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EVALUATION OF THE DISTRIBUITION MODELS OF "BURITI" AND "PARATUDO", ARBORAL SPECIES OF THE PANTANAL, WITH DATA OF THE QUATERNARY AND THE PRESENT CLIMATE

AVALIAÇÃO DOS MODELOS DE DISTRIBUIÇÃO DE "BURITI" E "PARATUDO", ESPÉCIES ARBÓREAS DO PANTANAL, COM DADOS DO CLIMA DO QUATERNÁRIO E DO PRESENTE

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ABSTRACT

During the Quaternary, climatic variations caused changes in the size of vegetation formations in the Pantanal, promoting the expansion of seasonal forests at the beginning of the Holocene. Climatic conditions change the patterns of vegetation diversity on continental scales. *Mauritia flexuosa* L. f., The "Buriti", is a palm tree that explores humid environments with acid soils. While, *Tabebuia aurea* (Silva Manso) Benth. &Hook.f. ex S.Moore is a species of monodominant occurrence in the Pantanal in extensive areas locally denominated as "paratudal". Data sets of past eras have contributed to the study of plant species biogeography. The models of the potential distribution of these species were generated from the algorithm of the Maxent program with climatic data set of the Last Glacial Maximum (ca 22,000 years AP), Holocene Medium (ca. 6,000 years AP) and present time in two different versions. Potential distribution models with climatic packets from the present in the newer version presented areas of environmental suitability greater than in the older version. In the Holocene Middle and Late Glacial Maximum periods, the areas of environmental suitability were higher than in the newer present version. Many studies on climatic variations on the South American continent confirm the suggestions of the proposed models. The areas of environmental suitability of the species treated in the present are smaller in comparison with Last Glacial Maximum and Average Holocene. The species presented a potential distribution according to the biogeographic history of South America.

Keywords: *Mauritia flexuosa*;*Tabebuia aurea;* species distribution; Mid-Holocene and Last Glacial Maximum.

RESUMO

Durante o Quaternário, variações climáticas provocaram mudanças no tamanho das formações vegetacionais no Pantanal, promovendo a expansão das florestas estacionais no início do Holoceno. As condições climáticas alteram os padrões de diversidade da vegetação em escalas continentais. *Mauritia flexuosa* L. f., o "Buriti", é uma palmeira arbórea que explora ambientes úmidos e solos ácidos. Enquanto, *Tabebuia aurea* (Silva Manso) Benth. &Hook.f. ex S.Moore é uma espécie de ocorrência monodominante no Pantanal, em áreas extensas denominadas localmente como "paratudal". Os conjuntos de dados das eras passadas têm contribuído para o estudo da biogeografia das espécies vegetais. Os modelos da distribuição potencial dessas espécies foram gerados a partir do algoritmo do programa *Maxent*com conjunto de dados climáticos do Último Máximo Glacial (ca. 22.000 anos AP), Médio Holoceno (ca. 6.000 anos AP) e tempo presente em duas versões diferentes. Modelos de distribuição potencial com pacotes climáticos do presente na versão mais nova apresentaram áreas de adequabilidade ambiental maiores que na versão mais antiga. Nos períodos Médio Holoceno e Último Máximo Glacial as áreas de adequabilidade ambiental se mostraram maiores que no presente na versão mais nova. Muitos trabalhos sobre variações climáticas no continente sul-americano confirmam as sugestões dos modelos propostos. As áreas de adequabilidade ambiental das espécies tratadas no presente são menores em comparação com Último Máximo Glacial e Médio Holoceno. As espécies apresentaram distribuição potencial de acordo com a história biogeográfica da América do Sul.

Palavras chave: *Mauritia flexuosa;Tabebuia aurea;* distribuição de espécies; médio Holoceno e Último Máximo Glacial.

