NATURAL DISTRIBUTION OF *Myracrodruon urundeuva* FR. ALL. IN BRAZIL AT CURRENT AND FUTURE CLIMATE SCENARIOS DUE TO GLOBAL CLIMATE CHANGE

Lorena Frigini Moro Capo[2], Mario Luiz Teixeira de Moraes[3], Daniele Fernanda Zulian[2], Marcos Silveira Wrege[4], Renan Marcelo Portela[5], José Cambuim[6], Alexandre Marques Da Silva[3*], Márcia Toffani Simão Soares[4], Valderês Aparecida de Sousa[4] and Ananda Virginia de Aguiar[4]

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[2] Universidade Estadual Paulista Júlio de Mesquita Filho, Programa de Pós-Graduação em Agronomia, Ilha Solteira, SP - Brasil. E-mail: <lorenafmc@gmail.com> and <danizullian@gmail.com>.

[3] Universidade Estadual Paulista Júlio de Mesquita Filho, Departamento de Fitotecnia, Ilha Solteira, SP - Brasil. E-mail: <mario.moraes@unesp.br> and <alexandre.marques@unesp.br>.

[4] Embrapa Florestas, Colombo, PR - Brasil. E-mail: <marcos.wrege@embrapa.br> , <marcia.toffani@embrapa.br> , <valderes.sousa@embrapa.br> and <ananda.aguiar@embrapa.br>.

[5] Universidade Estadual do Centro-Oeste, Programa de Pós-Graduação em Ciências Florestais, Guarapuava, PR - Brasil. E-mail: <renorlim@hotmail.com>.

[6] Universidade Estadual Paulista Júlio de Mesquita Filho, Doutor em Agronomia, Ilha Solteira, SP - Brasil. E-mail: <josecambuim@yahoo.com.br>.

*Corresponding author.

ABSTRACT – In this work, the prediction of the distribution of *M. urundeuva* Fr. All. was performed based on the region of natural occurrence of the species. Its geographic coordinates were obtained from online databases CRIA and SpecialLinks, from scientific articles and fieldwork carried out by Universidade Estadual Paulista (UNESP) in Ilha Solteira, São Paulo, Brazil. *M. urundeuva* is a native tree species with great potential for commercial use in Brazil. For this purpose, ecological niche modeling was used, with current layers of climate variables and layers prepared for future climate scenarios, according to the 4th Report of the Intergovernmental Panel on Climate Change (AR4/IPCC), using Worldclim data on Brazil. With the Open Modeller and ArcGIS programs, maps were generated to predict its occurrence for the current period and future climate scenarios, made according to the projections of global climate changes. With the projection of increases in temperature and precipitation in the area where the species occurs, it tends to migrate to areas of Brazil where the climate is currently milder, in the south and southeast regions. Due to climatic changes, the species tends to undergo changes in distribution and area size until 2080. It was projected for Caatinga and Pantanal, in both periods, an increase in area, while for the Cerrado, in the first period, the area increased, and, for the second, it decreased. Therefore, according to the results of the maps of future projections for the next decades, it is concluded that there will be changes in the distribution of *M. urundeuva*, with a significant reduction of the potential area of occurrence in the region.

Keywords: Brazilian biomes; Climatic changes; Ecological modeling niche.

DISTRIBUIÇÃO NATURAL DE Myracrodruon urundeuva *FR. ALL. NO BRASIL EM CENÁRIOS CLIMÁTICOS ATUAIS E FUTUROS DEVIDO A MUDANÇAS CLIMÁTICAS GLOBAIS*

RESUMO – Neste trabalho, foi realizada a previsão da distribuição de ***M. urundeuva*** *Fr. All., com base na região de ocorrência natural da espécie. Suas coordenadas geográficas foram obtidas nas bases de dados online CRIA e SpecialLinks, a partir de artigos científicos e trabalhos de campo realizados pela Universidade Estadual Paulista (UNESP) em Ilha Solteira, São Paulo, Brasil.* ***M. urundeuva*** *é uma espécie arbórea nativa com grande potencial para uso comercial no Brasil. Para tanto, foi utilizada a modelagem de nicho ecológico,*

