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Potential distribution of *Ocotea odorifera* (Vell.) Rohwer in urban areas of Curitiba, Paraná state, Brazil

Distribuição potencial de *Ocotea odorifera* (Vell.) Rohwer na área urbana de Curitiba, Paraná, Brasil

Allan Rodrigo Nunho dos Reis[I], Daniela Biondi[II], Mayssa Mascarenhas Grise[III], Jennifer Viezzer[IV], Bruna Kovalsyki[V], Eduarda Ximenes[VI]

Abstract

Ocotea odorifera is an endangered tree species, threatened by the urbanization process that occurs in the region of Curitiba, Paraná state, among other factors. Thus, the knowledge about their geographical distribution becomes necessary to plan protected areas that mitigate the effects caused by anthropic pressures on their populations. Therefore, the objective of this research was to develop a model of the potential geographic distribution of *Ocotea odorifera* and to verify the region of the municipality of Curitiba more relevant to its conservation. First, we georeferenced individuals of the species found in the municipality, while the model of potential distribution of the species was performed using the Maxent® algorithm, using meteorological and topological data as environmental variables. The Jackknife test indicated the most relevant variables to the model and the Area Under the Curve (AUC) indicated its accuracy. The potential distribution map was superimposed on a shapefile file containing the delimitation of 80 protected green areas with fragments of native vegetation. As a whole, 12 occurrence points of the species were located in seven sites. The map generated by Maxent indicated that the central-northern region of Curitiba presents the highest probability of *Ocotea odorifera* occurrence, corresponding to 19,550.30 ha. The model explained 96.3% of the species distribution in the study area. The relative contribution and the Jackknife test indicated that the most relevant variable to the model was pedology. In future plantings of the species, the pedology should be considered during its planning, as well as other specific characteristics of the soil at each site.

Keywords: Canela-sassafrás; Maxent; Species distribution modeling; Urban forest

Resumo

Ocotea odorifera é uma espécie arbórea ameaçada de extinção devido ao processo de urbanização que ocorre na região de Curitiba, Paraná. Assim, visando o planejamento de áreas de conservação que mitiguem os efeitos ocasionados pelas pressões antrópicas sobre as suas populações, torna-se necessário o conhecimento sobre a sua distribuição geográfica. Portanto, o objetivo da pesquisa foi desenvolver um modelo de distribuição geográfica potencial de *Ocotea odorifera* e verificar a região do município de Curitiba mais relevante a sua conservação. Primeiramente, foram georreferenciados indivíduos da espécie encontrados no município, enquanto a modelagem de distribuição potencial da espécie foi realizada por meio do algoritmo *Maxent*®, sendo utilizados como variáveis ambientais os dados meteorológicos e topo-edáficos. O teste de *Jackknife* indicou as variáveis mais relevantes ao modelo e a Área Sob a Curva (AUC), a sua acurácia. O mapa de distribuição potencial foi sobreposto a um arquivo *shapefile* contendo a delimitação de 80 áreas verdes protegidas com remanescentes de vegetação. Ao todo, 12 pontos de ocorrência da espécie foram localizados, em sete locais. O mapa gerado pelo *Maxent* indicou que a região centro-norte de Curitiba apresenta as maiores probabilidades de ocorrência de *Ocotea odorifera*, correspondendo a 19.550,30 ha. O modelo explicou 96,3% da distribuição da espécie na área de estudo. A contribuição relativa e o teste de *Jackknife* indicaram que a variável mais relevante ao modelo foi pedologia. Em futuros plantios da espécie deve-se considerar a pedologia durante o seu planejamento, além de outras características específicas do solo em cada local de plantio.

Palavras-chave: Canela-sassafrás; Floresta urbana; *Maxent*; Modelagem de distribuição de espécies

[I] Engenheiro Florestal, Doutorando, Programa de Pós-Graduação em Engenharia Florestal, Universidade Federal do Paraná, Av. Lothário Meissner, 632, CEP 80210-170, Curitiba (PR), Brasil. allan.nunho@gmail.com (ORCID: 0000-0001-5878-4707)

[II] Engenheira Florestal, Drª., Professora Titular, Programa de Pós-Graduação em Engenharia Florestal, Universidade Federal do Paraná, Av. Lothário Meissner, 632, CEP 80210-170, Curitiba (PR), Brasil. dbiondi@ufpr.br (ORCID: 0000-0003-0532-7363)

[III] Bióloga, Drª., Professora, Secretaria Estadual de Educação do Paraná, Av. Água Verde, 2140, CEP 80240-900, Curitiba (PR), Brasil. mayssamonteiro@gmail.com (ORCID: 0000-0001-5200-1652)

[IV] Engenheira Florestal, Doutoranda, Programa de Pós-Graduação em Engenharia Florestal, Universidade Federal do Paraná, Av. Lothário Meissner, 632, CEP 80210-170, Curitiba (PR), Brasil. jen.viezzer@gmail.com (ORCID: 0000-0002-5733-2212)

[V] Engenheira Florestal, Doutoranda, Programa de Pós-Graduação em Engenharia Florestal, Universidade Federal do Paraná, Av. Lothário Meissner, 632, CEP 80210-170, Curitiba (PR), Brasil. kovalsyki.b@gmail.com (ORCID: 0000-0002-1213-2102)

[VI] Engenheira Florestal, Mestranda, Programa de Pós-Graduação em Engenharia Florestal, Universidade Federal do Paraná, Av. Lothário Meissner, 632, CEP 80210-170, Curitiba (PR), Brasil. eduardaximenes@live.com (ORCID: 0000-0003-1151-3947)

Introduction

Species extinction is a major element of the current environmental crisis, mainly in the context of urbanization. Discussions about biodiversity loss and its consequent extinction rate have been intensified due to its extent worldwide.