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1. INTRODUCTION

Biodiversity is currently not taken into account when it comes to environmental policy. Therefore a very broad concept has been considered to be applied in the real world. This problem can be corrected if biodiversity is measurable through indicators and recognized as an end in itself. The study of vegetation is one of the indicators on the state of conservation of biodiversity (NOSS, 1990, p.360).

The Pantanal is one of the largest extension of wetlands. The region is alluvial plain influenced by rivers that drain the Upper Paraguay basin, characterized by cyclical floods. In Brazil, the Pantanal is located in the states of Mato Grosso and Mato Grosso do Sul, comprising an area of about 138.183 km², the rest of which is located in Bolivian and Paraguayan territory (SILVA & ABDON, 1998, p.1710).

The climatic conditions are often indicated as the main guideline for the diversity patterns in continental and world scales (NOSS, 1990, p 361;

Climatic variations in the Holocene caused variations in the size of the vegetation formation in the Pantanal because, according to Whitney et al. (2011, p.182), the region was occupied by the expansion in the seasonal forests in the beginning of the Holocene and such period was markedly the driest of all Holocene.

It is not always possible to obtain records of occurrence, since the complete real distribution of the species is difficult to obtain due to factors that make it impossible to carry out exhaustive inventories (SCHMIDT, 2007, p.45).

In addition to producing models of potential distribution in biogeographic analyzes, modeling may be useful for the study of the conservation of rare or endangered species, reintroduction of species, impacts of climate change, evaluation of the invasive potential of exotic species, study of possible dissemination routes of infectious diseases, aid in the determination of priority areas for conservation, among others (GIANNINI et al., 2012, p.740).

The ecological niche modeling approach (ENM), together with paleo-climatic simulations, have been increasingly applied to predict the paleodistribution on both regional and global scales (Nogueira et al., 2010). 2029, SVENNING et al., 2011, p2939). In addition, it has been used to test biogeographic hypotheses, such as the dynamics of the geographic distribution of extinct and extant species through the last glacial cycle (MARTÍNEZ-MEYER and PETERSON, 2006, p.1785, NOGUÉS-BRAVO et al., 2008, p. 688; WALTARI and GURALNICK, 2009, p. 156; VARELA et al., 2010, p. 2030).

In this way, the present study had the objective to evaluate the variations of the "buriti" and "paratudo" distribution models generated with climatic data of the Last Glacial Maximum, Holocene Middle and present time, Pantanal tree species in Mato Grosso do Sul State, Brazil, based on the collection of virtual herbaria and field trips.

2. MATERIAL AND METHODS

Mauritia flexuosa L. f. is a tree species of humid environments and acid soils, being confined to the east of the Pantanal and cited as a species of Cerrado and Amazonian Biomes typical of the regions known as "buritizais" (POTT and POTT, 2009, p 1068). It inhabits the low floodplain (igapós), the river banks and igarapés, forming the characteristic miritizais or buritizais (FERREIRA, 2005, page 2). Additionally, it is an important indicator of the wetlands of the Pantanal, found in Paraguay and Brazil (POTT et al., 2011, p.268). The distribution of occurrence records can be observed in Figure 1.

