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Papers

Modeling and potential distribution of tree species relevant to the sociocultural and ecological dynamics in the Sete Cidades National Park, Piauí, Brazil

José Américo de Souza Gaia[1]
Bartolomeu Israel de Souza[2]
Reinaldo Farias Paiva de Lucena[3]
Ramon Santos Souza[4]
Carolina Lima Bezerra Gaia[5]

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Abstract
Ecological Niche Modeling is an important tool for establishing predictions of species distribution in geographic space. The Sete Cidades National Park, in Piauí, Brazil, is a Federal Conservation Unit for Integral Protection, with 6,221 hectares. The objective of this work was to determine the geographic distribution and to evaluate the impact of the variables in the prediction of the habitat of current suitability of some tree species. Six species were selected, according to their ecological and sociocultural value: Hymenaea courbaril L; Himatanthus drasticus (Mart.) Plumel; Parkia platycephala Benth .; Magonia pubescens A.St.-Hil .; Caryocar coriaceum Wittm and Handroanthus impetiginosus (Mart. Ex DC.). As a result, 130 tree species were identified, where it was identified that: the potential distribution of Parkia platycephala was concentrated in 26.19 km²; Himatanthus drasticus had the potential niche occupying 18.44 km²; Hymenaea courbaril had an estimated area of 16.19 km²; Handroanthus impetiginosus had a potential area estimated in the model at 12.01 km²; Caryocar coriaceum covered 15.06 km²; Magonia pubescens was estimated at 16.66 km². It was observed that in the landscape scale, the topoclimatic and texture variables of the vegetation cover presented a model with good performance and validity to predict the potential distribution.

[1] Universidade Federal da Paraíba, João Pessoa, Paraíba, Brazil. americogaia@hotmail.com
[2] Universidade Federal da Paraíba, João Pessoa, Paraíba, Brazil. bartolomeuisrael@gmail.com
[3] Universidade Federal da Paraíba, João Pessoa, Paraíba, Brazil. rlucena@dse.ufpb.br
[4] Universidade Federal da Paraíba, João Pessoa, Paraíba, Brazil. ramonssouza93@gmail.com
[5] Universidade Federal do Acre, Rio Branco, Acre, Brazil. carolina.gaia@hotmail.com

INTRODUCTION

Ecological niche modeling (ENM) has become a common procedure for determining the predictive distribution amplitude of tree species (AUSTIN, 2002; SOBERÓN; PETERSON, 2005). The model is an important tool because it can establish predictions of species distribution in the geographic space in several lines of studies, thus becoming a fundamental tool such as for the potential identification of rare or endangered species occurrence (GUISAN et al. 2006), as well as for choosing priority conservation areas (ARAÚJO et al., 2004), selecting species to recover degraded areas, and analyzing the effect of global climate change on biodiversity (HEIKKINEN et al., 2007).

In general, the ENM of predictive model of species distribution is based on a computational treatment, which combines occurrence data of one or more species with environmental variables, thus building a representation of the conditions required by the species (ANDERSON et al., 2003). Some algorithms have been applied to develop models that represent these conditions, projecting on a map showing the current and potential areas of species occurrence.

This method predicts an environmental suitability for species according to environmental variables. For this reason, the maximum entropy algorithm (Maxent) has been widely used to model this environmental suitability for one or more species, finding the maximum entropy distribution, i.e., more dispersed, or closer to the uniform, subject to a set of restrictions that represent incomplete information about the target distribution (PHILLIPS, et al. 2006).

Maxent belongs to a category of algorithms that allows the development of models even without records of species absence, because it generates pseudo-absences in the study area (WISZ et al. 2008). This characteristic is very important, mainly because for many biological species there are few available records of their absence (SOBERÓN; PETERSON, 2005). he Maxent method has been shown to be highly efficient for habitat modeling in studies that assess the predictive capacity of different algorithms (HIJMANS; GRAHAM, 2006; GIBSON et al. 2007; GUISAN et al. 2007).

This study aimed to determine the geographical distribution of some ecological and socio-cultural relevant tree species in the National Park of Sete Cidades (Piauí, Brazil) and evaluate the impact of the studied variables in the prediction of their habitat of current adequacy.

MATERIALS AND METHODS

This study was conducted in the National Park of Sete Cidades (SCNP), from May 21 to June 8, 2018, through an exploratory research in the internal area of the conservation unit and in its immediate surroundings (a buffer zone), specifically in the community of Cachoeira, aiming at identifying the occurrence of tree species and their relevance for use in this area. Data was collected with theof 27 residents of the rural community of Cachoeria (NUNES, 2019).

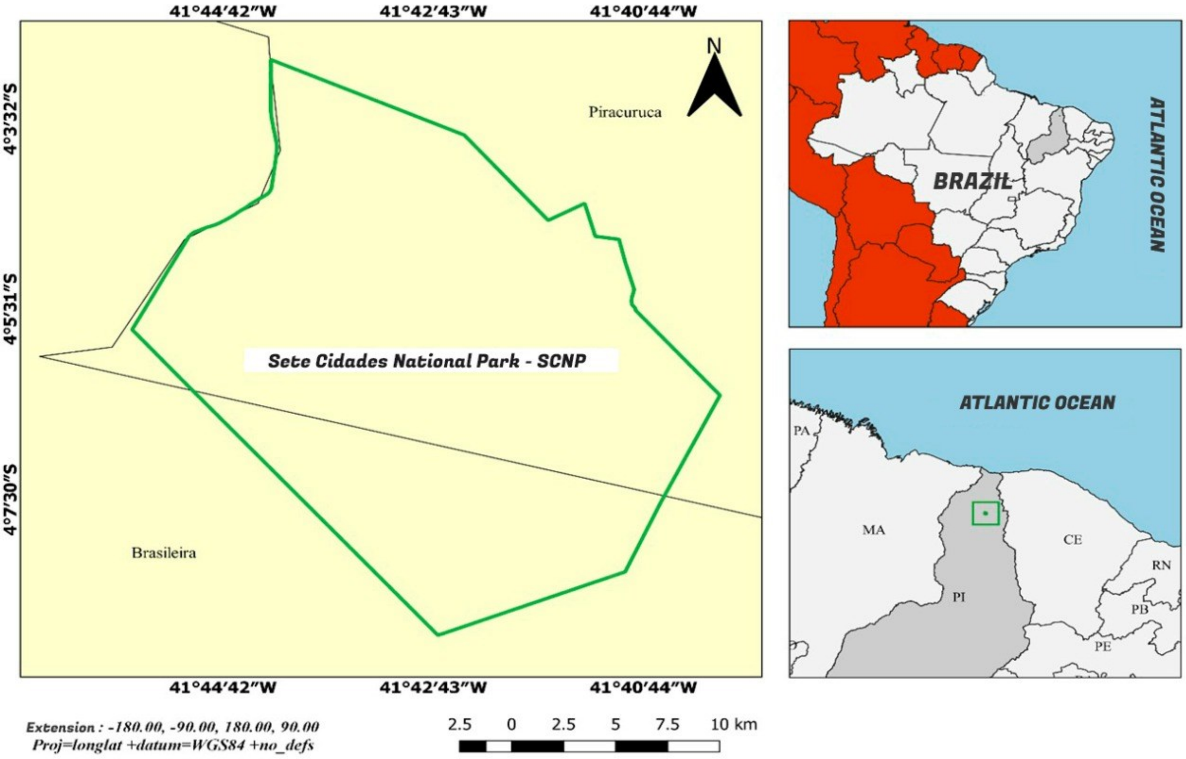
The walking method was used as field research technique in the SCNP, during 24 hours, to obtain phytophysiognomic information on the study area, elaborate a list of specimens, assess the current occurrence of species, and analyze results (FILGUEIRAS et al. 1994). The specimens were plotted using GPS, in the traditional format, in which longitude and latitude are represented in degrees and minutes. The quadrants of the globe were represented as N/S (north/south) and E/W (east/west)