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com camadas atuais de variáveis climáticas e camadas preparadas para cenários climáticos futuros, de acordo com o 4º Relatório do Painel Intergovernamental sobre Mudanças Climáticas (AR4/IPCC), utilizando dados do Worldclim no Brasil. Com os programas Open Modeller e ArcGIS, foram gerados mapas para prever sua ocorrência para o período atual e para cenários climáticos futuros, feitos de acordo com as projeções de mudanças climáticas globais. Com a projeção de aumentos de temperatura e precipitação na região onde ocorre a espécie, ela tende a migrar para áreas do Brasil onde o clima é atualmente mais ameno, nas regiões Sul e Sudeste. Devido às mudanças climáticas, a espécie tende a sofrer mudanças na distribuição e tamanho de área até 2080. Foi projetado para a Caatinga e Pantanal, nos dois períodos, um aumento de área, enquanto para o Cerrado, no primeiro período, a área aumentou e para o segundo, diminuiu. Portanto, de acordo com os resultados dos mapas de projeções futuras para as próximas décadas, conclui-se que haverá mudanças na distribuição de ***M. urundeuva****, com redução significativa da área potencial de ocorrência na região.*

Palavras-Chave: Biomas brasileiros; Mudanças climáticas; Nicho de modelagem ecológica.

1. INTRODUCTION

Myracrodruon urundeuva Fr. All. (Anacardiaceae) is a tropical tree species, popularly known as aroeira, aroeira do sertão, aroeira preta, and is characterized by high basic density (1,19 g cm^{-3}) and wood durability (Lorenzi, 2000). Due to its qualities, it was the subject of intense anthropic exploration, reaching significant importance (Monteiro et al., 2012). As a result, it became a member of the Red List of Endangered Species and classified in the Vulnerable Category (Brazil, 2014).

M. urundeuva has a wide natural distribution area compared to most native forest species. It can be found in Argentina, Brazil, Bolivia, and Paraguay. In Brazil, it is widely found in the Midwest, Southeast, Northeast, and, to a lesser extent, in the South Region (Lorenzi, 2000; Rizzini, 1971). Its extensive geographic distribution indicates high genetic diversity thus facilitating its adaptation in different phytoecological regions (Kageyama et al., 2003) as the Seasonal Forest, both Semi-deciduous and Decidual, Cerrado, Caatinga and Pantanal (Carvalho, 1994). In this way, the species presents a characteristic that favors studies related to genetic conservation and climatic changes. Monitoring in the main biomes of the species can be carried out in terms of adaptation, development, population density, and reproductive phenology. However, *a priori*, the projections of scenarios related to the distribution of the species need to be performed to identify the ecosystems that will require priority for conservation and studies.

Several changes in natural ecosystems in favor of economic development have negatively affected the natural habitat of numerous species in recent years, and consequently the genetic structure of their natural populations. This situation has generated a climate imbalance in several regions, and this has contributed significantly to the changes in the populations during the last years, having each species reacted differently to these climatic effects (Lorenzen et al., 2011). Populations with lower genetic variability will be the most affected, thus characterizing the genetic diversity of populations will also assist in decision making on genetic conservation and use of genetic resources in the face of climate effects. As environmental impacts are evidenced, the demand for a reliable prediction of ecosystem change from these impacts increases (Wang et al., 2012).

The ecological niche modeling then appears as a promising tool, generating maps of probability of occurrence of a certain species (Terrible et al., 2012) and correlating it with possible environmental and climatic variables, predicting geographic distributions for any individual (Wang et al., 2012). From the modeling are realized projections, which can be for different ecosystems and be used in diverse ways, orienting in the assembly of methods of adaptation to the climatic changes for the conservation of habitats with species, vegetal or animal, threatened of extinction (Wang et al., 2012), caused by reduced population size, resulting in loss of genetic diversity (Lovato, 2010).

Work on climate change versus forest species is still incipient compared to other species. *M. urundeuva*. Due to its large occurrence and multiple uses, can be considered a reference species in these studies. Thus, the objective of this work was to predict future scenarios for *M. urundeuva*, using ecological niche models for this purpose, according to the 4th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007) (Ar4 / IPCC). Based on this, will be proposed new sites for the conservation and planting of *M. urundeuva*.