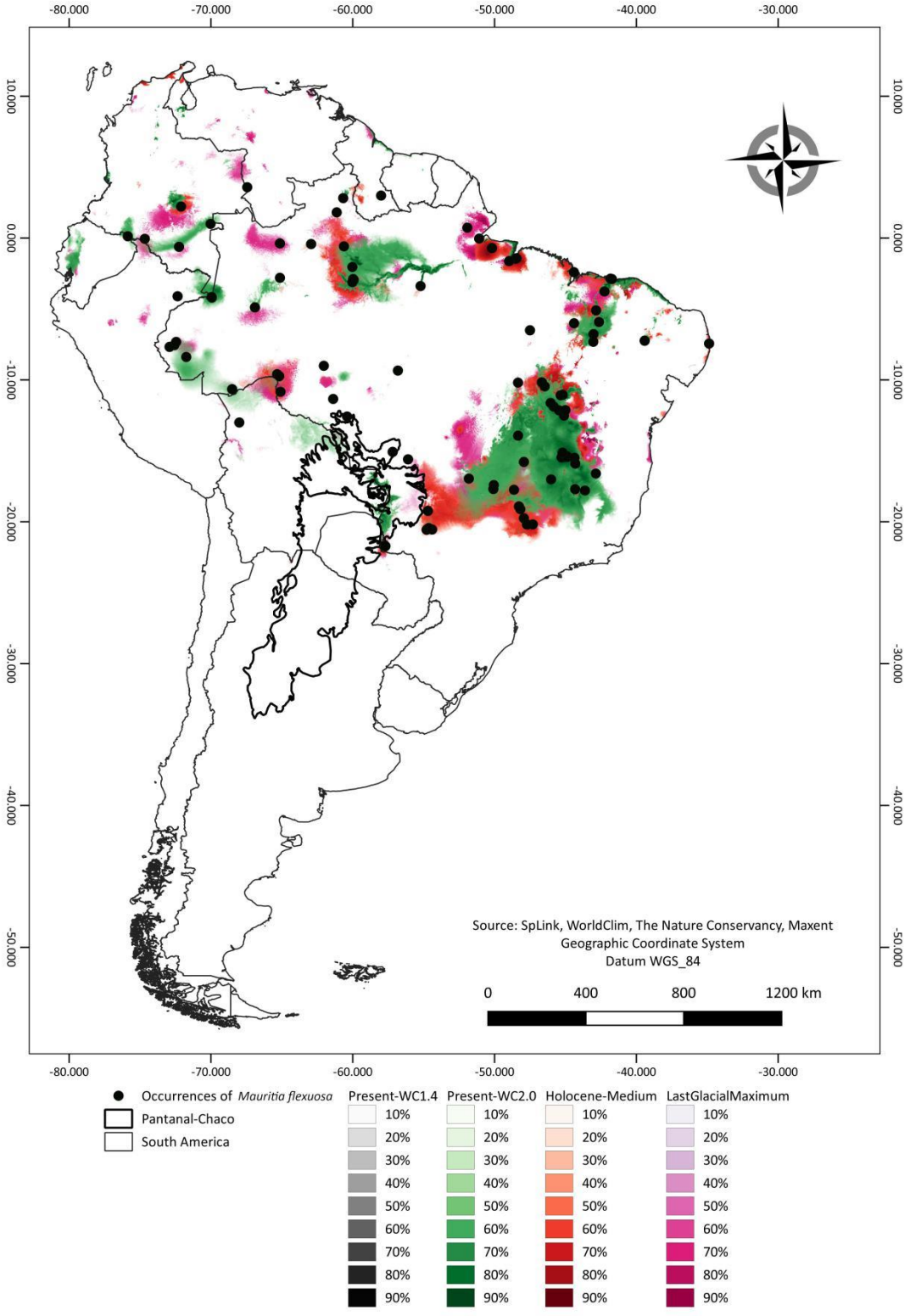

Figure 1 - Occurrences of *Mauritia flexuosa* L. f. and distribution models of the species based on climatic packets of the present, middle Holocene and last glacial maximum in South America. Source: The authors (2019).

Tabebuia aurea (Silva Manso) Benth. &Hook.f. ex S.Moore is a pioneer species with monodominant occurrence in the Pantanal, generating extensive areas denominated locally as "paratudal". In this study, we have investigated other biomes, such as the Atlantic Forest, Amazonian, Cerrado and Caatinga (PRADO et al., 1992, p.915, POTT and POTT, 2009, p.1068, LEITMAN et al., 2015, p.1 and LOHMANN, 2015, p.1), as can be observed in Figure 2.