The specimens identified during the walking were recorded based on their family, genus, species, habitat, habit, and occurrence. From this process, six species were selected according to the phytophysiognomy obtained in bibliographic searches and from the results of use value (UV), obtained from the information provided by the interviewed population (NUNES, 2019).

Characterization of the study area

The SCNP covers an area of 6,221 ha, with characteristics of different and interspersed biomes, characterizing an ecotonal zone between sub-humid and semi-arid areas (CASTRO et al. 2013). This conservation unit was instituted by Federal Decree No. 50,744 / 1961 and is located in the northeast region of Piauí, in the municipalities of Piracuruca and Brasileira, being accessed by highways BR-222, Piripiri/Fortaleza, and BR-343, Teresina/Parnaíba (MATOS; FELFILI, 2010) (Figure 1).

Figure 1. Location of the Sete Cidades National Park (Piauí, Brazil).



Source: by the authors, 2019.

In the Park, there are several springs that maintain intermittent streams: to the east and north, the water courses are affluents of the Piracuruca River, and to the west the courses feed the Brasileira stream (an affluent of Matos River), which comprise the Longa sub-basin, covering an area of 2,842 km² (MATOS; FELFILI, 2010).

The climate in the area is Aw (tropical climate, with dry winter), according to the Koppen classification system, with a mean annual temperature of 26.5°C, a maximum of 28.1°C, and mean annual rainfall of 1,200 mm (MATOS; FELFILI, 2010).

The relief of the park is characteristic of sedimentary basins, consisting of a pediplane surface with an altitude between 100 and 300 m with isolated hills in conical and tabular shapes. The regional vegetation is mainly characterized as a transition between the Cerrado and Caatinga biomes, with a predominance of species endemic to the Cerrado, with patches of open floodable fields and riparian forests (BARROS et al. 2014).

The SCNP has the followingvegetation coverage: occasionally flooded alluvial rainforest, semideciduous rainforest, open perennial latifoliate forest, open perennial latifoliate cerrado, extremely xeromorphic cerrado, and medium cespitous graminoid field (OLIVEIRA et al. 2007).

Environmental Data

The environmental database required for the modeling was made up of the ALOS/World 3D Digital Surface Model with 30 m of spatial resolution (AW3D30). The slope, in degrees and aspect, was calculated using the Google Earth Engine (GEE: <https://code.earthengine.google.com>).

Fluvial drainage was determined by the Terrain Analysis SAGA GIS algorithm, in QGIS 3.4 (QGIS Development Team, 2019).

The surface shapes and the Continuous Heat Insolation Load Index (CHILI), with spatial resolution of 90 m, were obtained from collections made available by Conservation Science Partners (THEOBALD et al. 2015). Maps of distances regarding shapes and surface drainage in the GEE were made.

The Soil-Adjusted Vegetation Index - SAVI (HUETE, 1988) was determined, using RED bands (Landsat 8 sensor) and NIR of the MSI/Sentinel-2 sensor (Multispectral Instrument on-board SENTINEL-2), from March 3, 2018, with 10 m spatial resolution, processed on the GEE platform.

Texture measurements based on SAVI were created using the Gray Level Coocurrence Matrix (GLCM) algorithm (HARALICK et al. 1973; CONNERS et al. 1984). The following texture descriptors were computed: mean, variance, correlation, contrast, dissimilarity, inverse difference moment (homogeneity), second angular moment and entropy.

All raster layers were cut to the extent of the SCNP and resampled at a resolution of 90 m. To reduce the multicollinearity between highly correlated variables, they were excluded from the model using Pearson's correlation ($r \geq 0.7$).

SAVIcor (correlation) and SAVIvar (variance) can be addressed as a result of this selection: aspect, elevation, slope, distance from the peak/summit (hot), distance from the upper slope (hot), distance from the upper slope (flat), distance from the lower slope (hot), distance from the lower slope (flat), distance from valleys and distance from the drainage.

Modeling

The ENM was performed using the MaxEnt software (version 3.3.3 k standards) to build the Maximum Entropy models, using the R software (programs or packages of the R programing packages that provides a wide variety of statistical techniques (linear and nonlinear modeling, classical statistical tests, time series analysis, classification, grouping, ..., R is available as Free Software under the terms of the "Free Software Foundation's GNU Public License" in source code form. It is compiled and executed on a wide variety of UNIX platforms and similar systems) by the MaxEnt algorithm (PHILLIPS et al. 2006), through the dismo package (oriented for modeling of species distribution) (HIJMANS et al. 2017). This algorithm has been shown to work better with small samples compared to other modeling methods (KUMAR; STOHLGREN, 2009).

The model was run using the Bootstrap method for 100 repetitions, selecting 75% and 25% of the data for training and testing the model, respectively (PHILLIPS, 2008), using k-fold partitioning.

The Jackknife test was performed to determine the importance of the variables. The area under the AUC curve or ROC curve (Area under the Receiving Operator Curve) was used to evaluate the model's performance. The AUC values range from 0 – 1 (FIELDING; BELL, 1997). A value of AUC up to 0.50 indicates that the model did not perform better than a random model, whereas a value of 1.0 indicates perfect discrimination (SWETS, 1988).

For later exhibition and analysis, predicting the presence of species (0–1), a reclassification was performed in the QGIS 3.4, based on a classification proposed by Yang et al. (2013) in five potential classes: unsuitable habitat (0–0.2); poorly suitable habitat (0.2–0.4); suitable habitat (0.4–0.6); highly suitable habitat (0.6–0.7); very highly suitable habitat (0.7–1.0). For each model, the distribution area was calculated, obtaining binary values of presence (1) and absence (0), using a cut-off threshold that maximizes the sum between sensitivity (true positives) and specificity (true negatives), according to the MaxSS test data, which simultaneously maximizes sensitivity and specificity (JIMÉNEZ-VALVERDE; LOBO, 2007; LIU et al. 2013).