2. MATERIAL AND METHODS

Primary and secondary data were obtained from *M. urundeuva* points of origin from four different databases, totaling 1,210 points of presence of the species distributed in Brazil.

2.1.Primary database

The primary databases contain georeferenced points of occurrence (latitude and longitude), with data from 19 natural populations, around 30 progenies per population, from the germplasm collection of UNESP, Ilha Solteira, Brazil.

2.2.Secondary database

The used secondary databases containing georeferenced points of occurrence (latitude and longitude) from information provided in the scientific literature. And data stored in Environmental Information Reference Center - CRIA (CRIA, 1999) and the Global Biodiversity Information Facility (GBIF) (GBIF, 2015) database. CRIA (1999) is a biological collections database freely accessible. It can be accessed through the SpeciesLink tool, a species information system (fauna, flora, and microbiota), which gathers historical information from several herbarium present in the whole country, associated to a system of prediction of geographic distribution of species, based on mathematical modeling. Likewise, the GBIF (2015) database collects information on species and their occurrence.

In a first analysis, the consistency and the errors of the data of the places of occurrence of *M. urundeuva* were verified. Outliers were isolated, which were isolated from the main groupings and did not represent the natural distribution zone of the species. In a second analysis, inverted coordinates (latitude with longitude and vice versa) were corrected and incorrect ones were excluded (occurrence on the sea, for example). There were excluded 295 occurrences, leaving 915 records of occurrence of *M. urundeuva* in the world. As the modeling of the occurrence prediction was made only for Brazil, the coordinates with the presence register of the species in other countries were removed, leaving 844 records remaining. For this purpose, a geographic information system - GIS was used.

2.3.Determination of bioclimatic variables

The climatic data of the base period (or the "current period") and the future scenarios were obtained from the Worldclim site and maps of the bioclimatic variables were generated with a spatial resolution of approximately 1 km^2. The bioclimatic variables were organized in the monthly, seasonal and annual time scale, the main variables of importance for determining the distribution of the species, such as air temperature and rainfall, among others (Kumar and Stohlgren, 2009). The current or present period is currently called the base period or reference period, since it deals with a period that, with climate change, has undergone major changes and has no meaning to be called current. Data from the base period consider the average of the climatic variables of the period between 1961 and 1990, according to the World Meteorological Organization (WMO). Future scenarios were projected for 2041-2060 and 2061-2080, according to the IPCC (2007). The Brazilian border was obtained from IBGE (2001).

The base period climate maps and future climate scenarios were elaborated using multiple linear regression, using latitude, longitude, and the digital elevation model (representing altitude), as predictor variables. The maps were made for Brazil, in a 1: 1,000,000 scale. The digital elevation model (DEM) used was the GTOPO30, developed by the United States Geological Survey (USGS, 1999), based on the Shuttle Radar Topography Mission (SRTM) (Farr and Kobrick, 2000).

For the modeling of occurrence prediction, 19 bioclimatic variables were selected, including minimum and maximum temperatures (ºC) and rainfall (mm) (Wrege et., 2017), described below: (Bio1) Annual mean temperature; (Bio2) Monthly mean of the daily temperature variation (maximum temp - minimum temp); (Bio3) Isothermality (Bio2/Bio7) (* 100); (Bio4) Seasonality of temperature (standard deviation *100); (Bio5) Maximum temperature in the hottest month; (Bio6) Minimum temperature in the coldest month; (Bio7) Annual temperature variation (Bio5-Bio6); (Bio8) Mean temperature in the wettest quarter; (Bio9) Mean temperature in the driest quarter; (Bio10) Mean temperature in the hottest quarter; (Bio11) Mean temperature in the coldest quarter; (Bio12) Cumulative rainfall in the year; (Bio13) Precipitation accumulated in the wettest month; (Bio14) Precipitation accumulated in the driest month; (Bio15) Seasonality of rainfall (coefficient of variation); (Bio16) Cumulative rainfall in the wettest quarter; (Bio17) Cumulative rainfall in the driest quarter; (Bio18) Cumulative rainfall in hottest quarter; (Bio19) Cumulative rainfall in the coldest quarter.