In these circumstances, conservation and restauration strategies for threatened species populations depend on the knowledge of their natural geographical distribution, which is determined by variables such as climate, soil and dispersal capacity (YANG *et al.*, 2013; ZUQUIM *et al.*, 2019). Thus, estimates of suitable areas for species based on their potential distribution is fundamental for a conservation planning that mitigate the effects caused by anthropic pressures over biodiversity (ZUQUIM *et al.*, 2019).

Species Distribution Predictive Models (SDPMs) are important tools to estimate geographical distribution of species. In general, these potential distribution modelings create cartographic representations of a suitable spatial region for the presence of species according to environmental variables that match its distribution requirements (MATEO; FELICÍSIMO; MUÑOZ, 2011). Also, modelings are projected over maps providing numeric values of each point in the landscape to estimate the probability of each pixel as a potential point for the presence of the species (MATEO; FELICÍSIMO; MUÑOZ, 2011).

Previous studies of Species Distribution Predictive Models, however, have often focused on areas of great geographic extension wherein accuracy is decreased by its size, besides of considering weakly regional variations of environmental conditions and its interactions (MURPHY; LOVETT-DOUST, 2007; FRANKLIN, 2010). As a consequence, few researchers have addressed modeling in smallest areas such as municipalities or protected areas.

The municipality of Curitiba is in the Mixed Ombrophilous Forest (MOF) domain, as part of forestry formations and associated ecosystems that compose Brazil's Atlantic Forest. This region has several threatened species, such as *Ocotea odorifera* (Vell.) Rohwer (*canela-sassafrás*), species highlighted here since it is an indicator for this forest ecosystem. A reasonable explanation for *Ocotea odorifera* extinction risk is their high market value, inappropriate species management, and extensive urban development. Hence, these factors may be responsible for *Ocotea odorifera* being classified as "Endangered" (EN) according to the Official List of Brazilian Flora Threatened Species (BRASIL, 2014).

Taking into account that the greater detail of species potential distribution in a municipality may provide the greater relevant information to its conservation, the aim of this research was to develop a model of the potential geographic distribution of *Ocotea odorifera* and verify which regions of Curitiba are more important to conserve.

Material and methods

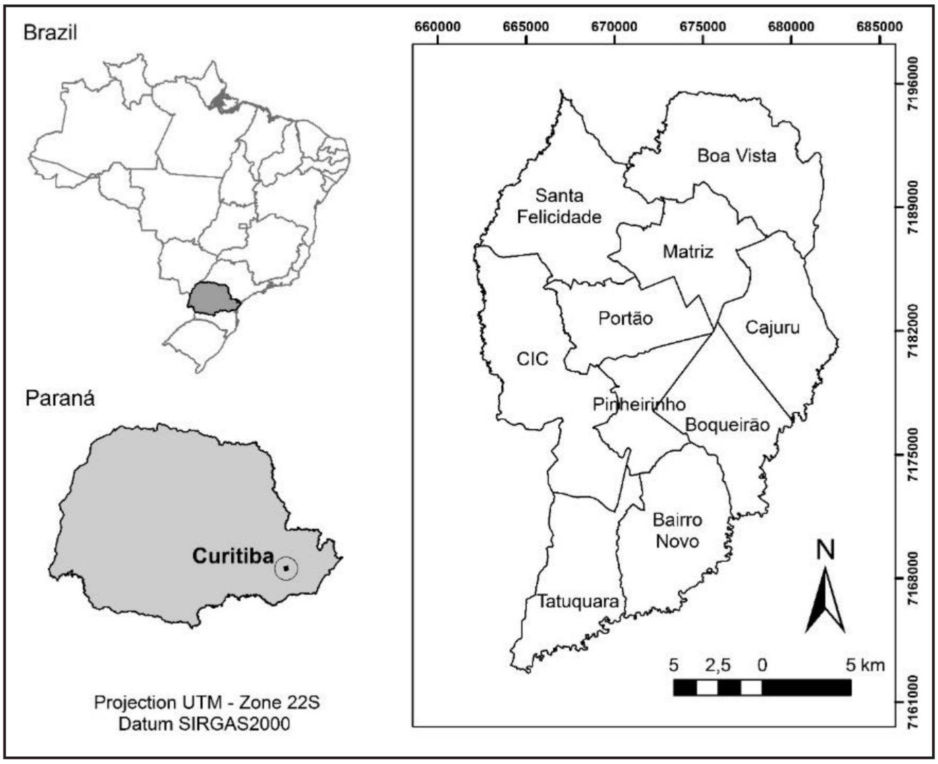
Study area

The municipality of Curitiba is situated in the Paraná State, Brazil, between geographical coordinates 25°25'46" S and 49°16'16" W, comprising a total area of 435.27 km^2 with 934.6 meters of altitude (Figure 1) (IPPUC, 2015). The forest area is mostly covered by the Atlantic Forest Biome and the terrain is flat or gently undulated, consisting of Guabirotuba formation sediments (IPPUC, 2015).

