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Distribution of *Handroanthus heptaphyllus* In Brazil and Future Projections According to Global Climate Change

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ABSTRACT

In this work, we mapped the distribution of *Handroanthus heptaphyllus* in Brazil and projected future scenarios of climate change, using potential distribution modeling (MDP). In the first step, we mapped the climate of the current period and for future scenarios (1961-1990, 2011-2041, 2041-2070 and 2071-2100, respectively). the next step, these maps were compared to the 114 points of occurrences of the species. The climate projections were made in accordance with scenarios presented in the 4th Assessment Report of the Intergovernmental Panel on Climate Change - AR4 / IPCC. The projections for the next decades indicate alterations in the distribution of *H. heptaphyllus*. Additionally, it demonstrated a significant reduction of distribution areas in the northern limit, with retreated ecological niche from latitudes south and to higher altitudes. We conclude that the preservation of *H. heptaphyllus*, protecting it from the climatic changes that will occur in the next decades. The BAGs with the populations this species should be established based on the same criteria for the seed collection areas, in order to maintain the similar environmental conditions and avoid the effects of undue external influences.

Keywords: Ipê, species ocurrence prediction, genetic conservation

Introduction

Handroanthus heptaphyllus (Vell.) Mattos, Known as ipê-roxo, is a late and shade tolerant secondary species in the juvenile stage. The species, when adult, is part of the upper forest extract, and has high longevity (LONGHI, 1995). In Brazil, it occurs naturally in northern areas, in western Bahia as well as in the states of Espírito Santo, Minas Gerais, Mato Grosso do Sul, Rio de Janeiro and São Paulo (CARVALHO, 1992). According to the classification of Köeppen, the species occurs in the following climatic types: Tropical (Af, Am and Aw); subtropical altitude (Cwa and Cwb); And Humid Subtropical (Cfa). These climatic types have well distributed rains in all areas (except in the north of Paraná), and rainfall varies from 850 mm to 3,700

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mm in state of Minas Gerais and São Paulo, rescpectively (CARVALHO, 2003).

H. heptaphyllus has been widely studied due to its high economic value (DA PONTE et al., 2017) and ecological importance (CARPANEZZI & CARPANEZZI., 2006). There are records of its use for wood purposes in Brazil since the Jesuit period (SCHULZE-HOFER, 2010). More specifically, there is evidence regarding its intrinsic properties, density, physical-mechanical resistance, resistance to attack by xylophagous organisms and natural durability. In medicine, its extractives are used to treat inflammation and parasitic diseases (MACHADO et al., 2003). In addition to its exuberant beauty, it is widely used in urban afforestation (MORI, 2010). It is recommended for environmental restoration by facilitating the regeneration of pioneer species (CALLEGARO et al., 2013). It is also suggested for forest compositions aimed at mitigating the negate,ve effects of global climte change (MIRANDA et al., 2011; MELO et al. , 2015). Although widely used in urban afforestation during which its seeds are commercialized, the exploitation of its wood leads to population decline (NCFlora, 2012). For the purposes of forest planning in pure plantations or for conservation purposes, potential distribution modeling is presented as a tool for mapping potential species occurrence and adaptation areas (BADER et al., 2008; MELO et al., 2015). Thus, this work aims to model the climatic aptitude of *Handroanthus heptaphyllus* in Brazil and to design possible changes in their spatial distribution according to future climatic scenarios presented in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) with the use of Modeling of Potential Distribution of Species.

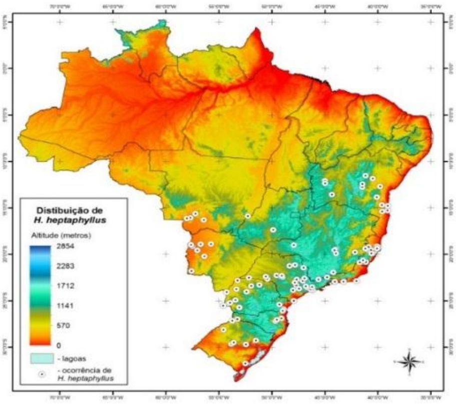
Material and Methods

Elaboration of climatic variables spreadsheet of and distribution of *H. heptaphyllus*

We obtained 114 *H. heptaphyllus* occurrences in Brazil (Figure 1). Those were extracted from the database of biological collections of the Reference Center on Environmental Information (CRIA), available at http://www.cria.org.br/ (CRIA, 1999), in the SpeciesLink tool. This is a resource of information on species of fauna, flora and microbiota, which gathers historical data on the places of species occurrence, obtained from herbaria present in all areas of Brazil. The system works in association with another system of predictions (forecasting) of geographical distribution of species using mathematical modeling.