RESULTS

One hundred and thirty tree species were identified, with the following potentials for use: food, fuel, construction, fodder, medicinal, ornamental, technology, poison-abortive, veterinary, and magical-religious. Pau d'arco (4.70), Pequi (3.3) and Jatobá (3.11) were the most expressive species, regarding the UV, and the most cited by the informants, followed by Janaguba (0.59), Faveira (0.59) and Tingui (0.22). Faveira and Janaguba have the highest occurrence in the SCNP, identified during the walking.

Evaluation of models and contributions of variables

The collection of data on the number of specimens (NS) per species, supports the development of models defined by their environmental variables and all models were statistically more robust than the random model ($AUC \geq 0.5$), (Table 1).

Table 1. SN and AUC for Maxent models.

Family	Species	Popular name	AUC	SN
Fabaceae	Parkia platycephala Benth.	Faveira	0.76	963
Apocynaceae	Himatanthus drasticus (Mart.) Plumel	Janaguba	0.82	780
Fabaceae	Hymenaea courbaril L.	Jatobá	0.83	845
Bignoniaceae	Handroanthus impetiginosus (Mart. ex DC.)	Pau d'arco	0.77	241
Caryocaraceae	Caryocar coriaceum Wittm	Pequi	0.86	302
Sapindaceae	Magonia pubescens A.St.-Hil.	Tingui	0.82	304

Source: by the authors, 2018.

The environmental variables and contributions related to the predictions of the Maxent models, classified by the mean relative importance of the species, are shown in Table 2.

Table 2. Predictive environmental variables for the selected plant species.

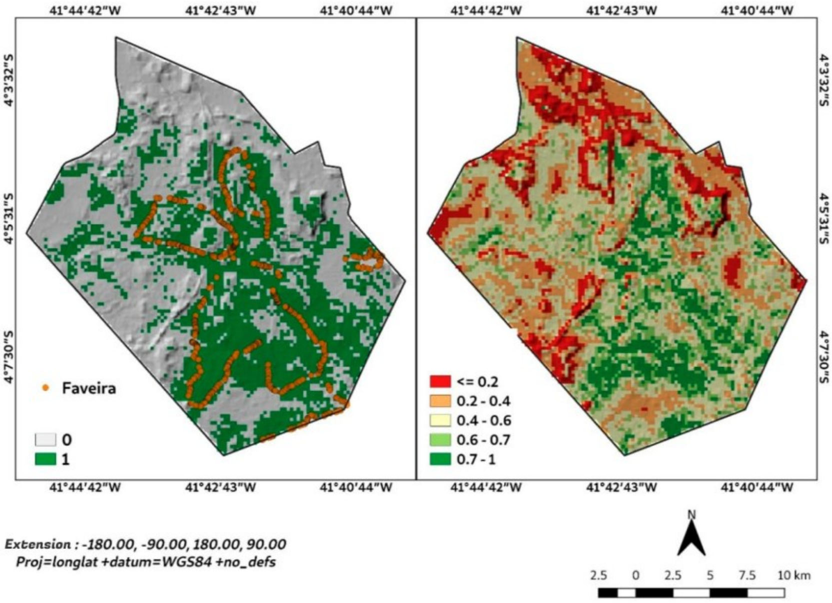
Variables	Parkia platycephala Benth.	Handroanthus impetiginosus (Mart. ex DC.)	Himatanthus drasticus (Mart.) Plumel	Hymenaea courbaril L.	Caryocar coriaceum Wittm.	Magonia pubescens A.St.-Hil.
aspect	9.10	21.28***	5.78	15.03**	6.22	9.99
elevation	10.37*	3.52	11.59*	9.62	14.86*	5.64
SAVIcor	1.64	1.29	0.38	18.48**	0.63	8.26
SAVIvar	2.26	4.44	2.25	4.81	0.29	0.94
slope	51.89***	19.71**	40.46***	25.94***	19.16**	37.65***
distance from the peak/summit (hot)	8.42	12.26*	24.59***	2.10	31.58***	5.30
distance from the upper slope (hot)	1.53	16.31**	5.39	3.28	4.66	20.50***
distance from the upper slope (flat)	6.13	0.52	3.29	7.45	1.44	1.35
distance from the lower slope (hot)	4.82	6.84	3.78	4.00	2.02	3.76
distance from the lower slope (flat)	1.78	9.44	1.94	0.17	12.73*	1.12
distance from valleys	0.66	1.52	0.25	8.28	0.31	2.95
distance from drainage	1.41	2.87	0.29	0.84	6.09	2.55

Prediction: ***relative importance >20%, **relative importance >15%, and *relative importance >10%).
Source: by the authors, 2019.

Potential Distribution of Species

The predictive map obtained in the modeling shows that *Parkia platycephala* covers the largest area of potential occurrence (26.19 km²) among the other species, distributed mainly in areas close to or partially flooded by streams. The presence of this species, when not associated with water courses, is associated with smooth-wavy relief (Figure 2).

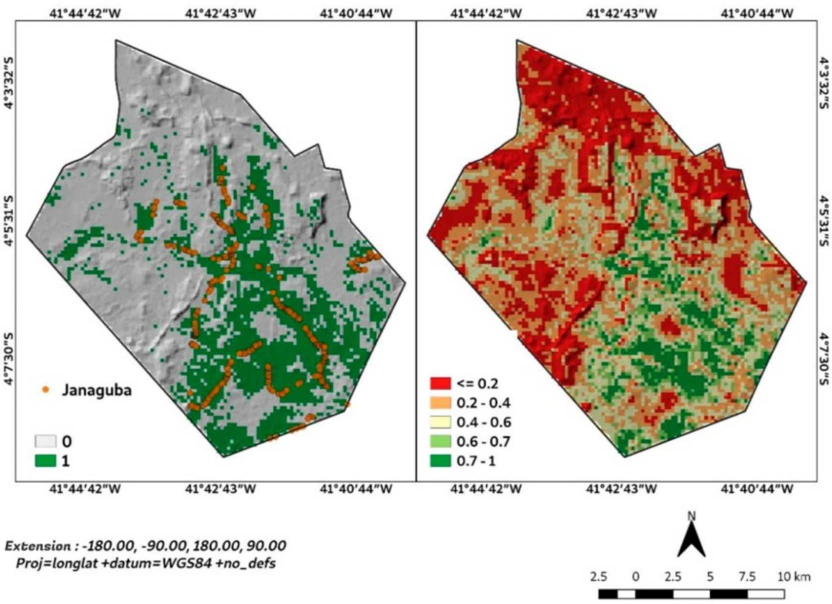
Figure 2. Prediction of current habitat for *Parkia platycephala*: (a) binary map and distribution points and (b) potential distribution.



Source: by the authors, 2019.

The potential niche of *Himatanthus drasticus* extended for 18.44 km², mainly distributed in mosaics of forest spots, field formations, or in areas flooded by perennial and temporary streams (Figure 3).