According to the climatic classification of Köeppen-Geiger, this region exhibits Cfb characteristics (subtropical and mesothermal) (IPPUC, 2015). Its average annual temperature and rainfall are 17. 4°C and 1,486.5 mm/year, respectively (IPPUC, 2015).

Figure 1 – Map of Curitiba's municipality and their administrative regions in the state of Paraná, Brazil.

Figura 1 – Mapa do município de Curitiba e suas regiões administrativas no Estado do Paraná, Brasil.



Source: Authors (2019)

Grassland and forest formations with species characteristic of MOF (both Montane and Alluvial) occurred in Curitiba. The MOF regions had a high physiognomic relevance of species *Araucaria angustifolia* (Bertol.) Kuntze (Paraná pine), *Ocotea porosa* (Nees & Mart.) Barroso (Brazilian-walnut), and *Ocotea odorifera*, besides other species of the *Ocotea* genus and the Fabaceae and Myrtaceae botanic families (RODERJAN *et al.*, 2002). In most of the municipality area, there was grassland composed mainly of species of Poaceae, interspersed by small forest nuclei wherein *A. angustifolia*, *O. porosa* and *Ocotea odorifera* predominated. The mentioned *Ocotea* forms dense sub-forests which characterized the plant physiognomy of the region (RODERJAN *et al.*, 2002).

In regard to the current municipality vegetation in terms of its urban forest, the area covered by vegetation corresponds to 43.69% of the city, in which 34.70% is private urban forest inserted within the blocks and 8.98% is public urban forest, considering the streets, green areas and water bodies (GRISE; BIONDI, ARAKI, 2016a). Additionally, 4.99% of Curitiba's vegetation area is corresponded by flower beds, 3.23% by green areas and 0.76% by riparian areas (GRISE; BIONDI, ARAKI, 2016a).

Data collection and analyses

Firstly, we researched *Ocotea odorifera* on specialized bibliography, botanical collections and observation records within the study area, such as herbalized material available at the *SpeciesLink* database (CRIA, 2017); floristic surveys conducted in Curitiba; management plans of protected areas; and reports from the Municipal Secretary of Environment and experts from the Federal University of Paraná.

Thereafter, we conducted field collections as recommended by Kamino *et al.* (2012), where we recorded the geographic location; altitude; and the following habitat's characteristics: topography, area conservation status, and vegetal cover; of each *Ocotea odorifera* found in the city. The habitat's characteristics are important information due to its fast transformation in the urban context. The geographic location of each individual was registered using Garmin GPS® 78s, with as approximate error of 10 meters. All specimens were recorded for this study, including the young ones.

We model the potential distribution of *Ocotea odorifera* in Curitiba through the Maxent® algorithm (PHILLIPS; DUDÍK; SCHAPIRE, 2004), version 3.4.1. of 2017. Maxent uses species presence data and environmental variables from the confirmed geographic location to estimate a range of probabilities for the species potential distribution. A logistic function is used by the model setup which provides an estimate probability from 0 to 1% of species presence (PHILLIPS; DUDÍK; SCHAPIRE, 2004), indicating the habitat's environmental suitability for the species occurrence (KHANUM; MUMTAZA; KUMAR, 2013). We established 1,000 combinations with 10 replications in cross-validate mode and adjusted its radius with "-30" according to the working scale.

We selected the environmental variables most relevant to the species distribution as a function of spatial scale, aiming to avoid using variables that would provide unnecessary restrictions to the model (PEARSON *et al*., 2007; FIGUEIREDO *et al*., 2015). Thereby, we evaluated the meteorological and topological data, with 30 meters of spatial resolution (Table 1).

Table 1 – Abiotic variables used for the elaboration of the potential distribution modelling of *Ocotea odorifera*.

Tabela 1 – Variáveis abióticas utilizadas para a elaboração do modelo de distribuição potencial de *Ocotea odorifera*.