The data with the occurrence of *H. heptaphyllus* were analyzed for completeness, consistency and occurrence of errors. The errors were corrected them whenever possible.

Figure 1. Altitude and occurrence map of *H. heptaphyllus* in Brazil from CRIA (1999) and USGS MNT (1999), adapted by de Weber and Hasenack (2004).



The data were discarded when not possible to correct. The outliers were eliminated after previous analysis. In this way the non-representative regions of the natural occurrence of the species were verified, due to the existence of any existing plantations outside the natural occurrence zone and were recorded in the occurrence database of the species.

The climatic variables of Brazil were obtained in the database elaborated by Hamada et al. (2008), which gathers data from historical series comprising the period from 1961 until 1990. This data set contain a network of agrometeorological stations distributed throughout the national territory.

The baseline climate maps (considered as current climate - 1961-1990) and future maps were elaborated based on the occurrence points (geographic coordinates) of the climate change scenarios in the future. Seasonal averages of minimum and maximum air temperatures (spring, summer, autumn, winter), average temperatures and total rainfall accumulated in one year were calculated.

The data were organized on maps using geographic information systems (GIS). The numerical model of the terrain - MNT (USGS, 1999) and latitude and longitude were used in the 1: 250,000 scale. Adaptations and clippings of the MNT images from the United States Geological Survey (USGS) in association with a research unit of the Brazilian Federation were made by Weber et al. (2004). The original radar images were corrected to compensate for the existing gaps when there was a lack of information due to the existence presence of clouds or other types of image noise made by Shuttle Radar Topographic Mission (SRTM). This model was used to generate temperature maps of the occurrence region of *H. heptaphyllus* (Figure 1).

The following regression equation was used:

Temperature = a + b x altitude + c x latitude + d x longitude

Values of variables:

a: constant;
b: altitude coefficient (NTM);
c: latitude coefficient;
d: coefficient of the longitude.

The regression equation, mentioned previously, was used in GIS in the ArcGIS 10 program and in the map calculator function (raster calculator), generating all the regional temperature maps. The other data were generated using ordinary kriging, using semivariogram models.

The same data used to define the boundaries of each homogeneous climatic zone were also used in the time series elaborated for the future scenarios; defining new boundary zones for the development of forest species.

Elaboration of climate scenarios for the next decades

The selected climate models were compiled and grouped by Hamada et al. (2008), according to the 4th report of the Intergovernmental Panel on Climate Change (AR4 / IPCC) (IPCC, 2012). The selected scenarios were A2 and B1, with A2 being the most pessimistic scenario, taking into account the maintenance of the greenhouse gas (GHG) emission standards observed in the last decades. This would imply the existance of atmospheric CO2 concentrations of about 850 parts per million. In volume (ppmv) in the year 2011, B1 is the scenario of lower emissions or less pessimistic scenario. Furthermore, it demonstrated a tendency for the stabilization of GHG emissions, and concentration at the end of this century of about 550 ppmv (NAKICENOVIC and SWART, 2000). Distribution projections for the coming decades encompassing the years 2011 to 2100 were divided into three periods: 2011-2040; 2041-2070 and 2071-2100.

Potential Distribution Modeling (MDP)

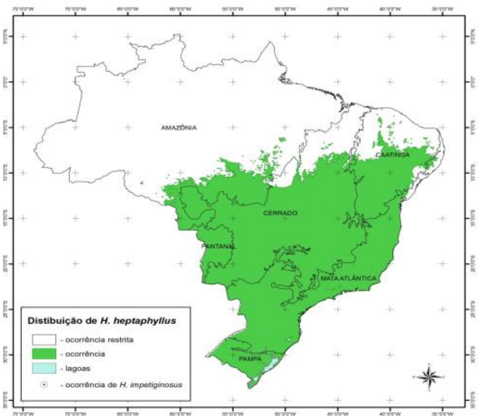
Predictions of occurrence were made with five models: Bioclim, Climate Space Model, Envelope Score, Environmental Distance and Niche Mosaic. The evaluation of the models were performed by parameters: the Area Under Curve (AUC), test set default (omissão??) and p value(binominal probability) (PEARSON, 2007). The most representative model was selected and four new simulations were run. In ArcGIS, the averages were calculated between the maps of the five simulations.