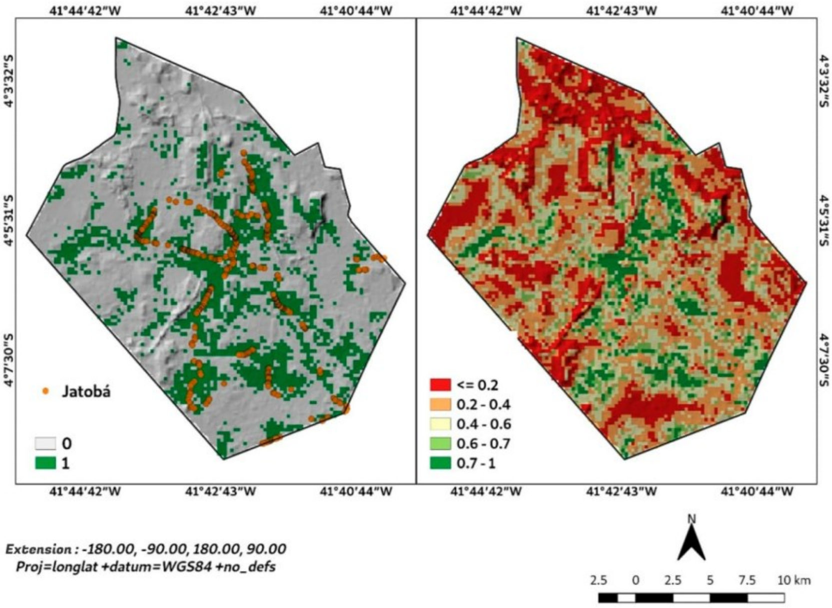
Figure 3. Prediction of current habitat for *Himatanthus drasticus*: (a) binary map and distribution points and (b) potential distribution.



Source: by the authors, 2019.

The potential niche of *Hymenaea courbaril* was estimated at 16.19 km², distributed in areas close to or partially flooded by streams, mainly concentrated in tree-shrub vegetation areas (Figure 4).

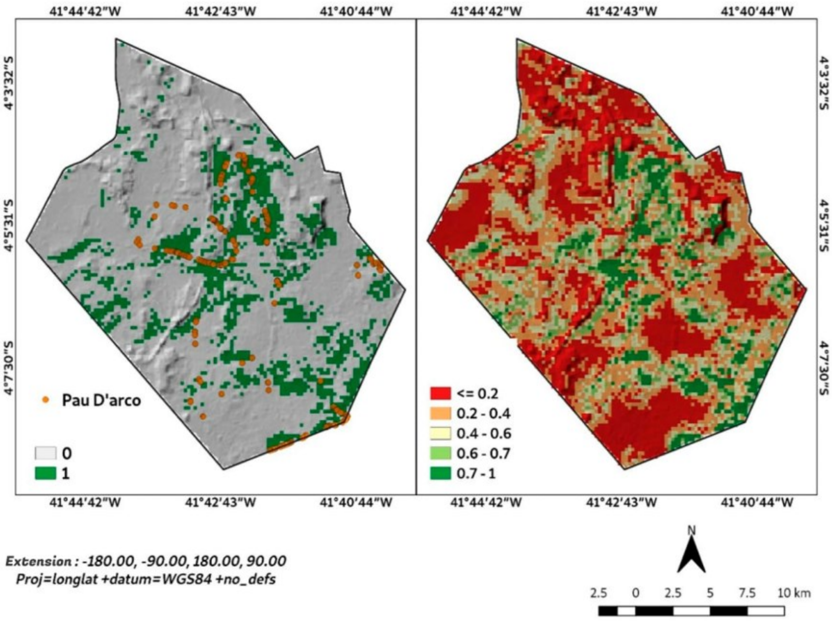
Figure 4. Prediction of current habitat for *Hymenaea courbaril*: (a) binary map and distribution points and (b) potential distribution.



Source: by the authors, 2019.

The model predicted 12.01 km² of current potential area for *Handroanthus impetiginosus*, mainly distributed in areas bordering water bodies and in open areas of Cerrado, with characteristics of forests in secondary succession process (Figure 5).

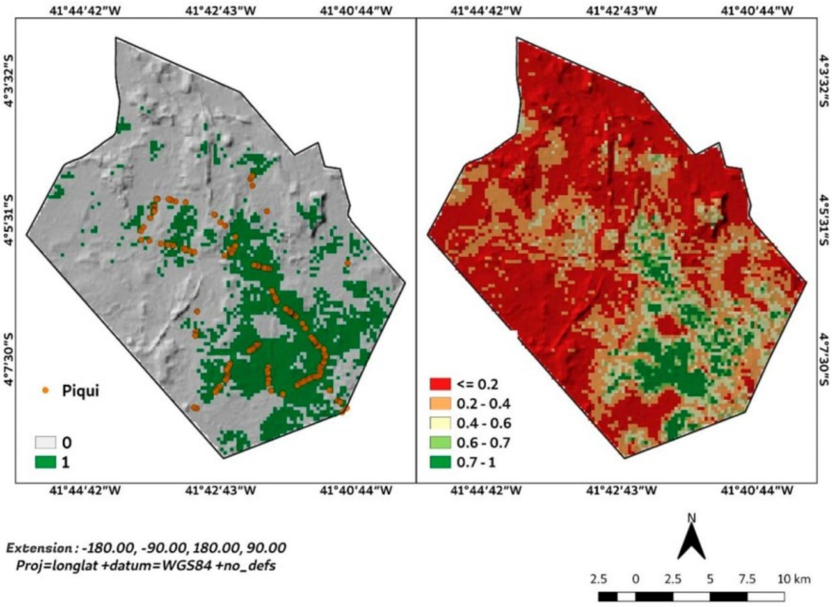
Figure 5. Prediction of current habitat for *Handroanthus impetiginosus*: (a) binary map and distribution points and (b) potential distribution.



Source: by the authors, 2019.

The potential map for *Caryocar coriaceum* comprised 15.06 km², characterized by a distribution concentrated in the central and southeastern regions of the Park (Figure 6).

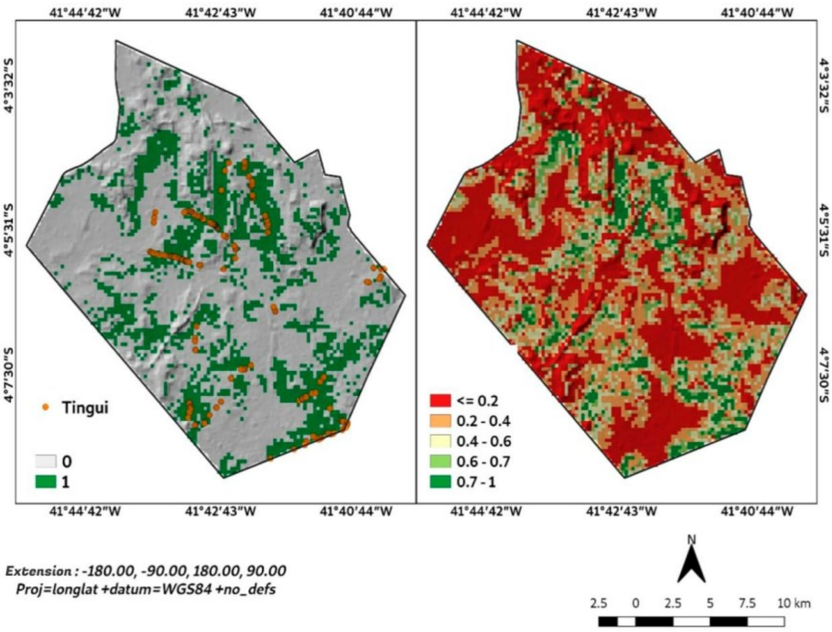
Figure 6. Prediction of current habitat for *Caryocar coriaceum*: (a) binary map and distribution points and (b) potential distribution.