Code	Abiotic variable	Variable type	Unit	Variable range	Source
bio.1	Altitude	Continuous	m	859.58 – 1087	Instituto Nacional de Pesquisas Espaciais - INPE (2011)
bio.2	Terrain horizontal curvature	Continuous	°/m	- 5 – 5	INPE (2011)
bio.3	Terrain vertical curvature	Continuous	°/m	- 0.145 – 0.139	INPE (2011)
bio.4	Declivity	Continuous	°	0.178 – 68.709	INPE (2011)
bio.5	Phytogeography	Categorical	-	*	Instituto de Terras, Cartografia e Geologia do Paraná - ITCG (2017)
bio.6	Terrain shape	Continuous	-	1 – 9	INPE (2011)
bio.7	Geology	Categorical	-	**	ITCG (2017)
bio.8	Terrain orientation	Continuous	°	0 – 359.99	INPE (2011)
bio.9	Pedology	Categorical	-	***	IPPUC (2017)
bio.10	Average annual precipitation	Continuous	mm	1657.73 – 1756.71	Instituto das Águas do Paraná - ÁGUAS PARANÁ (2017)
bio.11	Shaded relief	Continuous	-	0 – 0.999	INPE (2011)
bio.12	Maximum temperature	Continuous	°C	28.82 – 32.17	Leal, Biondi and Batista (2014)
bio.13	Minimum temperature	Continuous	°C	6.62 – 9.12	Leal, Biondi and Batista (2014)

Source: Authors (2019)

Where: *: Montane Mixed Ombrophilous Forests, Alluvial Mixed Ombrophilous Forests and grassland; **: Yellow Cambissol, Red-yellow Latossol, Red-yellow Argissol, Aluminic Argisol e Hydromorphic Soil; ***: Modern Sediments, Gneiss Migmatitic Complex e Guabirotuba Formation.

The precipitation values refer to annual collections from four monitoring points within the municipality limits, during the period from 1993 to 1999 (ÁGUAS PARANÁ, 2017). The temperature data were recorded during the four seasons of 2011, from 44 collection points distributed in four transects in the urban area of Curitiba (LEAL; BIONDI, BATISTA, 2014). The Inverse Distance Weighting (IDW) procedure was used to interpolate the meteorological variables.

We converted the environmental layers corresponding to the environmental variables to the ASCII format (.asc), cut out based on the geographical boundaries of the municipality of Curitiba, and defined with the same spatial resolution of 30 m due to the resolution of the topographic data. We used the QGIS® software, version 2.18, to perform these analyses.

In order to avoid multicollinearity, when there are high correlations (close to 1) among the abiotic variables, we analyzed the environmental data in pairs through the Principal Component Analysis (PCA) in software R, considering on the analysis values lower than 0.7 on Pearson correlation (FIGUEIREDO *et al.*, 2015).

We used the *Jackknife* test to verify the most relevant variables to the model and the estimation of its accuracy was performed through the Receiver Operating Characteristic (ROC), which evaluates its performance through a single value that represents the Area Under the Curve (AUC) (KHANUM; MUMTAZA; KUMAR, 2013, FIGUEIREDO *et al.*, 2015). The closer to 1 the AUC value, the better the model ability to estimate the presence of environmental conditions for the species (MARCO JÚNIOR; SIQUEIRA, 2009). We used the model which AUC values displayed both the total set and sub-set of occurrence (Training data), chosen randomly to test the predictive capacity of the model (Test data). The results were closer to 1, as recommended by Gomes (2012).

The final map of *Ocotea odorifera* potential distribution in the municipality of Curitiba overlapped a *shapefile* containing the delimitation of protected green areas: parks, forests, Private Reserves of Municipal Natural Patrimony (PRMNP, IUCN category IV), Urban Biodiversity Conservation Forests (UBCF), Ecological Station (IUCN category Ia) and Wildlife Refuge (IUCN category III) (Figure 4). This approach aimed to verify the most suitable sites to conserve the species (GOMES, 2012). The Municipal Botanical Garden, the Zoological Garden of Curitiba and the Public Walk were categorized as parks.

We used the typologies of protected green areas because they reveal the greatest amount of remaining vegetation coverage among the typologies of green areas of the municipality, in the case of parks and forests (GRISE; BIONDI, ARAKI, 2016b), as they have fewer anthropic impacts and because they offer greater conservation possibilities of the species in relation to other typologies, once they already have their using consolidated by the specific legislation (CURITIBA, 2000; 2015). However, since all the typologies of the protected green areas in Curitiba were not selected, the term Selected Protected Green Areas (SPGAs) was chosen in the present study, considering those that meet the criteria mentioned above.

A shapefile for the SPGAs was created based on the vectoral files overlapping provided by the Institute for Research and Urban Planning of Curitiba (IPPUC), dated July 2018, containing the delimitations of 48 parks and forest areas; 21 Private Reserves; 9 BCBUs; one Ecological Station and one Wildlife Refuge, totalizing 80 protected areas.

Results

Twelve individuals of *Ocotea odorifera* were found in Curitiba, located in seven green areas of the city: the PRMNP *Airumã* (1 specimen) and *Bosque da Coruja* (2); the Forest *Boa Vista* (1); the Parks *Barigui* (1) and *Barreirinha* (1); the *Barreirinha* Municipal Garden (1); and one area of public interest belonging to the Municipality of Curitiba (5); all presented in Table 2.

Table 2 – *Ocotea odorifera* occurrence in Curitiba, Paraná, Brazil.

Tabela 2 – Ocorrência de *Ocotea odorifera* em Curitiba, Paraná, Brasil.