2.4.Prediction of occurrence of *M. urundeuva*

The climate data used in the work were organized, compiled, and consisted. The base period averages of the climate variables listed in Table 1 were calculated. Based on the trends in the 4th Assesment Report of the Intergovernmental Panel on Climate Change (AR4 / IPCC) (IPCC, 2007), future climate scenarios were expected. The selected scenarios were A2 and B1, with A2 being the most pessimistic scenario, with the maintenance of current GHG emissions standards, and B1, a scenario of lower emissions or less pessimistic scenario (Nakicenovic et al., 2000). Climate projections for the coming decades were made for 2041-2060 and 2061-2080 periods.

The prediction of geographic distribution was made by six algorithm models: Bioclim, Climate Space Model, Envelope Score, Maximum Entropy, Niche Mosaic, and Enviromental Distance (Figure 1). The modeling of the future prediction of occurrence of the species occurred with the use of Open Modeller software (Muñoz et al., 2011). This program works with geographic distribution data of species (latitude and longitude) and with maps or environmental layers (climate, soil and relief), composing a mathematical system of prediction of species distribution.

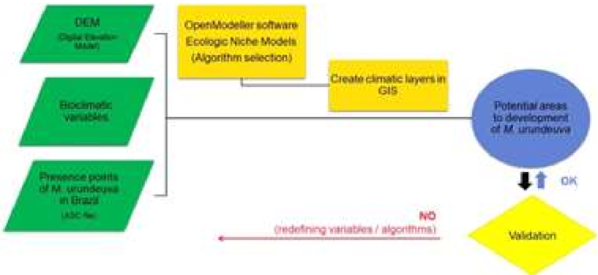

Figure 1 – Schematic model of ecological niche modeling.
Figura 1 *– Modelo esquemático de modelagem de nicho ecológico.*

The environmental variables were the same for the base period and for the future. The output maps of the models were transformed into numerical values, varying between 0 and 1. Each pixel of the map came to represent a value, 0 or 1, 0 being related to the no possibility of occurrence of *M. urundeuva* and 1 the maximum possibility of occurrence. The maps formed in the Open Modeller in ASCII text format (American Standard Code for Information Interchange), containing these binary values, were imported into ArcGIS and transformed into 'raster' format. Classes were then created with a gradient varying from '0' to '1', representing from the zones with no possibility of occurrence until the zones with maximum possibility of occurrence, respectively, for the development of the species.

The evaluation of the quality of the adjusted models was done by calculating the area under the curve (AUC), obtained from the integration of the Receiver Operating Characteristic (ROC) curve. The maximum AUC value is theoretically 1.0 and indicates perfect discrimination, while values lower than 0.5 denote poor modeling performance. The Jackknife test was applied to diagnose the relative contribution of each bioclimatic variable.

Thus, in this study, through the prediction of occurrence of the species, sites were identified where conservation programs of natural populations of *M. urundeuva* should be prioritized and where there is aptitude for new plantings, considering the climate of the base period and that of the next decades, designed according to the analysis of global climate change.

3. RESULTS

From the used databases, it was possible to obtain 915 points of occurrence of *M. urundeuva* in the world, all concentrated in South America (Figure 2A) and 844 points within of the Brazilian territory (Figure 2B), after the elimination of discrepant points, with location error or located outside Brazil. The mapping of the current distribution of *M. urundeuva* (Figure 3), based on these points of presence of the species, was significant for all the models used ($p < 0.001$). Among the generated models, the most representative of the distribution was selected. The most similarity to

A: Data on the presence of M. urundeuva in South America (Source: CRIA, GBIF, UNESP - Ilha Solteira Campus and papers); B: Data on the occurrence of M. urundeuva by biomes in Brazil (Source: CRIA, GBIF, UNESP - Ilha Solteira Campus and papers) after exclusion of coordinates from other countries.
A: Dados sobre a presença de M. urundeuva na América do Sul (Fonte: CRIA, GBIF, UNESP - Campus Ilha Solteira e artigos); B: Dados sobre a ocorrência de M. urundeuva por biomas no Brasil (Fonte: CRIA, GBIF, UNESP - Campus Ilha Solteira e artigos) após exclusão de coordenadas de outros países.