We used the Open Modeller, an ecological niche modeling program (available at: http://openmodeller.sf.net/) The program works with geographic distribution of species (latitude and longitude) and with environmental maps (climate, soils, relief, etc.), composing a mathematical prediction system for geographic distribution of species (MUÑOZ et al., 2009).

Results and Discussion

The mapping of the distribution of *H. heptaphyllus* (Figure 2) was significant for all models used (p <0.001). Among the generated models, the most representative of the distribution was selected. The Envelope Score, with AUC of 0.84, and with greater similarity to the distribution of the species was presented by Carvalho (2003). The other AUC values were: 0.72, 0.82, 0.85 and 0.99 for the Niche Mosaic, Climate Space Model, Bioclim and Enviromental Distance models respectively. It can be verified in Figure 2 that the model used allowed the expression of the potential occurrences of the species in an area that covers the domain of the five Brazilian biomes. All of which can be verified in records compiled by Carvalho (2003) and Aguiar & Santos (2007)), Espírito Santo et al. (2014), including the boundaries between the Pantanal, Cerrado and Amazon. The projections for future climatic scenarios (Figure 3) point to a reduction in areas suitable for the development of the species in the three individual evaluated periods (2011-2040, 2041-2070 and 2071-2100). A reduction also holds true for areas most sensitive to the decrease of populations that are concentrated in the latitudinal limits north and longitudinal limits east and west ("northeast" and "northwest" respectively). The generated models indicate the fragility of *H. heptaphyllus* populations in the Caatinga, Pantanal and Cerrado biomes, and in the border.

Figure 2. Distribution of *H. heptaphyllus* in Brazil by the Envelope Score model.

