The phytosociological surveys carried out by these authors may not be suitable because they allocated the plots or transects in very specific areas, failing to record specimens in other areas, where the guided tour could be a good complementary alternative, as can be seen through the 64 specimens recorded.
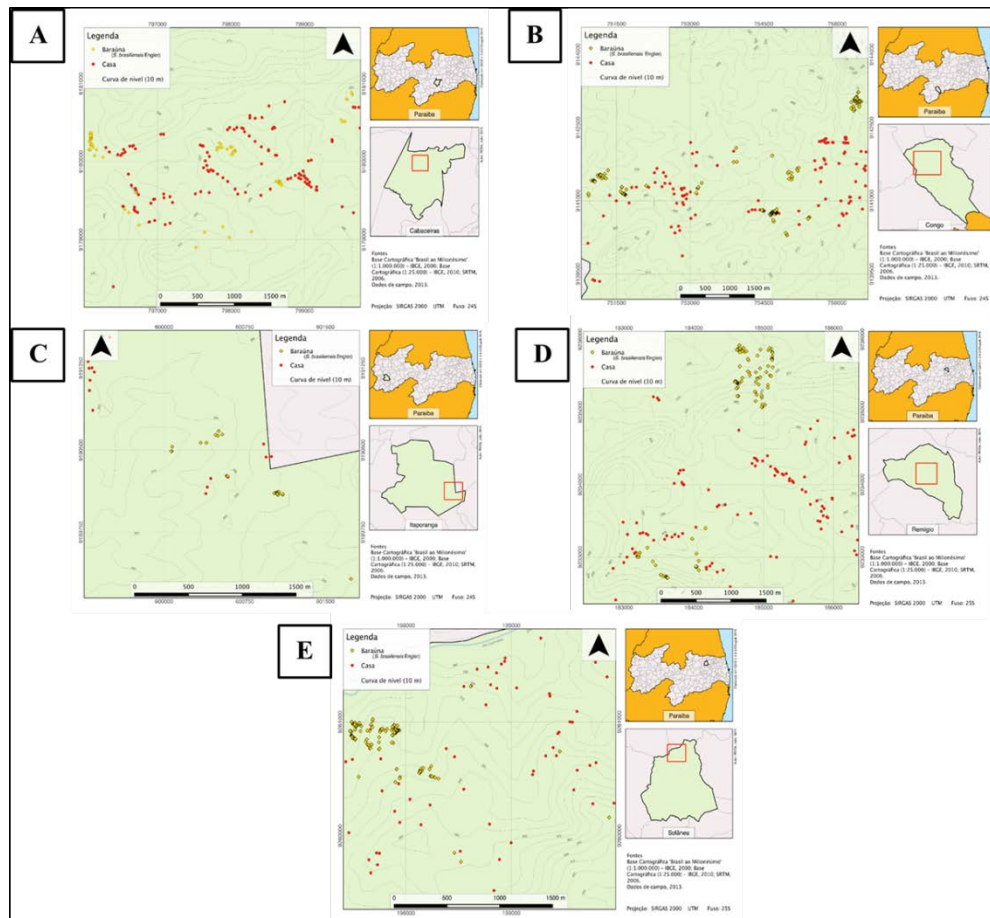
Figure 4. Spatial distribution of specimens of *Schinopsis brasiliensis* Engler in communities in the State of Paraíba, Northeastern Brazil. A - São Francisco (Municipality of Cabaceiras); B - Santa Rita (Congo); C - Pau d'Arco (Itaporanga); D - Coelho (Remígio); E - Capivara (Solânea).

Apgaua et al. (2014), studying tree communities through plots in dry forest remnants, recorded six specimens of *S. brasiliensis*. Oliveira et al. (2009), studying plots in four forest remnants in mountains in the Cariri Oriental microregion in the municipalities of Caturité and Boqueirão (Paraíba) found only 32 specimens. Both studies recorded a smaller number of specimens in comparison with our research, excluding the community of Várzea Alegre, where no specimen was found.

