IMPACTS OF CLIMATE CHANGE AND HABITAT LOSS ON *Araucaria angustifolia* , A CRITICALLY ENDANGERED SPECIES

Cesar A. Marchioro[1], Karine L. Santos[1], Alexandre Siminski[1]

[1] Universidade Federal de Santa Catarina, Departamento de Agricultura, Biodiversidade e Florestas, Programa de Pós-Graduação em Ecossistemas Agrícolas e Naturais (PPGEAN), Curitibanos, Santa Catarina. E-mail: cesmarc@gmail.com

INTRODUÇÃO

The Araucaria Forest, an eco-region of the Atlantic Forest, is mainly distributed in southern Brazil and isolated areas in the states of São Paulo, Minas Gerais and Rio de Janeiro (southeastern Brazil), as well as northern Argentina. The Araucaria Forest has been reduced to only 12.6% of its original cover (Ribeiro *et al*., 2009) and the remaining populations are found in degraded and fragmented areas (Vibrans *et al*., 2011). *Araucaria angustifolia* (Bertol.) Kuntze (araucaria) is the dominant species in the Araucaria Forest and the only species of the Araucariaceae family found in Brazil.

The intense degradation of the Araucaria Forest has led the International Union for Conservation of Nature to list *A. angustifolia* as critically endangered for the first time in 2006. In addition to deforestation, climate change is another anthropogenic impact that has the potential to affect *A. angustifolia*, given that paleontological data suggests that climate has had a critical role in the past and present distribution of araucaria (Dutra and Stranz, 2009). Ecological niche models (ENMs) have been widely employed to investigate the effects of climate change on species distribution. These models correlate species occurrence records with environmental data, and can be used to assess the distribution range of a given species under current and future climate conditions. In this context, the present study aimed to assess (i) the recent land use changes within the distribution range of araucaria, (ii) the impacts of climate change on its distribution, as well as (iii) the effectiveness of the existing protected areas for its conservation.

MATERIAIS E MÉTODOS

Overall, 207 unique occurrence records were obtained from the literature and the online databases Global Biodiversity Information Facility and SpeciesLink. Elevation, soil and climate data were used as environmental variables. Data on soil depth to the bedrock, as well as clay and silt content were obtained from the SoilGrids database. Climate data included annual mean temperature, temperature seasonality, maximum temperature of warmest month, minimum temperature of coldest month, temperature annual range, annual precipitation, precipitation of wettest and driest month and precipitation seasonality. Data from the nine bioclimatic variables were also obtained for 2050 and 2070 based on the climate change scenarios RCP 4.5 and RCP 8.5 developed by the Intergovernmental Panel on Climate Change of the United Nations (UN). A Pearson's correlation test was carried out to ensure that the variables included in the model were not correlated. Temperature seasonality, minimum temperature of coldest month and precipitation of driest month were correlated with other variables and, therefore, removed from the analysis.

ENMs were developed based the maximum entropy algorithm implemented in MaxEnt v.3.3.3k which is a general-purpose machine learning software. We followed the same methodology employed by Marchioro (2016) and generated 15 models using different combinations of linear (L), quadratic (Q), product (P), hinge (H), and threshold (T) feature classes (L, H, LQ, LQH, and LQHPT) and regularization multiplier values (1, 3 and 5). Model performance was compared using the Corrected Akaike Information criterion (AICc), and the Area under the Curve (AUC) was used to evaluate the discriminatory ability of the selected model. AUC values vary between 0 and 1, while values closer 0.5 indicate that the model did not performed better than random, values closer to 1 indicate high performance.

The selected model fitted using current climate data was projected onto different years (2050 and 2070) and climate change scenarios (RCP 4.5 and RCP 8.5). The distribution shifts resulted from climate change was quantified by comparing current and future distributions. In order to quantify land use changes within the predicted distribution range of *A. angustifolia*, land use maps for 1985 and 2018 obtained from the MapBiomas initiative were overlaid with the generated suitability maps under current climate conditions. Additionally, the suitability maps were intersected with maps of the Brazilian protected areas to quantify the percentage of the estimated suitable ranges in the present and in the different years and scenarios of climate change under legal protection. In this analysis we assumed that the number and size of existing protected areas will remain constant over the years evaluated.

DISCUSSÃO E RESULTADOS

The model combining linear, quadratic, and hinge feature classes and regularization multiplier settings of three (LQH3) had the best performance among the 15 models tested, showing an AUC value of 0.85 (SE = 0.02). Current climatically suitable habitats for *A. angustifolia* were predicted in most of the Atlantic Forest domain in southern Brazil, except for the coastal region, north-western Parana, and western Rio Grande do Sul (Figure 2 and Figure S2). Suitable habitats were also predicted in high-altitude areas in the southern Minas Gerais, Rio de Janeiro, and eastern and southern São Paulo.

The model predicted a drastic reduction in the climatically suitable areas for *A. angustifolia* of 45% in 2050 and 53% in 2070 in the scenario RCP 4.5, and 53% in 2050 and 77% in 2070 in the scenario RCP 8.5. Most areas predicted as unsuitable in the future are located in the northern and western regions of araucaria distribution.

An increase of 327% in forest plantation and a reduction of 8% and 35% in natural forest and grassland, respectively, were recorded between 1985 and 2018 within the distribution range of araucaria. Proportionally, forest plantation that occupied 1.5% of the suitable areas in 1985 currently comprises 6.5%. Similarly, natural forest and grassland comprised 42.6% and 7.0% of the suitable range in 1985, and currently comprise 39.3% and 4.5%, respectively. Although the areas predicted as suitable and legally protected have declined according to the years and magnitude of climate change, the percentage of protected suitable ranges remained close to 10%.

CONCLUSÃO

In summary, we showed that despite the efforts to prevent the conversion of AF into agricultural use, this continues to occur within the current distribution range of *A. angustifolia*. Our models also predicted a drastic reduction in the suitable range for araucaria trees due to climate change. The magnitude of this reduction varied depending on the year and climate change scenario assessed. Regardless of year or climate change scenario, the effectiveness of the protected areas in the conservation of araucaria remained close to 10%.

REFERÊNCIAS BIBLIOGRÁFICAS

DUTRA, T.L.; STRANZ, A. 2009. Biogeografia, evolução e ecologia da família Araucariaceae: o que mostra a paleontologia. In: Floresta com Araucária: ecologia, conservação e desenvolvimento sustentável. FONSECA, C.R.; SOUZA, A.F.; LEAL-ZANCHET, A.M.; DUTRA, T.L.; BACKES, A.; GANADE, G. (Eds.). Ribeirão Preto, Holos, pp. 15- 33.

MARCHIORO, C.A. 2016. Global potential distribution of Bactrocera carambolae and the risks for fruit production in Brazil. PLoS One 11, e0166142.

RIBEIRO, B.R.; SALES, L.P.; LOYOLA, R. 2018. Strategies for mammal conservation under climate change in the Amazon. Biodiversity and Conservation 27, 1943-1959.

VIBRANS, A.C., SEVEGNANI, L., UHLMANN, *et al.* 2011. Structure of mixed ombrophyllous forests with Araucaria angustifolia (Araucariaceae) under external stress in Southern Brazil. Revista de Biologia Tropical 59, 1371-1387.

AGRADECIMENTOS

Os autores agradecem ao Dr. Alexandre ten Caten pela autorização do uso do software ArcGIS 10.2.