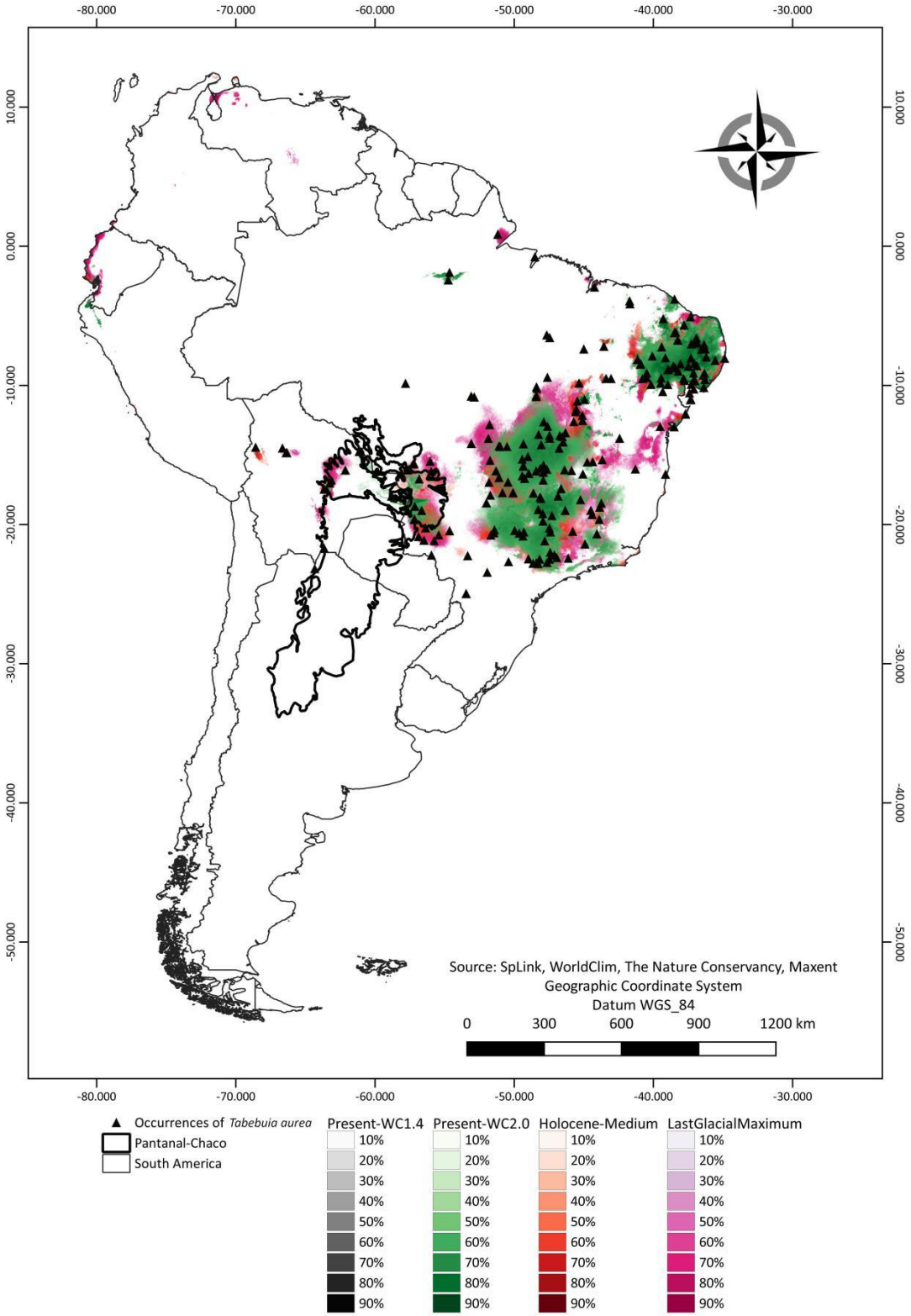

Figure 2 - Occurrences of *Tabebuia aurea* (Silva Manso) Benth. &Hook.f. ex S.Moore and models of distribution of the species based on climatic packages of the present, average Holocene and last glacial maximum in South America. Source: The authors (2019).