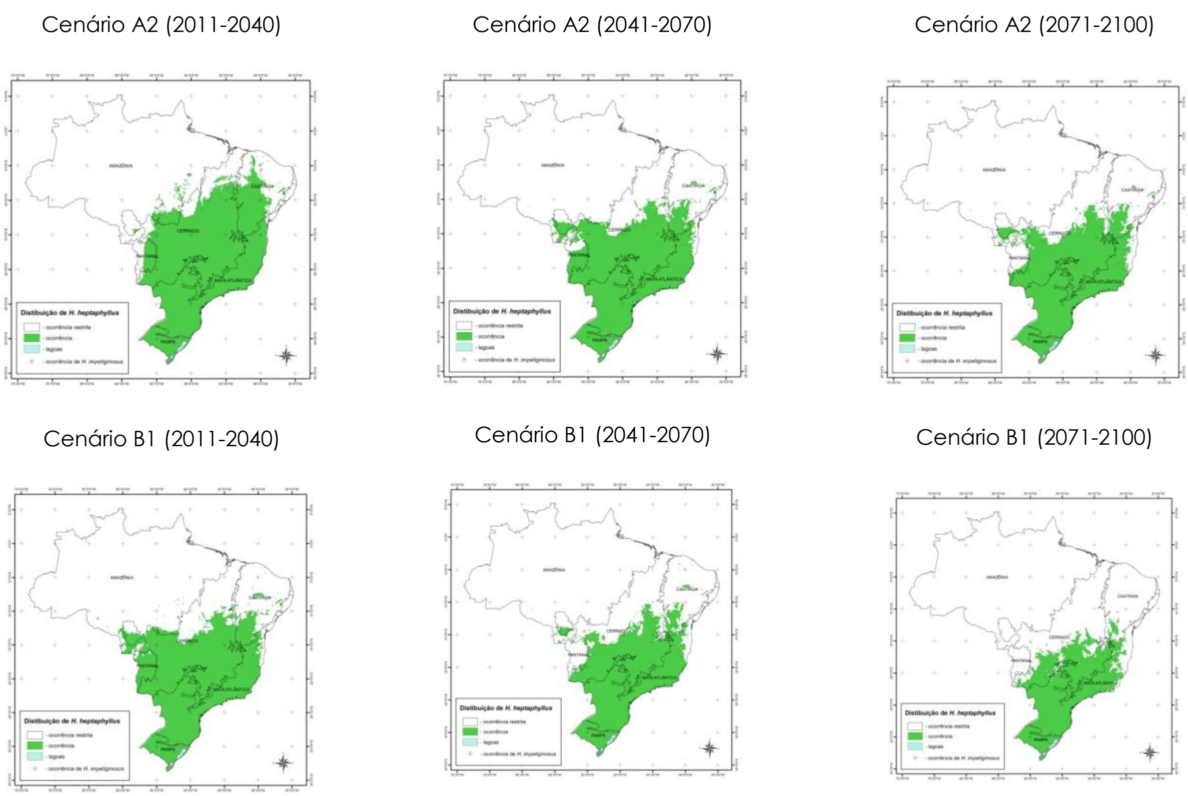


It is important to point out that the Caatinga is, along with the Amazon, among the ecosystems most sensitive to climatic variability, according to the map of vulnerability proposed by Seddon et al. (2016). It is also noted that areas vulnerable to population reduction coincide with regions that suffer intense anthropogenic pressure from land use change. In the state of Mato Grosso most of the 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 & SAITO, 2013).

The Pantanal Matogrossense is one of the most important Brazilian biomes and one of the largest continuous floodplains in the world. Its ecological functioning is dependent on the complex hydroclimatological dynamics of the region. Although there are uncertainties regarding the results obtained by climate models regarding the future behavior of the hydrological cycle against future scenarios in the region (MARENGO & VALVERDE, 2007), there are significant microclimatic changes in the conversion of forested areas to pasture in this biome, with potential changes in rainfall, temperature and energy balance regime (BIUDES et al., 2012). Such anthropic alterations provoked by the change in the use of the soil, can potentiate and amplify the inherent risks and associated consequences of climate changes on the native vegetation in the Brazilian bimas, as pointed out also by Vale et al. (2009), for different terrestrial ecosystems.

It has been verified that potential distribution modeling is an alternative tool for the mapping of potential areas of adaptation of the species. A smaller number of variables allows the extrapolation of the projections of the occurrence of the species in future scenarios, according to the global climate changes. That also would be required for the establishment of the occurrence by the zoning method (BADER et al., 2008, MELO et al., 2015). However, it is also important to consider that the presented model was generated with a climatic database is still inadequate to attend to the monitoring of the entire national territory. This is especially the case in remote areas with difficult access, where these natural populations are concentrated. A more specific survey of the occurrence areas of this species could contribute more efficiently to this study. as This information on the genetic variability of populations, and consequently the potential for adaptation, along with interactions, not considered in this work, could also modify the projection of occurrence of the species (GARCIA et al., 2014), as recorded by Silva (2013) for *H. heptaphyllus*. This may further diminish areas with potential for occurrence of the species in the future, since the projections presented here do not consider the edaphic physico-chemical characteristics or restrictions where the species is projected to occur.

Figure 3. Projections for the next decades of the distribution of *H. heptaphyllus* in Brazil according to global climate change (Model Envelope Scorore)



Conclusions

Future projections indicate changes in the distribution of *H. heptaphyllus* in climatic scenarios A2 and B1, as presented in the 4th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), with a significant reduction in the potential area of occurrence in its current northern latitudinal limits. These changes in spatial distribution have different intensities according to the individual periods evaluated (2011-2040, 2041-2070 and 2071-2100). The projections presented here should be evaluated considering the existence of other environmental factors conditioning the occurrence and development of the species. This information, when available, can be used in new studies aimed at understanding the current distribution and projected for the near future. These results suggest the need for population monitoring in the coming decades, as well as a better understanding of the direct and indirect effects of global climate change on species.

The creation of conservation or environmental preservation areas at strategic locations may help protect the species in regions of greater vulnerability, including, for example, populations found in fragments further north of the region of occurrence.

Preserving populations across the range of natural occurrence of the species would be ideal for ensuring greater genetic diversity and thus enabling a better response of the species to global climate change. As this strategy is very ambitious, in view of the country's economic development scenario, commercial and conservationist plantations with the support of agricultural research institutions, rural extension, private companies and rural owners will need to be more cognizant and make realistic decisions. Strategic plantations could be better planned based on the projection of areas of occurrence of the species in the face of global climate change.

Planting and germplasm banks (BAGs) should be established in climatic regions similar to seed collections, to ensure the maintenance of the genetic diversity of the species, conserving the genes of local adaptation and contributing to avoid the effect of undue external influences.. These plantations and BAGs should be encouraged in research and development projects carried out by research, extension and inspection institutions.

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