Source: by the authors, 2019.

Magonia pubescens covered the second largest potential area (16.66 km²) among the species, characterized by a distribution in higher altitudes, in agglomerated plant fragments, and in a more open cerrado vegetation (Figure 7).

Figure 7. Prediction of current habitat for *Magonia pubescens*: (a) binary map and distribution points and (b) potential distribution.



Source: by the authors, 2019.

DISCUSSION

Evaluation of models and contributions of variables

Topoclimatic variables such as elevation, slope, aspect (degree of relief exposure), distance from the peak/summit (hot), distance from the upper slope (hot), and distance from the lower slope (flat) play an important role in the potential distribution of species. Therefore, the characteristics of changes in phytophysiognomy and biodiversity of plants typical of the Cerrado are also related to topographic characteristics that favor the difference in the soil water regime, declivity and rockiness (LINDOSO et al. 2011).

Thus, the conditioning factors of land surface slope are responsible for the transport dynamics of leached material from high to low areas, conditioning a fertility gradient, produced by a water flow converging on concave surfaces and diverging on convex surfaces, favoring the development of species (BOTREL et al. 2002; RESENDE et al. 2007).

Thus, slope is considered an important factor for the distribution of *Parkia platycephala*, *Himatanthus drasticus*, *Hymenaea courbaril*, and *Magonia pubescens*.

The elevation stood out for *Parkia platycephala*, *Himatanthus drasticus*, and *Caryocar coriaceum*. This variable can be related to the so-called indirect gradients, which are those in which the variable has no direct effect on plant physiology, but has a correlation with other factors such as temperature and rainfall (AUSTIN, 2002).

The aspect as a factor of species exposure to luminosity due to the relief is also a limiting factor to the distribution of some species such as *Himatanthus drasticus*, *Handroanthus impetiginosus*, *Caryocar coriaceum*, and *Magonia pubescens*. Topographic variables are indirectly related to productivity and water retention capacity of the soil, where forest formations such as gallery forest and riparian forest are closely linked to streams and rivers (SOLÓRZANO, 2011).

The aspect can also play the role of presence or absence surrounding the topography that causes shade, besides controlling solar insolation, resulting in a direct effect on soil temperature and evapotranspiration rate. Therefore, precipitation rates uniformly distributed in the area, with higher evapotranspiration rates, depending on the slope position, results in a decrease in soil moisture or water accumulation in rocks (PELLETIER; SWETNAM, 2017).

Potential Distribution of Species

The habitats of the tree species (*Parkia platycephala*) with the largest area of suitability, about 22% of the total limit of the SCNP, were mapped in this research.

Himatanthus drasticus, a shrub-tree species typical of the Cerrado, had the second largest area of suitability (16% total limit of the Park). In another study in the SCNP, Castro et al. (2010) point out that the typical Cerrado covers the largest area of the park (37.6%), characterized by the presence of two strata (herbaceous-shrub and shrub-tree). Thus, the results obtained in the present study confirm this information.

Juvenile specimens of *Himatanthus drasticus* were found after recurrent fires, which apparently justifies the predominant distribution of this species, as it can sprout from roots after the death of its aerial parts by fire (MORO et al. 2011).

Magonia pubescens had the second largest area of suitability (14.44%), corroborating the results found by Carvalho (2016), who found an abundant presence of this species in the park, in the shrub-tree strata.

Different light intensities can cause changes in seedling morphology and physiology, depending on the level of species accommodation (SCALON et al. 2003). In this context, species of gallery forest have shown better initial growth under intermediate light conditions (VALADÃO et al. 2014), although results on perfect light conditions are questioned. Salgado and Laboriau (1973) found that Tingui seeds germinate only in the presence of light, being classified as positive photoblastic. On the other hand, Joly et al. (1980) state that seeds of this species are not influenced by light.

Hymenaea courbaril covered an area of 14.03%. This species has considerable ecological importance because it is tolerant and resistant to unfavorable environmental conditions under which other species cannot survive, some of which are among the most present in gallery forests, usually close to springs or along rivers and streams, contributing to their protection.

Thus, this species can be used for reforestation of degraded areas and riparian forest, in poorly wetted or well-drained soils (DURIGAN et al. 1990), and is also considered promising for recovering areas contaminated by heavy metals: cadmium (Cd), lead (Pb), copper (Cu) and zinc (Zn) (MARQUES et al. 1997). This is a prominent species in savanna formations, open cerrado vegetation cover (OLIVEIRA et al. 2007). This species is from riparian forest and open field.

Caryocar coriaceum is distributed in 13.06% of the SCNP's area, and is highlighted by Mesquita and Castro (2007) as one of the tree species of Cerrado *lato sensu* most present in the park.

The man (collectors), agouti (*Dasyprocta aguti*), deer (*Ozotoceros bezoarticus*), "mocó" (*Kerodon rupestris*), seriema (*Cariama cristata*), jacu (*Penelope* sp.), and even a scarab beetle species are the main dispersion agents of Pequi (FERREIRA et al. 2009). There are reports of bats (MELO-JUNIOR, et al. 2004) and also large-sized ants (glass-head ants) contributing as dispersers of this species (FERREIRA et al. 2009).

Local knowledge of species occurrence

Traditional knowledge brings an inevitable link between culture and human society. The development of a community, constructions, theories of diseases, diagnoses, treatment and cure are part of the cultural index of groups of people and vary in time and space in line according to cultural variation (RIVERS, 1924; NASCIMENTO; CÓRDULA, 2016; NASCIMENTO et al. 2014).

Local knowledge leads to the classification and concepts attributed to the use of plants, requires responsibilities and respect, consisting of traditions that span generations. The information regarding local knowledge aims to comprise relationships between plants and human culture. Thus, the use values of the species recorded in the community of Cachoeira were relevant and supported the present research.

Jatobá is widely used in the wood trade, popular medicine, furniture production, and civil and naval construction, and is relevant for indigenous peoples and traditional, agroextractive and agricultural communities, in consumption and as a productive chain, ranging from collection to marketing of fruits and derivatives. It is consumed as food and used for phytotherapic and artisanal purposes (COSTA, 2011; COSTA et al. 2015).

Janaguba has a very high ecological importance, considering that it grows at altitudes ranging from 200 to 1500 m, composing the cerrado and caatinga vegetation, and blooms and fructifies practically all year round. It is a species very representative in popular medicine, and its latex has given relevant answers for the treatment and cure of some types of cancer (AMARO et al. 2006).