In order to obtain the geographic location data of the species collections and subsequent modeling of the species distribution, data from the herbariums registered in Specieslink-INCT (2018) and records of the occurrence of field trips were used. The data of *Mauritia flexuosa* are sub-sampled by the difficulty of collecting and preserving the material, using 177 records of occurrence of virtual herbaria and 22 records in field trips. 300 records of occurrence of *Tabebuia aurea* were found in the virtual herbaria.

Data from the Middle Holocene (MH - ca. 6,000 years old AP) and the current scenario were obtained from the Worldclim site (2017). We used 67 weather variables from the WorldClim version 1.4. This data set is formed by the climatic means of variables that can interfere in the living conditions of the world's meteorological stations between 1960 and 1990, with a spatial resolution of 5 km, which reflect various parameters of temperature, precipitation and seasonality that may be important to determine the distribution of the species. For the period of the Middle Holocene (MH), 170 variables were used, while 55 variables were used in the last glacial maximum (LMG) in the same spatial resolution (HIJMANS et al., 2005, p.1965). 67 climatic variables of the present time were also used in the WorldClim version 2.0. Furthermore, the data is also formed by the climatic means of variables that can influence living beings as the WorldClim version 1.4 and was collected between the period of 1970 and 2000, in the same spatial resolution (FICK and HIJMANS, 2017, p.4302). The bioclimatic layers were extracted to an extent that covered all South America.

The models generated consisted of computational processing that associated the geographical information of occurrence points (biotic data) with environmental variables (abiotic data) of the present and the past, generating a representation of the conditions required by the species. The use of algorithms has been applied to create models that represent such conditions and that can also be projected on a map that shows the potential areas of occurrence of these species (Giannini et al., 2012, p.735).

Moreover, the shapes of ecological regions such as Chaco and Pantanal were obtained from The Nature Conservancy (TNCMaps) in 2016.

The models were processed through the Maxent algorithm contained in the free and open-source application of the same name, version 3.4.1 (PHILLIPS et al., 2017, p.887). To evaluate the quality of the generated models, the Maxent algorithm uses a set of independent data for each of the climatic variables tested in two sets of data (75% test and 25% training) selected by the algorithm itself (PHILLIPS et al., 2009, p.10).

The Maxent program generates statistical analyzes that serve to evaluate its own performance. One of the analyzes is the "area under the curve" (AUC) index, which provides an estimate of how well the model distinguishes the occurrence of the species from random locations, being the models with values above 0.75 the ones considered potentially useful (ELITH et al. al., 2011, p.50).

The results were organized with the geographic information system (GIS) in free software QGIS 3.4.4. (SHERMAN et al., 2014).

3. RESULTS AND DISCUSSION

The models only generated with data from WorldClim version 1.4 at the present. Both species presented smaller areas of environmental suitability than the models generated with the data of the variables group of WorldClim version 2.0, as it can be visualized in Figures 3 and 4.