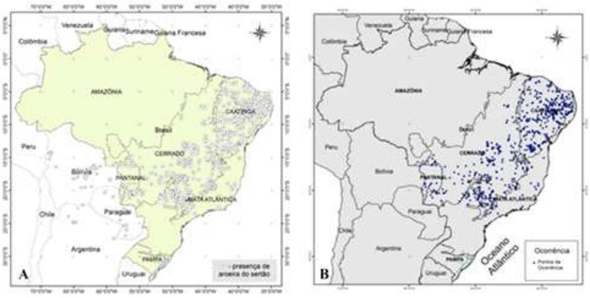

Figure 2 – Data on the presence of *M. urundeuva* by countries and biomes in Brazil.
Figura 2 *– Dados sobre a presença de* ***M. urundeuva*** *por países e biomas no Brasil.*

the species distribution was Environmental Distance, with AUC of 1.00. The model used allowed to express the potential occurrence of the species in an area that covers the domain of four Brazilian biomes, including the Pantanal, Cerrado, Mata Atlântica, and Caatinga limits. The projections for future climatic scenarios (Figure 4) point to the reduction of areas suitable for the development of the species in the two evaluated periods (2041-2060 and 2061-2080), with the most sensitive areas species are concentrated in the northern latitudinal limits of the Cerrado and Caatinga biomes.

The models generated indicate the fragility of *M. urundeuva* populations in the Caatinga, Pantanal, and Cerrado biomes, and the change for each period (2041-2060 and 2061-2080) was of a total increase in scenario A2, with Caatinga in both periods, an increase of 0.05% and 0.07%, while for the Cerrado an estimated loss of 5.6% for the period 2041-2060 and an increase of 1.2% for the second period, and in the biome Pantanal area increased by 0.2% in both periods. For scenario B1, loss of area in the Caatinga of 1.10% in the period of 2041-2060 and of 10.0% in the period of 2061-2080, while for the Pantanal the first period was an increase of 0.2% in the area and loss of 99% for the second period studied and, for the Cerrado biome, there was a loss of area in both

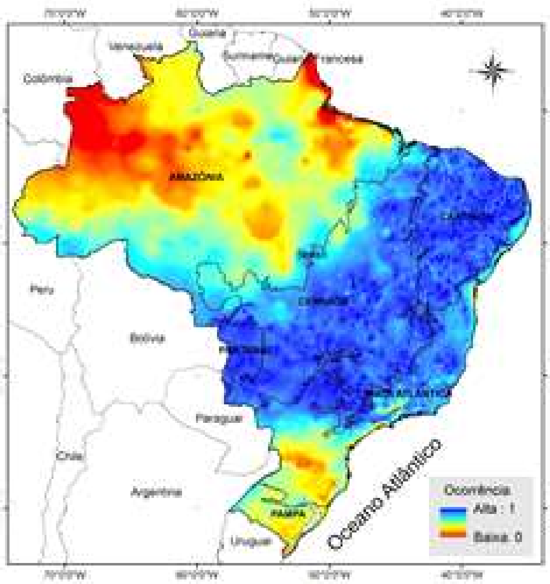

Figure 3 – Distribuition of *M. urundeuva* in Brazil by biomes in the current period.
Figura 3 *– Distribuição de* ***M. urundeuva*** *no Brasil por biomas no período atual.*

A: Projection for the period 2041-2060, in scenario A2; B: Projection for the period of 2061-2080; C: Projection for the period 2041-2060, in scenario B1; D: Projection for the period of 2061-2080, in scenario B1.
A: Projeção para o período 2041-2060, no cenário A2; B: Projeção para o período de 2061-2080; C: Projeção para o período 2041-2060, no cenário B1; D: Projeção para o período de 2061-2080, no cenário B1.