Area	Stage	Coord. X	Coord. Y	Local features
1	A	673230	7190135	Sloping, moderately altered, with regeneration
1	Y	673248	7190115	Sloping, moderately altered, with regeneration
2	Y	672862	7191567	Sloping, little altered, with regeneration
2	A	672761	7191622	Sloping, little altered, with regeneration
2	A	672706	7191605	Sloping, little altered, with regeneration
2	A	672699	7191620	Sloping, little altered, with regeneration
2	Y	672669	7191605	Sloping, little altered, with regeneration
3	A	676083	7189906	Flat, heavily altered, without regeneration, senescent
4	A	675185	7193523	Flat, heavily altered, without regeneration
5	A	669163	7191257	Undulated, little altered, with regeneration
6	A	675096	7194068	Undulated, little altered, with regeneration
7	A	670419	7187739	Undulated, little altered, with few regenerating specimens

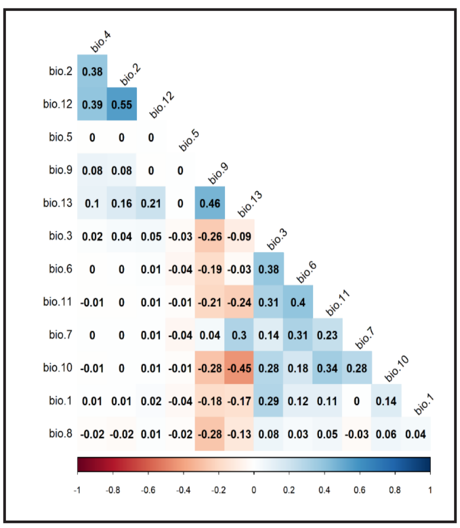
Source: The authors (2019)

Where: Area: 1 = PRMNP Bosque da Coruja; 2 = Area from Municipality of Curitiba; 3 = Forest Boa Vista; 4 = Barreirinha Municipal Garden; 5 = PRMNP Airumã; 6 = Barreirinha Municipal Park; 7 = Barigui Park. Stage: A = Adult; Y = Youth.

PCA analysis did not indicate Pearson correlation values higher than 0.7 (Figure 2). Thus, all the variables selected for the study were used to compose the potential distribution model, being considered pertinent to its autoecology. Most of the variables used to compose the model were non-climatic (10 variables of the 13 used).

Figure 2 – Analysis of main components for the environmental variables used for modeling.

Figura 2 – Análise de Componentes Principais para as variáveis ambientais utilizadas para a modelagem.



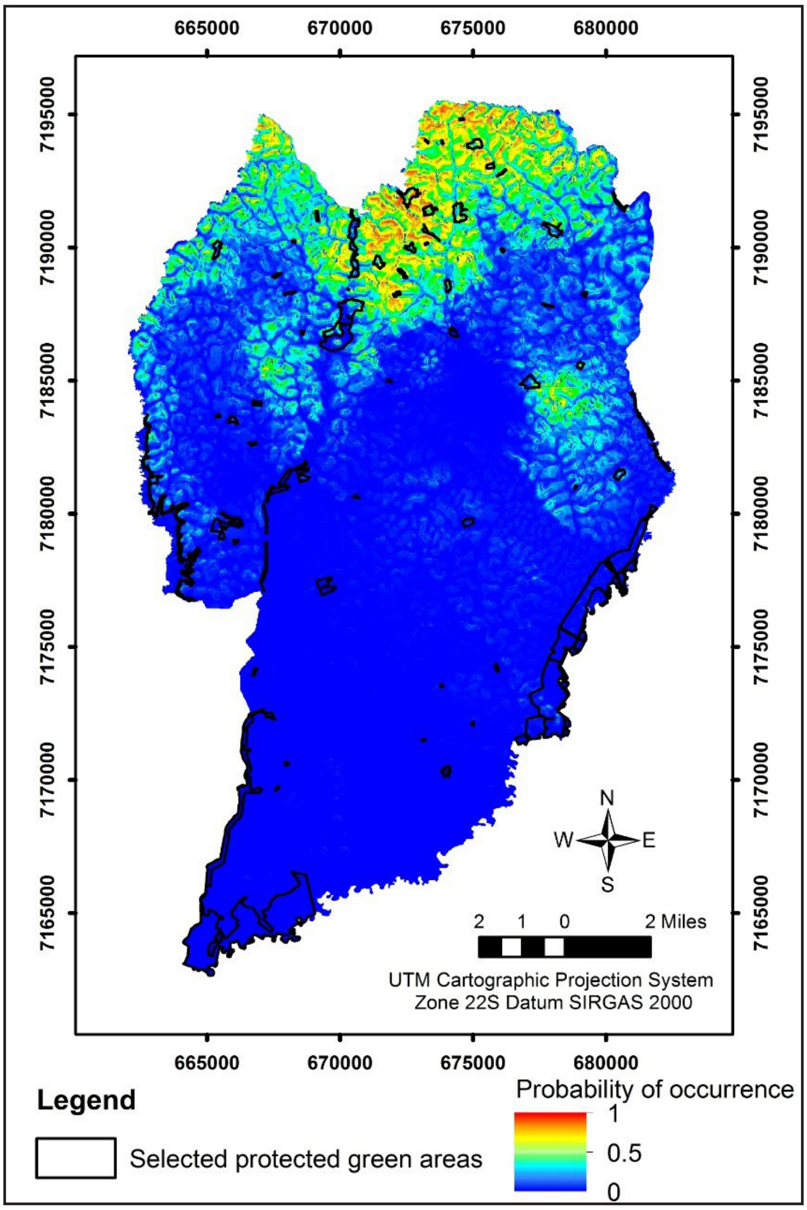
Source: Authors (2019)