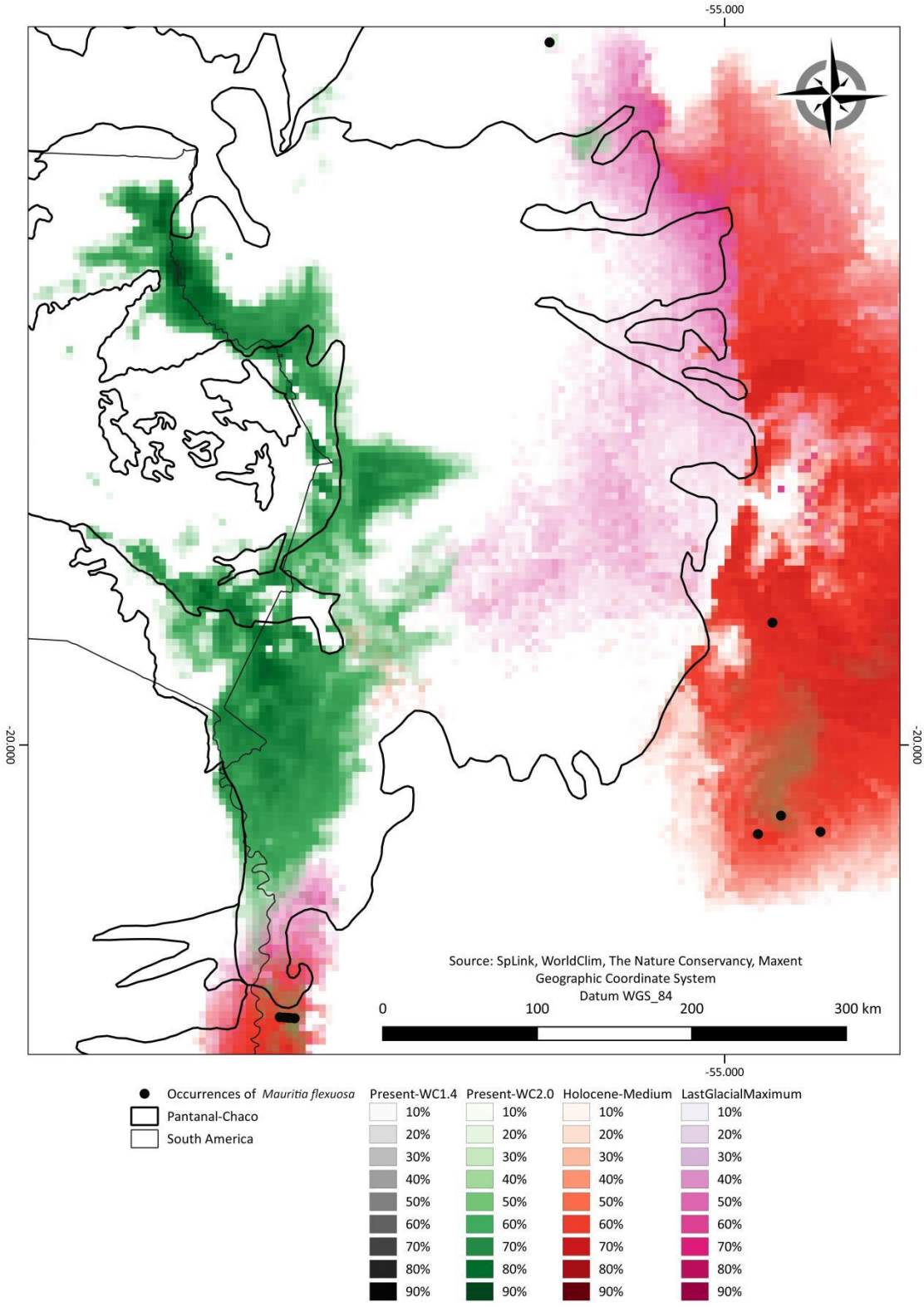

Figure 3 - Occurrences of *Mauritia flexuosa* L. f. and models of species distribution based on climatic packets of the present, middle Holocene and last glacial maximum in the Pantanal areas of part of the Chaco. Source: Authors (2019).