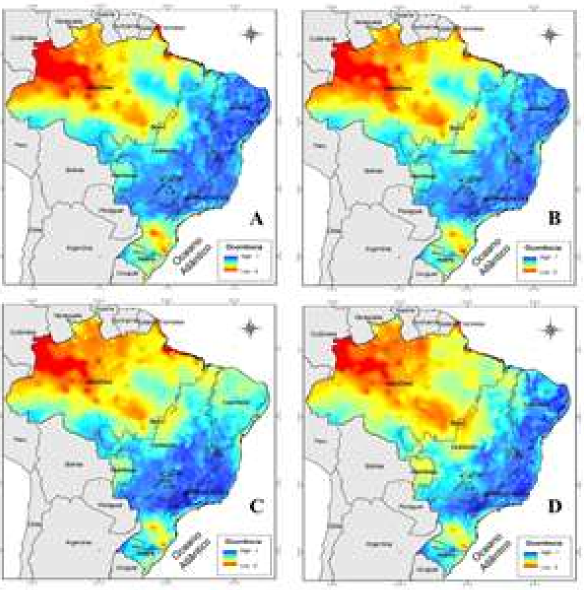

Figure 4 – Projection of the distribution of *M. urundeuva* in Brazil by biomes according to global climate change (*Environmental Distance Model*).
Figura 4 *– Projeção da distribuição de* ***M. urundeuva*** *no Brasil por biomas de acordo com as mudanças climáticas globais (****Modelo de Distância Ambiental****).*

A: scenario B1; B: scenario A2.
A: cenário B1; B: cenário A2.

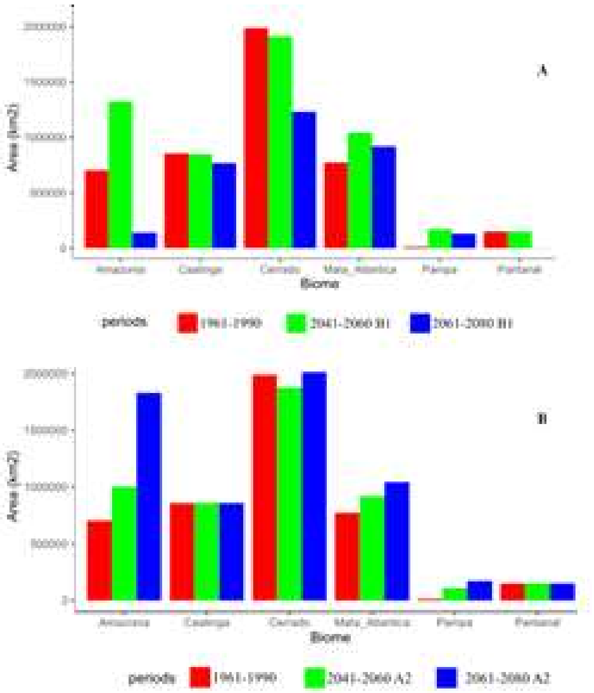

Figure 5 – Distribution area (km²) per biome of *M. urundeuva* in both time periods (*Environmental Distance Model*).
Figura 5 – *Distribuição da área (km²) por bioma de **M. urundeuva** nos dois períodos (**Modelo de Distância Ambiental**).*

periods of 4% and 38%, respectively (Figures 5A and 5B). Therefore, the natural populations located in these biomes should be prioritized for sampling, aiming the implantation of collections of germplasm, breeding, and commercial plantations.

4.DISCUSSION

The Caatinga is among the most sensitive ecosystems to climate change (Seddon et al., 2016). Vulnerable areas to population reduction have also been found to coincide with regions suffering from severe anthropogenic pressure from land use change. In the Cerrado biome, in its northern limit of distribution of the species, great loss of area with potential for development of the species in the next decades, coinciding with the Arch of Deforestation, could occur. In the state of Mato Grosso, most deforestation has occurred in these transitional areas between biomes (Fausto et al., 2016) and in non-flooded areas of the Pantanal, under pressure from agricultural occupation (Azevedo and Saito, 2013).