Where: bio.1 = altitude; bio.2 = terrain horizontal curvature; bio.3 = terrain vertical curvature; bio.4 = declivity; bio.5 = phytogeography; bio.6 = terrain shape; bio.7 = geology; bio.8 = terrain orientation; bio.9 = pedology; bio.10 = average annual precipitation; bio.11 = shaded relief; bio.12 = maximum temperature; bio.13 = minimum temperature.

The map generated by Maxent (Figure 3) indicated that the north-central region of Curitiba, which includes the *Boa Vista*, *Matriz*, *Santa Felicidade* and *Cajuru* regions, presents the highest probability of occurrence of *Ocotea odorifera*, corresponding to 19,550.30 ha.

Figure 3 – Potential distribution of *Ocotea odorifera* **in Curitiba, Paraná state, Brazil.**

Figura 3 – Distribuição potencial de *Ocotea odorifera* em Curitiba, Paraná, Brasil.

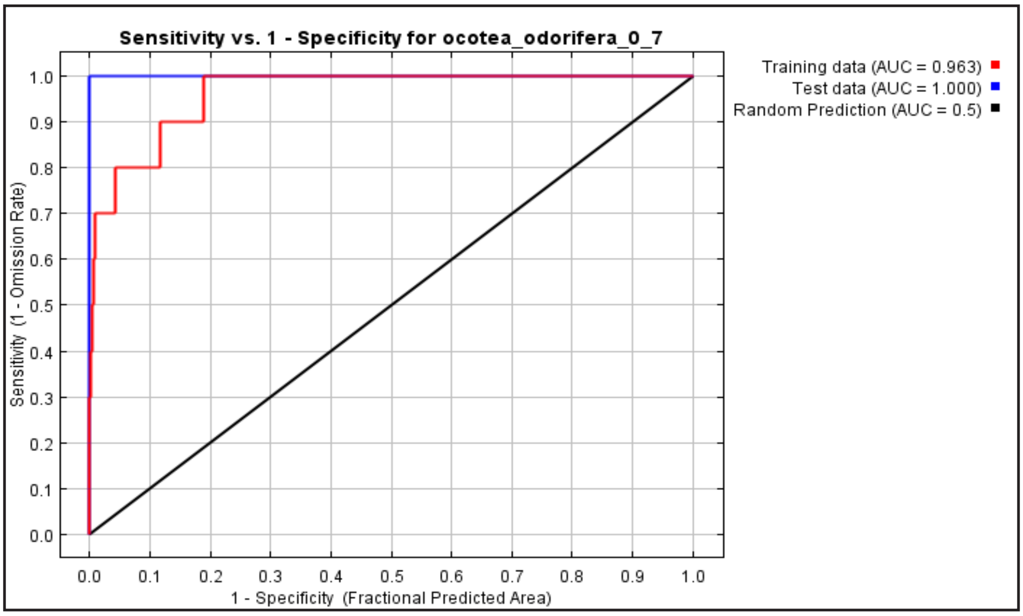


Source: Authors (2019)

The AUC values ranged from 0.954 to 0.988 for the Training data, and from 0.285 to 1.0 for the Test data. We chose the models which AUC values were 0.963 for the Training data, and 1.0 for the Test data (Figure 4).

Figure 4 – Area Under the Curve (AUC) for *Ocotea odorifera* in Curitiba, Paraná state, Brazil.

Figura 4 – Área Sob a Curva (AUC) para *Ocotea odorifera* em Curitiba, Paraná, Brasil.



Source: Authors (2019)

The analysis of the variable relative contributions to the model (Table 3) indicated that the most relevant variable was pedology, contributing with 48.9% of the response indicated by the model. The second and third variables that contributed the most were terrain shape and precipitation, with 12.7% and 11.3%, respectively. Minimum temperature and terrain orientation did not contribute to the model.

Table 3 – Percentage contribution of each abiotic variable used for modeling.

Tabela 3 – Contribuição percentual de cada variável abiótica utilizada para a modelagem.

Variable	Contribution (%)
Pedology	48.9
Terrain shape	12.7
Precipitation	11.3
Altitude	7.4
Geology	6.4
Phytogeography	3.6
Declivity	3.3

Continued ...

Table 3 – Conclusion ...
Tabela 3 – Conclusão ...