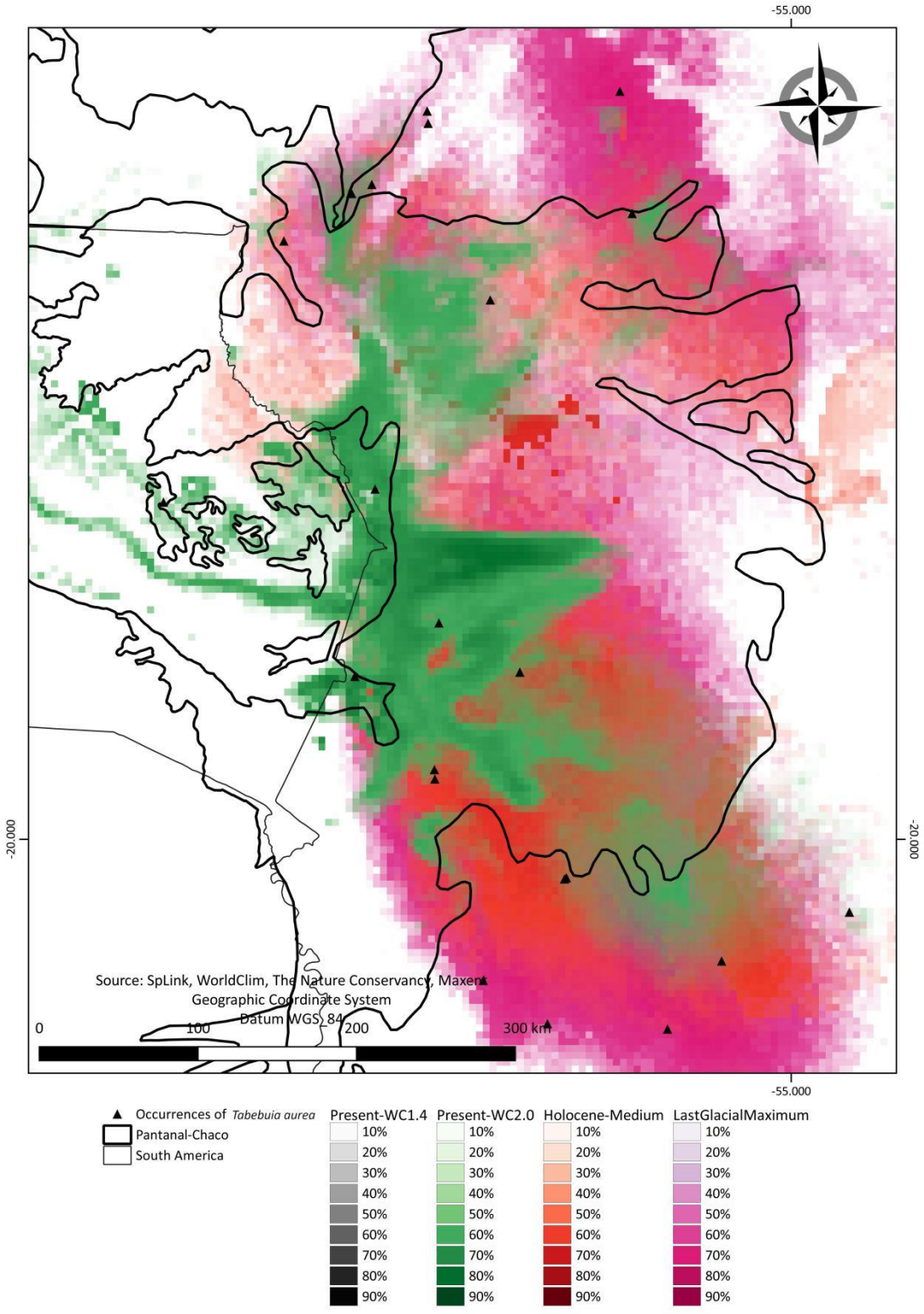

Figure 4 - Occurrences of *Tabebuia aurea* (Silva Manso) Benth. &Hook.f. ex S.Moore and species distribution models based on the present, middle, and Holocene climatic packets and the last glacial maximum in the Pantanal and Chaco part areas. Source: Authors (2019).

In the case of the Middle Holocene (MH) and Last Glacial Maximum (LGM) periods, the generated models suggest greater areas of environmental suitability than the present data in both versions. There are larger areas observed in the south-western south-east direction of South America.

The climate changes of the past varied significantly the temperature and humidity of the continent, modifying the occupation of the plant species, which is confirmed by carbon isotopes analyzed in the Amazon region (ROSSETTI et al., 2017).