The Pantanal Matogrossense is considered one of the most important Brazilian biomes, containing one of the largest continuous floodplains in the world, whose ecological functioning is dependent on the complex hydroclimatological dynamics of the region. Although there are uncertainties regarding the results obtained by climate models in relation to the behavior of the hydrological cycle in relation to future scenarios in the region (AR4/IPCC) (Marengo and Valverde, 2007), there are significant microclimatic changes in the conversion of forested areas to pasture in this biome, with potential changes in the regime of rainfall, temperature, and energy balance (Biudes et al., 2012). These anthropic alterations, caused by the change in the use of the soil, can potentiate the inherent risks of the climate changes on the native vegetation in the Brazilian biomes, as pointed out by Aleixo et al. (2010), for different terrestrial ecosystems.

Potential distribution modeling is an alternative tool for mapping potential areas for adaptation of species, using a smaller number of variables that would be required by the zoning method, making possible the extrapolation of species occurrence projections in future scenarios, according to global climate change (Bader et al., 2008; Melo et al., 2015). However, it has limitations and should be used in conjunction with other tools to aid decision-making (Garcia et al., 2014). An example is the various tests of provenances and/or progenies that present high values of genetic variability, which vary according to the place of origin. These also indicate a good adaptation to the climatic conditions, evidenced by the high survival rate and growing development of the *M. urundeuva* individuals (Guerra et al., 2009; Tung et al., 2010; Moraes et al., 2012; Bertonha et al., 2016; Pupin et al., 2017). In this way, the preservation of forest fragments and the conservation of *ex situ* materials are fundamental to maintain the genetic variability of this species over the years.

However, it is also important to consider that the presented ecological model was generated with a database of insufficient climatic data for the whole national territory, especially in remote areas of difficult access, where a large part of the individuals of this species are concentrated. A more detailed survey of the climate in the areas of occurrence of the *M. urundeuva* could contribute more efficiently to this study, as well as information on the genetic variability of the populations and, consequently, the potential of their adaptation in each environment.

The interactions, as edaphic conditions, not considered in this work, may also modify the projection of occurrence of the species (Garcia et al., 2014), which may further decrease the areas with potential for its occurrence in the coming decades, since the projections presented here did not consider such restrictions. The main biomes in which the *M. urundeuva* is found have distinct aspects, so it is of paramount importance a more detailed study regarding the characteristics of each one, in order to analyze the behavior of the species. In this way, it is possible to analyze its adaptation in the biomes, being more successful in the choice of the area for its conservation.

In the Caatinga biome, the annual temperature averages around 25°C and 30°C, with little difference between the colder and hotter months. The annual precipitation varies from 300 mm in the central area to 1,000 mm in the transition with other biomes. Although it has very shallow soils, which supply the need of the plant only for a few days, the greatest extension is of deep and well-drained soils, with good water retention (Garglio, 2010), which is important, since the dry season in the Caatinga can last seven to eight months (Scariot et al., 2005). The Cerrado biome, as well as the Caatinga, has several textures and soil depth. The accumulated rainfall in one year varies between 600 mm and 800 mm in the transition with the Caatinga and from 2,000 mm to 2,200 mm at the border with the Amazon. On average, it has accumulated rainfall in the year from 1,200 mm to 1,800 mm and a period of six months of drought (Scariot et al., 2005). The average temperature varies between 22°C and 23°C (Klein, 2002). In the Pantanal, the average annual temperature is between 23°C and 25°C, with a rainfall index of 1.110 mm accumulated in the year and seven months of drought (Garcia, 1986; Narcuzzo et al., 2011). In this biome, the soils are considered to be more fragile (Beirigo et al., 2011; Batista et al., 2014).

According to Costa et al. (2015) *M. urundeuva*, which is tolerant to drought, has a reduced photosynthetic rate with water deficit, but it is a species that recovers rapidly when drought ceases, as it has great plasticity, adapted to the conditions from the Atlantic Forest to the Cerrado, which leads us to believe that the species will adapt, even if slowly, to climate change, so there is a decrease in the area of survival, but not extinction.

The fact that *M. urundeuva* shapes more efficiently the prediction conditions considered more pessimistic may be directly linked to global warming. According to Nunes (2008), when there is a decrease in temperature, there is a greater fall of leaves in the individuals and the ripening of the fruit is affected, making it unfeasible, since it is carried out between the months of August and November, higher temperature.