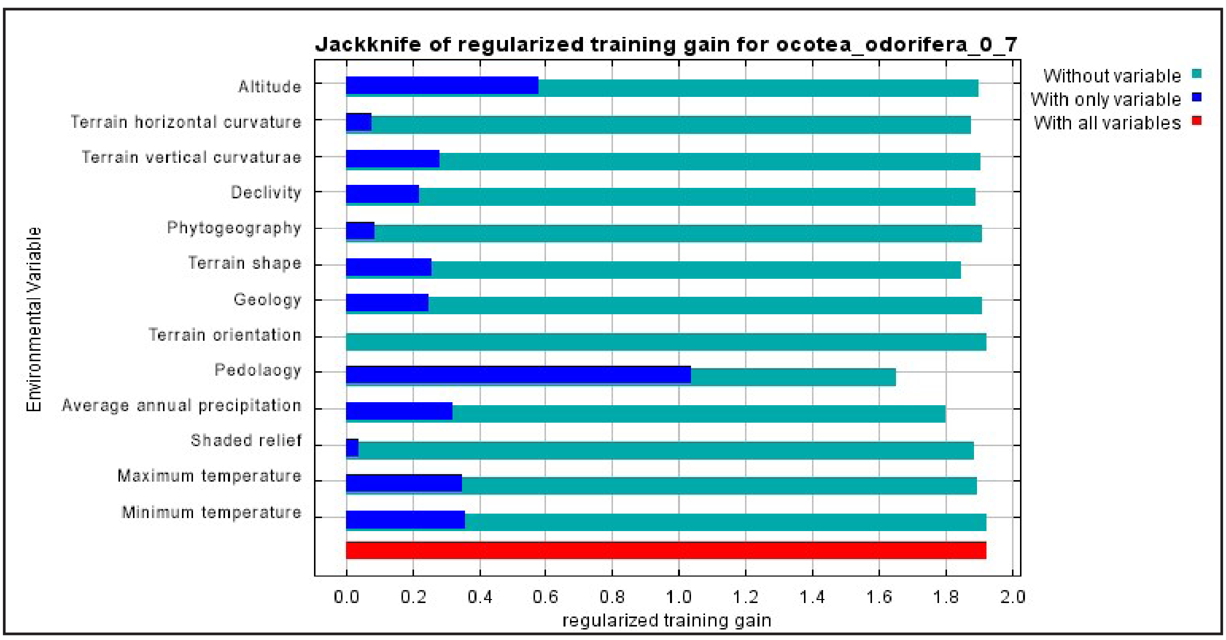
Variable	Contribution (%)
Terrain horizontal curvature	3.1
Shaded relief	2
Maximum temperature	0.8
Terrain vertical curvature	0.6
Minimum temperature	0
Terrain orientation	0
Total	100

Source: Authors (2019)

The Jackknife test (Figure 5) indicated that the occurrence of *Ocotea odorifera* seems to be influenced by the pedology variable, since it was the most relevant one to the model also when used alone. The second most important variable when used alone was altitude. The terrain orientation did not present relevance to the generated model, obtaining null value, being able to be excluded from the database of the model without any damage to its accuracy.

Figure 5 – Jackknife test indicating the importance of different variables adjusted to the model.

Figura 5 – Teste *Jackknife* indicando a importância de diferentes variáveis ajustadas ao modelo.



Source: Authors (2019)

Discussion

The *Ocotea odorifera* occurrence points, limited to the northern region of the study area, does not represent a modeling deficiency of the potential distribution of the species, since it provides indications about the most favorable sites for its occurrence. Not all places where individuals of a particular species are present, however, represents the best environments for their establishment, and may offer incomplete environmental conditions to meet their auto-ecological demands. Thus, although individuals can develop, they may not be healthy. Therefore, the potential distribution algorithm verifies the most relevant conditions for the species, independently of the vitality of the sampled individuals.

Franklin (2010) reinforces this idea by stating that a distribution model can be effective, even if the information used is from part of the whole study area, if the main objective is to predict habitat adequacy of non-inspected sites, especially in areas modified by human activities. In addition, sites with no occurrence records represent a background environment for the species environmental suitability, that is, with medium conditions for its establishment and which, for some auto-ecological reason, were never colonized (FRANKLIN, 2010).

However, models developed using few samples of biotic data, with less than 15 points of confirmed occurrence of the species, should be interpreted as indicators of regions with environmental conditions similar to those where the species is known (PEARSON *et al.*, 2007). The authors suggest that such models should be used in the segmentation of field surveys, as a basis for locating unknown populations and individuals, but not as estimates of the actual range limits for a species.

Cruz-Cárdenas *et al.* (2014), recommend that the main variables for the elaboration of SDPMs are topography and pedology, while climatic variables should be considered auxiliary. In addition, we highlight the number of top-soil variables used in the present study, higher than the amount commonly used in SDPMs' studies. Figueiredo *et al.* (2015) used four non-climatic variables: declivity, exposure, vertical distance to the nearest drainage, and Normalized Difference Vegetation Index (NDVI) to estimate the potential distribution of forest species in the state of Acre, Brazil.

The central-northern region of the city of Curitiba was indicated to be the most relevant for the occurrence of *Ocotea odorifera* due to the fact that the north region concentrates the highest altitudes of approximately 1,000 m and slopes, in addition to soils groups Latosols and Cambisols, indicated by Martins (2016) as preferred by the species. Besides these aspects, according to Grise, Biondi and Araki (2016b), the Boa Vista and Matriz regions, located in the north of the city, have the largest amounts of protected areas in the municipality. Thus, the results corroborate the places where the individuals of the species were recorded, and those with the highest probability of species' distribution are located closer to the northern limit of Curitiba and at higher altitudes.