São Francisco was one of the communities with the smallest number of specimens found during the guided tour, the second one in terms of specimens recorded, distributed in clusters (Figure 4A). An interesting fact is that some preserved specimens were found in private properties or yards. This preservation is intended for a potential resource, i.e., such specimens are a resource to be used in emergency times. These populations are located in small fragments of secondary forest, comprising areas that were used for agropastoral purposes several years ago and afterward abandoned, starting a recovery process, according to the locals.
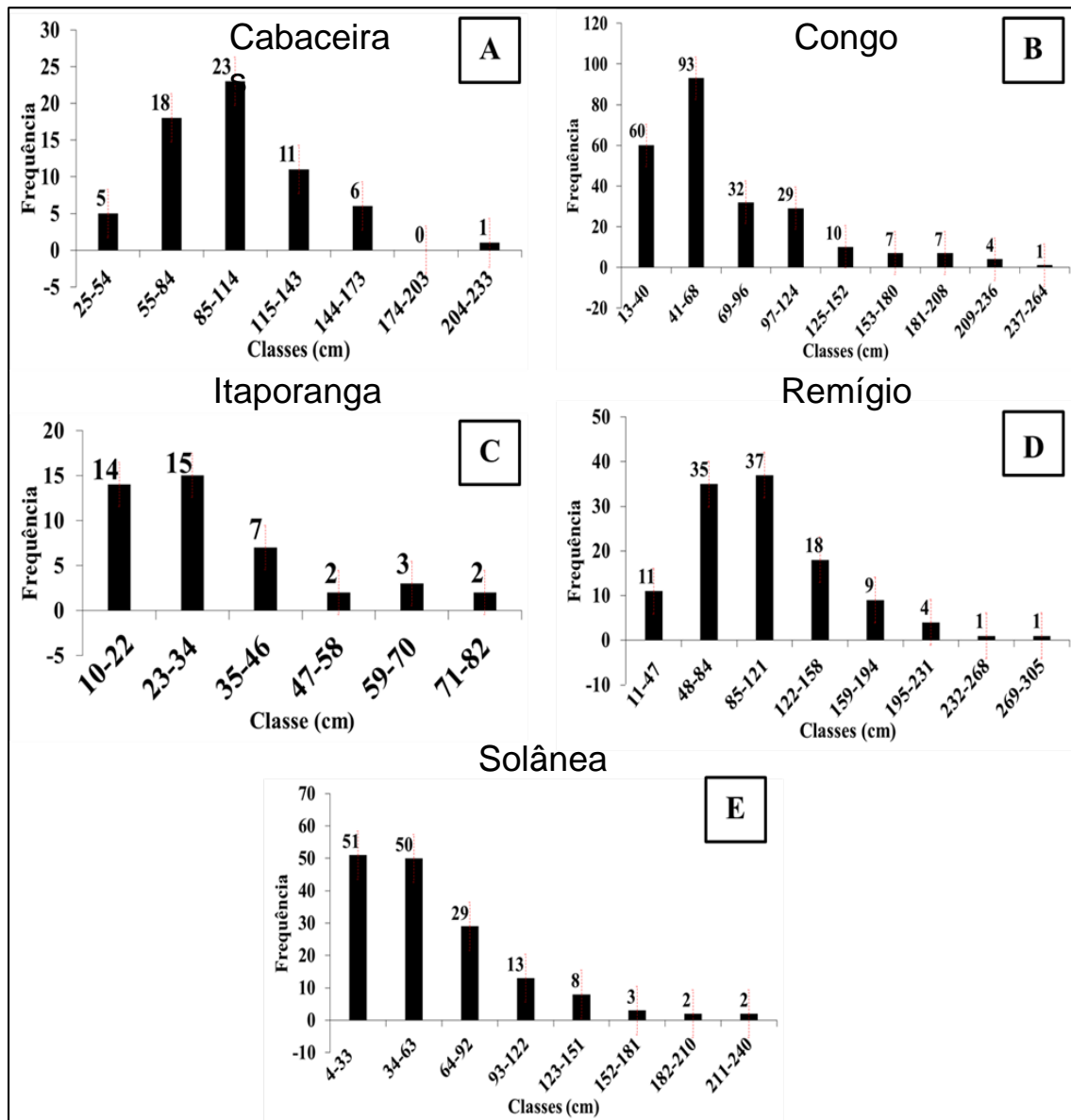
Figure 5. Classification of specimens of *Schinopsis brasiliensis* Engler in communities in the state of Paraíba, northeastern Brazil. A - São Francisco (municipality of Cabaceiras); B - Santa Rita (Congo); C - Pau D'Arco (Itaporanga); D - Coelho (Remígio); E - Capivara (Solânea).