Pequi, which is a perennial tree, classified as a fruit or oleaginous species, used for numerous purposes and applications in the artisanal industry, pharmacology, and regional cuisine, in addition to the potential for use in the production of fuels and lubricants (GOMES, et al. 2015).

Faveira stands out for its timber potential and is used as green manure and for reforestation of degraded areas, as well as in the production of fodder, as ripe pods are excellent in feeding ruminants (ALVES et al. 2007).

Pau d'arco has high density, durability and high value in the manufacture of furniture and floors, and in pharmacological application, using branches, leaves, stem, bark and inner bark, with anti-inflammatory, analgesic, antibiotic and antineoplastic activities (LORENZI, 2013).

From the Tingui bark, tannins can be extracted for the elimination of *Aedes aegypti* larvae and ticks (*Rhipicephalus microplus*) (SILVA et al. 2004). This species is also cited as capable of causing death when its roots are ingested in high doses and in the form of decoction (BRANDÃO et al. 2002).

FINAL CONSIDERATIONS

The species studied on a landscape scale, as for topoclimatic and texture variables of the vegetation cover, presented a model with good performance and validity to predict the potential distribution of the studied tree species.

About the binary maps of prediction of the current habitat of the highlighted plant species, the obtained results make it possible to monitor their distributions more precisely and, if necessary, redistribute them within the park and in the buffer zone.

Therefore, the results of the model can be used to support the management of the Park. Studies including more anthropogenic variables such as land use, as well as other biotic factors, such as dispersion range and competition, can be carried out to strengthen this research.

Despite the high use value recorded, mainly for *Handroanthus impetiginosus*, *Caryocar coriaceum*, and *Hymenaea courbaril* L., none of them are on the list of endangered species.

It is worth mentioning that the use of these species, of great utility and high commercial value, by the communities surrounding the SCNP, suffers restrictions within the park, due to the inspection and control by environmental bodies; thus, it is possible to observe these species abundance inside this conservation unit, in contrast with their relative scarcity in many surrounding areas. Therefore, there is a relative tension between the preservation role played by the park and the neighboring communities, which requires the development of alternatives in view of this situation in the surrounding areas, such as environmental education and the development of reforestation projects for extractive purposes.

REFERENCES

ALVES, A. A.; SALES, R. O.; NEIVA, J. N. M.; MEDEIROS, A. N.; BRAGA, A. P.; AZEVEDO, A. R. Degradabilidade ruminal in situ de vagens de faveira (*Parkia platycephala* Benth.) em diferentes tamanhos de partículas. **Revista Brasileira de Medicina Veterinária e Zootecnia**, v. 59, n. 4, p. 1045-1051, 2007. https://doi.org/10.1590/S0102-09352007000400034

AMARO, M. S.; MEDEIROS FILHO, S.; GUIMARÃES, R. M.; TEÓFILO, E. M. Morfologia de frutos, sementes e de plântulas de janaguba (*Himatanthus drasticus* (Mart.) Plumel - Apocynaceae). **Revista Brasileira de Sementes,** n. 28, v.1, 2006, p. 63-71, 2006. https://doi.org/10.1590/S0101-31222006000100009

ANDERSON, R. P.; LEW, D.; PETERSON, A.T. Evaluating predictive models of species' distributions: criteria for selecting optimal models. **Ecological Modelling** 162: 211-232. 2003. https://doi.org/10.1016/S0304-3800(02)00349-6

ARAÚJO, M. B.; CABEZA, M.; THUILLER, W.; HANNAH, L.; WILLIAMS, P. H. Would climate change drive species out of reserves? An assessment of existing reserve-selection methods. **Global Change Biology**, v. 10, n. 9, p. 1618-1626. 2004. https://doi.org/10.1111/j.1365-2486.2004.00828.x

AUSTIN, M. P. Spatial prediction of species distribution: an interface between ecological theory and statistical modelling. **Ecological modelling,** v. 157, n. 2-3, p. 101-118. 2002. https://doi.org/10.1016/S0304-3800(02)00205-3

BARROS, J. S.; FERREIRA, R. V.; PEDREIRA, A. J.; SCHOBBENHAUS, C. MINISTÉRIO DE MINAS E ENERGIA-SECRETARIA DE GEOLOGIA, MINERAÇÃO E TRANSFORMAÇÃO MINERAL. **Projeto Geoparques GEOPARQUE SETE CIDADES – PEDRO II - PI Proposta.** Serviço Geológico do Brasil - CPRM, 2014.

BOTREL, R. T.; OLIVEIRA FILHO, A. T; RODRIGUES, L. A.; CURI, N. Influência do solo e topografia sobre as variações da composição florística e estrutura da comunidade arbóreo-arbustivo de uma Floresta Estacional Semidecidual em Ingaí, - MG. **Revista Brasileira de Botânica**, v. 25, p. 195-213. 2002. https://doi.org/10.1590/S0100-84042002000200008

BRANDÃO, M.; LACA-BUENDIA, J. P.; MACEDO, J. F. **Árvores nativas e exóticas do Estado de Minas Gerais**. Belo Horizonte: EPAMIG, 528P. 2002.

CARVALHO, N. S. **Propriedades microbiológicas do solo ao longo de um gradiente vegetacional de cerrado no Parque Nacional de Sete Cidade.** 2016. 48f. Dissertação (Mestrado em Agronomia) – Universidade Federal do Piauí, Teresina, 2016.

CASTRO, A. A. J. F.; ARZABE, C.; CASTRO, N. M. C. F. Classificação e Caracterização dos Tipos Vegetacionais do Parque Nacional de Sete Cidades, Piauí, Brasil. Biodiversidade e ecótonos da região setentrional do Piauí. Teresina: EDUFPI, 2010. 208 p. (**Série Desenvolvimento e Meio Ambiente, 5**), 2010.

CASTRO, A. A. J. F. ; SILVA, C. B.; FARIAS, R. R. S.; RAMOS NETO, M. B. **Flora lenhosa em fragmentos de Floresta Estacional Semidecidual no Parque Nacional de Sete Cidades (PN7C), Piauí, Brasil**. In: Santos-Filho FS, Soares AFCL, Almeida Junior EB. (eds.) Biodiversidade do Piauí: pesquisas & perspectivas. Curitiba, Editora CRV. p. 101-119. 2013.