Another point to be observed regarding the decrease of the area occupied by the species is the pollinator, which has its flight affected by the climatic conditions. Honey bee, the main pollinator of the *M. urundeuva*, makes its displacement in the morning, usually between 8 and 11:00 AM. With the increase of temperature, this time can be altered, harming the pollination of the individuals. The different responses of plants and insects to climate changes can bring changes in the time and space of activity of bees, respectively related to their phenology and distribution, bringing serious demographic consequences for tree species, including *M. urundeuva*.

Pollinating agents are the key to the planet's biodiversity, providing vital ecosystem services to tree species with the pollination of flowers and, consequently, the exchange of genomes between individuals and populations. About 75% of species on the planet are dependent on this service, including *M. urundeuva*.

Climate changes related to the increase in droughts and air temperature can also affect the flowers, increasing the fall and reducing the production of nectar and the protein content in the pollen. These changes may result in less insect visitation to flowers and reduced pollen deposition, reducing seed production and gene exchange between different populations of *M. urundeuva*. This species seeds quality is related to the maximum, average, and minimum temperature, average and minimum humidity, and precipitation (Oliveira et al., 2020). However, these climate variables during the different phenological phases of *M. urundeuva* affect the physiological quality of the seeds, and, in climate change scenarios, there will be a reduction in the seed production of this species (Oliveira et al., 2020).

The results indicate the need for population monitoring in the coming decades, especially in areas where climatic aptitude may change with climatic changes (Garcia et al., 2014), as well as the need for a better understanding of the direct and indirect effects of global climate change on the occurrence and development of the species, increased mortality and species vulnerability to pest and disease attack.

The first populations to be affected will be those located in the border areas of the species' distribution zone, where its genetic diversity is greater, due to climate change between the area where the species is registered and the area where it no longer occurs. The climate is the main factor related to the occurrence of species and vegetation represents the expression of the climate of a place.

Ecological niche modeling, together with field assessments, can greatly contribute to improving knowledge on species distribution and distribution trends in the future, based on global climate change, including collaborating to define areas where they can be prioritized field trips to improve population sampling, especially in the Midwest and Northeast regions, at the Northern border of the species (in the vicinity of the Deforestation Arc) (Moscoso et al., 2013). This area is known as the region where there is great advance of the agricultural frontier and, thus, great deforestation. It comprises the regions between Maranhão and Rondônia (Ipam, 2015; Vieira et al., 2005). Another factor responsible for the great loss of original vegetation cover in the region is cattle breeding (Carvalho et al., 2016), which is responsible for soil erosion, silting of watercourses, and loss of drinking water quality (Capoane et al., 2016).

5. CONCLUSIONS

1. According to the results of the layers of future projections scenarios for the next decades, there are changes in the distribution of *M. urundeuva* in the climatic scenarios A2 and B1, with a significant reduction in the potential area of occurrence in the Northern latitudinal limits, mainly where the Arc of Deforestation;

3. The indication of strategic areas for the rescue of genetic material, such as the borders of the distribution area of *M. urundeuva*, may help to conserve the species.

4. With the increases in temperature and rainfall in the area where the species occurs, it tends to migrate to areas of Brazil where the climate is currently milder, in the south and southeast regions.

AUTHOR CONTRIBUTIONS

Lorena Frigini Moro Capo: Conceptualization, Data curation, Formal analysis, Investigation, Writing original draft, Writing - review & editing. Mario Luiz Teixeira de Moraes: Conceptualization, Resources, Writing - review & editing. Daniele Fernanda Zulian: Methodology, Writing - review & editing. Marcos Silveira Wrege: Formal análisis, methodology, review & editing. Renan Marcelo Portela: Methodology, review & editing. José Cambuim: Methodology, review & editing. Alexandre Marques Da Silva: Conceptualization, Resources, Writing - review & editing. Márcia Toffani Simão Soares: Conceptualization, Resources, Writing - review & editing. Valderês Aparecida de Sousa: Conceptualization, Resources, Writing - review & editing. Ananda Virginia de Aguiar: Conceptualization, Project administration, Supervision, Validation, Writing review & editing.

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