A total of 243 specimens were recorded in Santa Rita (Figure 5B), which had a minimum height of 1 m and a maximum height of 22 m. All of them were grouped into classes, a minimum of 13 cm and a maximum of 264 cm. The 41-68 cm and 69-124 cm perimeter classes accounted for 38.27% and 25.10% of specimens, respectively. These two classes represent 63.37% of the total recorded population. Based on these perimeters, it can be assumed that the vast majority of the specimens in this community are adults (Figure 5).

Ferreira (2011), in a vegetation survey in the Cariri Paraibano, recorded 20 specimens of *S. brasiliensis*. Lima (2007), analyzing distribution patterns of woody species in the Caatinga in a single plot of 100 x 100 m, in the Brazilian semi-arid region, found 6 specimens. These differences in the number of specimens may be related to the water

needs in each region, in addition to the fact that, in protected areas or private properties, the species is found in a high number and clustered. This clustering strategy is quite common in caatinga species because when they are established in this way their growth and development become easier (Lorenzi and Matos, 2002; Silva et al., 2009). This pattern was observed in practically all the study communities.

Costa et al. (2009) argue that water availability can be a determining factor in the distribution of species. Other authors add that the greater or lesser number of species and their distribution are responses to a set of factors such as topographical condition, successional class, soil depth and permeability, and non-availability of water; however, the lack of water is the main limiting factor (Amaral et al., 2012).

Santa Rita stood out for having the highest number of specimens recorded during the guided tour, which were found distributed in clusters in areas of difficult access, such as mountains, dense vegetation, and private properties, away from main roads (Figure 4B). Kaminski et al. (2013), in research in the central region of Pernambuco, found that the arboreal vegetation is restricted to small fragments in valleys on the edges of intermittent water bodies, where the soil is visually sandier and deeper, and in areas more distant from living beings.

The smallest number of specimens found during the guided tour was recorded in the Community of Pau d'Arco, only 43 (Figure 4C), with a minimum and a maximum height of 1 m and 12 m, respectively. All specimens were grouped into classes, a minimum of 10 cm and a maximum of 82 cm. The majority (51.62%) were classified into the 23-46 cm perimeter class, suggesting the occurrence of an adult population, and 32.56% were classified into the 12-24 cm perimeter class (Figure 5C). This shows that, although the majority of specimens have high perimeters, which can indicate an adult and old population, almost 1/3 of the specimens are young, showing that this population may be in an ecological regeneration process.

The situation observed in Pau D'Arco can be understood based on the literature data, which show that most of the areas of Caatinga have already suffered anthropogenic disturbance for having species with quality and resistant wood; therefore, the specimens tend to be younger (Kaminski et al., 2013). Leite et al. (2012), in this same study area, using phytosociological survey plots, recorded only one specimen of *S. brasiliensis*.

Souza et al. (2012), studying forest fragments in Minas Gerais, observed that most of the arboreal specimens, for being denser, tend to be classified into the first diameter classes, being considered younger specimens. The ecological groups of initial and late secondary species have a high concentration of specimens in the smallest, indicating high regeneration due to the high number of specimens and, consequently, a promising advance for mature successional stages (Cabral, 2014).

Most of the specimens recorded in Pau D'Arco were distributed in clusters, in areas of difficult access, within forests and private properties, away from main roads and residences.