CONNERS, R. W.; Trivedi, M. M. and Harlow, C. A. **"Segmentation of a High-Resolution Urban Scene Using Texture Operators"**, Computer Vision, Graphics, and Image Processing, Vol. 25, pp. 273-310. 1984. https://doi.org/10.1016/0734-189X(84)90197-X

COSTA, C. B.; CASTELLAN, D. C.; SOUZA, A. L.; SILVA, A. C. **Boas Práticas de Manejo para o Extrativismo Sustentável do Jatobá**. Brasília: Instituto Sociedade,

População e Natureza, ISBN 978-85-63288-16-5. 76 p., 2015.
COSTA, W. S. Projeto: **Prospecção do conhecimento científico de espécies florestais nativas** (Convênio de Cooperação Técnica FAPEMIG / FUNARBE). Polo de Excelência em Florestas Universidade Federal de Viçosa, Viçosa-MG. Departamento de Engenharia Florestal Universidade Federal de Viçosa. Viçosa – MG. Março, 2011.
DURIGAN, G.; DIAS, H. C. de S. Abundância e diversidade da regeneração natural sob mata ciliar implantada. In: Congresso Florestal Brasileiro, 6, Campos do Jordão. **Anais. São Paulo: Sociedade Brasileira de Silvicultura**, v.3, p.308-312. Publicado na Silvicultura, n.42, 1990.
FERREIRA, G. A.; SANTOS-VELOSO, V. R.; VELOSO-NAVES, R.; NASCIMENTO, J. L.; CHAVES, L. J. Biodiversidade de insetos em Pequizeiro (*Caryocar brasiliense*, Camb.) no cerrado do Estado de Goiás, Brasil. **Agrociencia Uruguay,** v. 13, n. 2, 2009.
FIELDING, A. H., BELL, J. F. A review of methods for the measurement of prediction errors in conservation presence/absence models. **Environ. Conserv**, 1997. https://doi.org/10.1017/S0376892997000088
FILGUEIRAS, T.S., BROCHADO, A.L., NOGUEIRA, P.E. & GUALLA II, G.F. Caminhamento - Um método expedito para levantamentos florísticos qualitativos. In: **Caderno de Geociência IBGE**. 12: 39-43. 1994.
GIBSON, L., BARRETT, B., BURBIDGE, A. Lidando com a ausência incerta na modelagem de habitat: estudo de caso de uma terra rara no solo . **Diversity and Distributions** 13, 704-713. 2007.
GOMES, S. O.; SILVA, R. A. O.; MARQUES, L. G. A.; SANTOS, M. R. M. C. **Prospecção tecnológica: potencialidades de uso do pequizeiro (*caryocar spp.*)**. Revista GEINTEC – ISSN: 2237-0722. São Cristóvão/SE. Vol. 5/n. 1/ p.1617-1625 1617, 2015. https://doi.org/10.7198/S2237-0722201500010002
GUISAN, A.; BROENNIMANN, O.; ENGLER, R.; VUST, M.; YOCCOZ, N. G.; LEHMANN, A.; ZIMMERMANN, N. E. Using niche-based models to improve the sampling of rare species. **Conservation Biology** 20: 501-511. 2006. https://doi.org/10.1111/j.1523-1739.2006.00354.x
GUISAN, A.; GRAHAM, C. H.; ELITH, J.; HUETTMANN, F.; The NCEAS **Species Distribution Modelling Group. Sensitivity of predictive species distribution models to change in grain size.** Diversity and Distributions 13: 332-340. 2007. https://doi.org/10.1111/j.1472-4642.2007.00342.x
HARALICK, R. M.; SHANMUGAM, K.; DINSTEIN, I. **"Textural Features for Image Classification"**, IEEE Trans. on Systems, Man and Cybernetics, Vol. SMC-3, pp. 610-621. 1973. https://doi.org/10.1109/TSMC.1973.4309314
HEIKKINEN, R. K.; LUOTO, M.; VIRKKALA, R.; PEARSON, R. G.; KÖRBER, J. H. BIOTIC interactions improve prediction of boreal bird distributions at macro-scales. **Global Ecology and Biogeography** 16: 754-763. 2007. https://doi.org/10.1111/j.1466-8238.2007.00345.x
HIJMANS, R. J.; PHILLIPS, J.; LEATHWICK, J. E. **Dismo: Species distribution modeling. R package version 1.1–4**. Date/Publication 2017-01-09 09:49:36. https://cran.r-project.org/web/packages/dismo/dismo.pdf. 2017.
HIJMANS, R. J.; GRAHAM, C.H. The ability of climate envelope models to predict the effect of climate change on species distributions. **Global Change Biology** 12: 2272-2281. 2006. https://doi.org/10.1111/j.1365-2486.2006.01256.x
HUETE, A. R. A. Soil-Adjusted Vegetation Index (SAVI). **Remote Sensing of Environment,** v. 25, p. 295-309. 1988. https://doi.org/10.1016/0034-4257(88)90106-X
JIMÉNEZ-VALVERDE, A.; LOBO, J. M. Threshold criteria for conversion of probability of species presence to either–or presence–absence. **Acta oecologica**, v. 31, n. 3, p. 361-369. 2007. https://doi.org/10.1016/j.actao.2007.02.001
JOLY, C. A.; FELIPPE, G. M.; DIETRICH, S. M. C.; CAMPOSTAKAKI, G. M. Physiology of germination and seed gel analysis in two populations of Magonia pubescens St. Hil. **Revista Brasileira de Botânica**, São Paulo, v. 3, p. 1-9. 1980.
KUMAR, S.; STOHLGREN, T. J. Maxent modeling for predicting suitable habitat for threatened and endangered tree *Canacomyrica monticola* in New Caledonia. **J. Ecol. Nat. Environ.** n. 1, p. 94-98. 2009.
LINDOSO, D. et al. **Climate Change and Vulnerability to drought in the Semiarid: the case of smallholder farmers in the**

Brazilian northeast. In: SEROA DA MOTTA, R. et al. (Eds.). Climate change in Brazil: economic, social and regulatory aspects. Brasilia: IPEA, p. 235–256. 2011.

LIU, C., WHITE, M.; NEWELL, G. Selecting thresholds for the prediction of species occurrence with presence-only data. **Journal of Biogeography** n. 40, p.778-789. 2013. https://doi.org/10.1111/jbi.12058

LORENZI, H. **Árvores brasileiras: manual de identificação e cultivo de plantas arbóreas nativas do Brasil**. 4. ed. Nova Odessa, SP: Instituto Plantarum, 384p., 2013.

MARQUES, T. C. L. L. S.; SIQUEIRA, J. O.; MOREIRA, F. M. S. **Crescimento de mudas de espécies arbóreas em solo contaminado com metais pesados.** In: SIMPÓSIO MATOS, M. Q.; FELFILI, J.M. Florística, fitossociologia e diversidade da vegetação arbórea nas matas de galeria do Parque Nacional de Sete Cidades (PNSC), Piauí, Brasil (PNSC), Piauí, Brazil. **Acta botânica brasílica**, v. 24, n. 2, p. 483-496. 2010. https://doi.org/10.1590/S0102-33062010000200019

MATOS, M. Q.; FELFILI, J. M. Florística, fitossociologia e diversidade da vegetação arbórea nas matas de galeria do Parque Nacional de Sete Cidades (PNSC), Piauí, Brasil (PNSC), Piauí, Brazil. **Acta botânica brasílica**, v. 24, n. 2, p. 483-496, 2010. https://doi.org/10.1590/S0102-33062010000200019

MELO-JUNIOR, A. F. de; CARVALHO, D.; POVOA, J. S. R.; BEARZOLI, E. Estrutura genética de populações naturais de pequizeiro (*Caryocar brasiliense* Camb). **Scientia Forestalis**, Piracicaba, v. 66, p. 56-65. 2004.