The variations of the models generated by the Maxent algorithm are considerable possibilities in the phytogeography of the treated species, since works such as Rossetti et al. (2017, p. 75) support such variations.

The distribution of Mauritia flexuosa in figures 1 and 3 is extensive in South America. Indeed, there are records of more concentrated occurrences in the central region as well as records of occurrence in the Northeast and North of Brazil and in the Amazon region. Regarding the Pantanal region, there are records in the southern portion of the South America.

For all the models generated in all periods, the *Mauritia flexuosa* index (AUC) was 0.96, a value that suggests that the algorithm is capable of generating satisfactory areas of suitability.

In the Pantanal region, *M. flexuosa* does not present many records of occurrence, however, the modeling suggests areas of environmental suitability favorable to the occupation in the present time. Furthermore, the models suggest that there were possibilities of favorable environments for the Pantanal occupancy towards South and East of the region in the MH and LMG.

Observing figures 2 and 4, the distribution of *T. aurea* shows that the species present high adaptability in different environments, since the distribution occurs in several Biomes of Brazil and South America. Occurrence records may be concentrated by local research with local flora, once many regions of Brazil and South America are lacking investment for collections and research. Therefore, the distribution of the records of this species was more concentrated in the diagonal between the Pantanal and the Brazilian Northeast.

For all generated *T. aurea* models in all periods, the AUC index was 0.90. Values above 0.75 confirm the ability of the algorithm to be sensitive to variations both in the environment and in locations where the species occur.

Tabebuia aurea in the Pantanal presents more records than *M. flexuosa*. Thus, the areas of environmental suitability are larger. In the MH and LMG periods, modeling suggests that there were favorable environments for an expansion of the Pantanal's occupation of the species in the North and East-West direction of the Biome.

The climatic variations proved by paleoclimatic and paleoenvironmental studies, such as the ones of Bissa et al. (2013, p.138) and Arruda et al. (2018, p.52), confirm the possibility of the environmental suitability areas proposed in the MH and LMG work models.

The models proposed for *T. aurea* show low distribution in the south of the Pantanal and also in other regions of the continent.

Southern areas were in the process of formation with no predominance of flooded sites and extreme temperatures (KRUCK et al., 2011, p.195).

The climate change scenario for today's drier environments is evident. Therefore, there is a prospect that the Pantanal will become desert with a possible change from the current local vegetation formations to the Savanna Forest (Pott, 2000, p 177).

The current distribution of the two species with areas of favorable environmental suitability in both the Pantanal and the Cerrado should be related with the vegetation formation variation as well as the capacity of these species to support such variations (ZANELLA, 2011, p. 252; BUENO et al., 2017, p. 408; ARRUDA et al., 2018, p. 51).

4. CONCLUSIONS

There is a difference between Worldclim climate packages in versions 1.4 and 2.0 from the present, considering that the areas of environmental suitability of these models are different. The climatic variables of the MH and LMG present different areas of environmental suitability, highlighting the climatic differences of the periods according to the distribution of species occurrences.

In both species, the models in the past periods (MH and LMG) suggest areas of environmental suitability greater than at the present and possibly there were favorable environments for the expansion of the occurrence of the two species throughout Pantanal and Chaco.

The models suggested in the MH for *Mauritia flexuosa* show areas of environmental suitability in the discontinuous Pantanal and Chaco region. In the LMG, there is a greater continuity of occurrence probabilities of environmental suitability areas through Pantanal and Chaco.

The models suggested in the MH for *Tabebuia aurea* present environmental suitability areas in the Pantanal and Chaco regions. In the LMG, as in *Mauritia flexuosa*, the models suggest greater environmental suitability areas than MH and the present.

Since *Tabebuia aurea* presents more records of occurrence through the Pantanal, it also shows larger environmental suitability areas both in the present and past.

This and other studies contribute to the discussions on environmental preservation, proposing areas of protection that mitigate the loss of current diversity.

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