Regarding the community of Coelho, 116 specimens were recorded, with a minimum height of 3 m and a maximum height of 20 m. The specimens were grouped into classes, a minimum of 11 cm and a maximum of 305 cm. The majority (62.06%) were classified into the 48–121 cm perimeter class, which may indicate a late adult population (Figure 5D).

Although no information on the occurrence and distribution of *S. brasiliensis* was recorded in Remígio for comparison with specialized literature, a discussion can be made based on the data recorded in the other study communities. Coelho was one of the communities where specimens of *S. brasiliensis* were most found, with a considerable number. This may be justified by the cultural and economic regional context, as some people said in informal conversations not to use this species, contributing in a certain way to the maintenance of its local populations.

The fact that the vast majority of the specimens have had a large perimeter and that few young and regenerating species have been recorded can be explained by several environmental conditions, such as climate change, and changes in seasonality and water regime dynamics, as well as the lack of conditions for environmental recovery of degraded areas.

Concerning Capivara, 158 specimens were found (Figure 4E). This community was the second largest in the number of specimens recorded during the guided tour, which had a minimum height of 2.0 m and a maximum height of 23.0 m. All specimens were grouped into perimeter classes (a minimum of 4 cm and a maximum of 240 cm). Half of them (50%) were classified into the 34-92 cm class. The 4-33 cm class accounted for 32.27% specimens, corresponding to approximately 1/3 of the total population. Similar to what was observed in Itaporanga, the results obtained in Solânea are important because they may indicate that the population is in a recovery process, justified by the high number of young specimens (Figure 5E).

Durães et al. (2014), studying remaining areas of Caatinga, using the free walking method on the affluent banks of the São Francisco River in Montes Claros (Minas Gerais, Brazil) found only 7 specimens of *S. brasiliensis*. On the other hand, Barbosa et al. (2012), recorded no specimen in their research in 40 plots in the municipality of Arcoverde (Pernambuco, Brazil).

Comparative studies on species diameters when relating degraded areas to non-degraded areas showed that the number of young specimens in the first area is proportionally higher than in the second one, indicating some type of disturbance (Ferraz, 2011). Possibly, the study area (Capivara) has suffered disturbance for a long time and today, due to the residents' awareness, it is more preserved, as the uniformity pattern of specimens distributed in the classes is equivalent.

Occurrence and predictive modeling

The current occurrence and the climate scenarios (RCP4.5 and RCP85) (Figure 6A) indicate the areas most likely to have niche characteristics of *S. brasiliensis*. In this case, there is a small decrease in its occurrence in both climate scenarios, mainly in the state of Bahia. Maranhão is the only state that had no occurrence of this species.

Regarding predictive modeling (Figure 7B), it is possible to identify a small decrease in highly suitable habitat (0.6-0.8) and very highly suitable habitat (0.8-1.0) in eastern Bahia, and a slightly more significant decrease in suitable habitat (0.4-0.6) in eastern Piauí, central-eastern Ceará, and southern Bahia culminating in the expansion of unsuitable habitat (0-0.2) and barely suitable habitat (0.2-0.4) in those regions.

The slight decrease in suitable habitat in the pessimistic climate scenario can be interpreted in a positive way considering the possibility of species fragility to the consequences of climate change. It is worth mentioning this fact means that, even if there is an extreme change in bioclimatic variables that influence the niche conditions for the occurrence of *S. brasiliensis*, it will probably occur in areas where it can be found under the current conditions.

This can also be an auxiliary answer to understand the environmental condition of the species' occurrence areas, which may mean that even in a pessimistic scenario, the ecosystem will still be able to support a species of an advanced level of ecological succession such as *S. brasiliensis*. Nevertheless, statements like this can only be confirmed through more in-depth ecological and predictive studies that can diagnose the species vulnerability (Gallagher et al., 2018).

Final considerations

Schinopsis brasiliensis Engler was recorded in different perimeter classes and, consequently, different ages, heights, and locations, evidencing the heterogeneity of its populations in different regions of the state of Paraíba. However, adult specimens are predominant, positively indicating a possible decrease in the extraction of plant resources, especially by local human populations. Possibly, considering the decreased pressure on this species, it will tend to regenerate naturally, if larger-scale disturbances occur.