MESQUITA, M. R.; CASTRO, A. A. J. F. **Florística e fitossociologia de uma área de cerrado marginal (Cerrado Baixo), Parque Nacional de Sete Cidades, Piauí.** Publicações Avulsas em Conservação de Ecossistemas 15: 1–22. 2007. https://doi.org/10.18029/1809-0109/pace.n15p1-22

MORO, M. F.; CASTRO, A. S. F.; ARAÚJO, F. S. **Composição florística e estrutura de um fragmento de vegetação savânica sobre os tabuleiros prélitorâneos na zona urbana de Fortaleza, Ceará.** Rodriguésia 62:407-423 2011. https://doi.org/10.1590/2175-7860201162214

NACIONAL DE RECUPERAÇÃO DE ÁREAS DEGRADADAS, 3., Ouro Preto. **Do substrato ao solo: trabalhos voluntários.** Viçosa: Universidade Federal de Viçosa, 1997. p.429-436. 1997.

NASCIMENTO, G. C. C.; CÓRDULA, E. B. L. Tradições, cultura e misticismo nas comunidades tradicionais: **'A antropólog'**. **Educação Pública**, Rio de Janeiro, v. 16, n. 5, 2016.

NASCIMENTO, M. E. C.; NASCIMENTO, G. C. C.; CÓRDULA, E. B. L. **Cultura e a oralidade nos contos tradicionais. Educação Pública**, Rio de Janeiro, v.14, n. 20, 2014.

NUNES, G. M. **Disponibilidade e uso de plantas medicinais na zona de amortecimento do Parque Nacional de Sete Cidades. Piauí – Brasil**. Dissertação (mestrado). Universidade Federal da Paraíba, 2019.

OLIVEIRA, M. E. A; MARTINS, F. R.; CASTRO, A. A. J. F.; SANTOS, J. R. Classes de cobertura vegetal do Parque Nacional de Sete Cidades (transição campo-floresta) utilizando imagens TM/Landsat, NE do Brasil. **Anais XIII Simpósio Brasileiro de Sensoriamento Remoto, Florianópolis, Brasil**. 21-26 abril 2007, INPE, p. 1775-1783. 2007.

PELLETIER, J. D.; SWETNAM, T. L. Asymmetry of weathering-limited hillslopes: the importance of diurnal covariation in solar insolation and temperature. **Earth Surface Processes and Landforms,** v. 42, n. 9, p. 1408-1418. 2017. https://doi.org/10.1002/esp.4136

PHILLIPS, S. J. Transferability, sample selection bias and background data in presence-only modeling: a response to Peterson et al. and **Ecography,** n.31, p.272–278, 2008. https://doi.org/10.1111/j.0906-7590.2008.5378.x

PHILLIPS, S. J.; ANDERSON, R. P.; SCHAPIRE, R.E. Maximum entropy modeling of species geographic distributions. **Ecol. Model.** n. 190, p. 231–259. 2006. https://doi.org/10.1016/j.ecolmodel.2005.03.026

RESENDE, M.; CURI, N.; REZENDE, S. B.; CORRÊA, G. F. **Pedologia: base para distinção de ambientes**. 5. ed. Lavras, Editora da UFLA, 2007.

RIVERS, W. H. R. ***Medicine, magic and religion.*** London, Kegan Paul, 1924.

SALGADO-LABORIAU, M. L. S. A semente de *Magonia pubescens* St. Hil. - Morfologia e germinação. **Anais da Academia Brasileira de Ciências**, Rio de Janeiro, v. 45, n. 3, p. 1-537, 1973.

SCALON, S. P. Q.; MUSSURY, R. M.; SCALON FILHO, H. **Crescimento inicial de mudas**

de Bombacopsis glabra (Pasq.) A. Robyns sob diferentes níveis de sombreamento. Revista Árvore, v. 27, n. 6, p. 753-758. 2003. https://doi.org/10.1590/S0100-67622003000600001

SILVA, H. H. G.; SILVA, I. G.; SANTOS, R. M. G.; RODRIGUES FILHO, E. ELIAS, C. N. Larvicidal activity of tannins isolated of *Magonia puberscens* St Hil (*Sapindaceae*) *against Aedes aegypti* (Diptera, Culicidae) **Revista da Sociedade Brasileira de Medicina Tradicional**, Ubatuba, v. 37, n 5, p. 396-399, 2004. https://doi.org/10.1590/S0037-86822004000500005

SOBERÓN, J.; PETERSON, A.T. Interpretation of models of fundamental ecological niches and species distributional areas. **Biodiversity Informatics** 2: 1-10. 2005. https://doi.org/10.17161/bi.v2i0.4

SOLÓRZANO, A. **Análise Fitogeográfica do cerradão:** conexões florísticas, padrões estruturais, relações ecológicas e modelagem de sua distribuição potencial. 2011. 115 f. Tese (Doutorado em Ecologia), Universidade de Brasília, Brasília, 2011.

SWETS, J. A. Measuring the accuracy of diagnostic systems. **Science,** n. 240, p.1285–1293. 1988. https://doi.org/10.1126/science.3287615

THEOBALD, E. J.; ETTINGER A. K.; BURGESS, H. K.; DEBEY, L. B.; SCHMIDT, N. R.; Wagner, H. E. C.; HILLERISLAMBERS, J.; TEWKSBURY, J.; HARSCH, M. A.; PARRISH, J. K. Mudança global e soluções locais: Aproveitar o potencial não realizado da ciência cidadã para a biodiversidade pesquisa. **Biol. Conserv.** , 181, pp. 236 – 244. 2015. https://doi.org/10.1016/j.biocon.2014.10.021

VALADÃO, M. B. X.; MARIMON JR, B. H.; MORANDI, P. S.; REIS, S. M.; OLIVIERA, B.; OLIVEIRA, E. A.; MARIMON, B. S. Initial development and biomass patitioning of *Physocalmma scaberrimum* Pohl (Lythraceae) under different shading levels **Scientia Forestalis**, Piracicaba, v. 42, n. 101, p 129-139. 2014.

WISZ, M. S.; HIJMANS, R. J.; LI, J.; PETERSON, A.T.; GRAHAM, C.H.; GUISAN, A.; NCEAS. **Predicting species distributions working group. Effects of sample size on the performance of species distribution models.** Diversity and Distributions 14: 763-773. 2008. https://doi.org/10.1111/j.1472-4642.2008.00482.x

YANG, X. Q.; KUSHWAHA, S. P. S.; SARAN, S.; XU, J.; ROY, P. S. **Maxent modeling for predicting the potential distribution of medicinal plant, Justicia adhatoda L. in Lesser Himalayan foothills**. Ecol. Eng. n. 51, p.83-87, 2013. https://doi.org/10.1016/j.ecoleng.2012.12.004