The fact that no specimen was found in Várzea Alegre during the guided tour does not indicate the study species is locally extinct; specimens may be distributed in areas of difficult access, so they were not found.

The regional analysis showed a slight decrease in the populations of *S. brasiliensis* in its occurrence area, which may indicate that climate changes do not significantly interfere with its distribution.
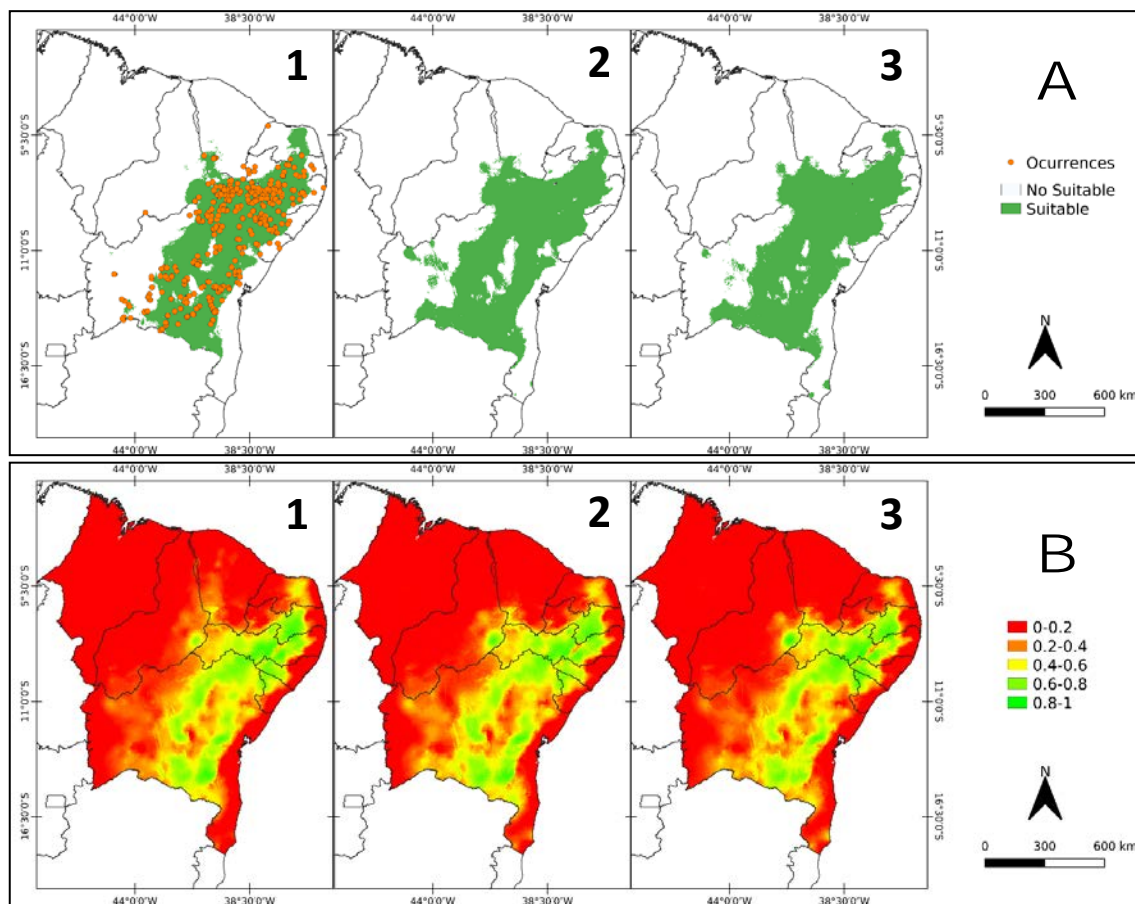

Figure 6. Distribution map of *S. brasiliensis* in northeastern Brazil. Where: A = current distribution; B = predictive distribution; 1 = species distribution areas; 2 = distribution according to the optimistic (RCP4.5) scenario; 3 = distribution according to the pessimistic (RCP8.5) scenario.

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