Even in a relatively small area, the Maxent algorithm indicated a limited potential distribution area for *Ocotea odorifera* to a small portion of Curitiba, probably due to the scale of the abiotic variables used, which favors the greater detail of the adequacy for the species.

The model of potential distribution of *Ocotea odorifera* made by Martins (2016) for Brazil as a whole indicated that part of the Curitiba region should be one of the priority areas for the species' conservation, due to the greater environmental suitability it provides. Thus, we highlight the importance of modeling in a smaller scale, since, as noted, there may be significant differences in the occurrence probability. In addition, this approach can contribute to species conservation efforts by providing guidance to the best sites for the establishment of protected areas, and for the reintroduction of their populations. Thus, if the distribution of *Ocotea odorifera* is considered only on a greater scale, addressing all its ecological limits, conservation strategies may be impaired.

The non-occurrence modeling of *Ocotea odorifera* throughout the study area can be justified by the arguments of Murphy and Lovett-Doust (2007), which explain that individuals of a species tend to respond in exactly the same way to environmental conditions. However, a regional variation in the distribution of these conditions may influence the development of individuals. Thus, the results indicate that, although the municipality of Curitiba presents environmental factors relevant to the *Ocotea odorifera* occurrence, environmental variability may favor or hinder its establishment. Thus, other endangered species with environmental sensitivity may also benefit if more detailed studies of their potential distributions are made.

Therefore, the most important value of AUC indicates that the model generated using such environmental variables explains 96.3% of the species distribution in the study area. According to Yang *et al.* (2013), the AUC values found in our study are considered excellent because they are higher than 0.9. The AUC values found in this paper are similar to those of other studies for species of the genus *Ocotea*, corroborating the ability of the algorithm to predict the potential occurrence of this group of species. Using the algorithm Maxent®, Coelho, Carvalho and Gomide (2016) found a similar value of AUC (0,964) for *Ocotea corymbosa* (Meisn.) Mez, in Minas Gerais. Martins (2016) found that *Ocotea catharinensis* Mez, *O. odorifera* and *O. porosa* presented AUC values of 0,940, 0,910 and 0,960, respectively, in a study that includes part of the Atlantic Forest, from Bahia to Rio Grande do Sul.

The importance of pedology, both in its relative contribution and in its predictive capacity when used alone, is explained by the migration of the species, which may be restricted by soil suitability in its potential propagation pathway, as suggested by Zuquim *et al.* (2019). *Ocotea odorifera* has a preference for shallow soils and fast drainage, in addition to high chemical fertility (CARVALHO, 2005; POTTKER *et al.*, 2016).

When the soils have inadequate conditions for the species' establishment, the area is outside its tolerance and with low probability of its occurrence, even if the climatic conditions are favorable (ZUQUIM *et al.*, 2019). Furthermore, the most pertinent variables to the distribution of the species are only indicative of the best areas for their establishment, so that in the case of planting, other specific parameters to each location should also be considered.

Other studies on the modeling of potential distribution of species of the Lauraceae family did not find a relation between their occurrence and the topography and pedology variables, possibly due to the scale of work, which covers large areas where species distribution tends to be more influenced by climatic variables. Additionally, estimates of potential distribution using only climatic parameters are imprecise (ZUQUIM *et al.*, 2019). Velazco *et al.* (2017) thus recommend the inclusion of topography and pedology data along with climatic variables to the potential distribution models, aiming to reach more precise forecasts, with the increase of the model accuracy.

The second most relevant variable to the model, the altitude, demonstrates the autoecological preferences of the species, corroborating the assertion of Pottker *et al.* (2016), in which *Ocotea odorifera* prefers high and steep slopes to develop. This variable is important because it systematically affects climatic behavior, especially temperature and orographic precipitation (FRANKLIN, 2010). Thus, possibly the slope regulates microclimatic differences in the central-northern region of Curitiba in relation to the rest of the municipality, favoring the abiotic requirements of the species.

Bispo, Valeriano and Kuplich (2010) add that altitude is also related to the pedological distribution gradient, conditioning different vegetation patterns in the landscape, which matches with the vegetation original distribution in Curitiba. Arboreal vegetation was predominant in the central-north portion of the city, as opposed to herbaceous vegetation in the rest of the municipality's area.

Thus, the abiotic variables that present near zero gains by the Jackknife test, represent the prediction of a random model, whereas those with gains close to 1, being able to be superior to the unit, present information highly correlated to the occurrences, indicating good predictions (COELHO; CARVALHO; GOMIDE, 2016).

Other studies have shown that the terrain orientation had no influence on the establishment and development of *Ocotea odorifera*. Martins (2016) also found a low value in this variable for the prediction of the area occupied by *Ocotea odorifera* in Brazil, with a value of 1.09% of contribution to their model. However, the terrain orientation influences the amount of solar radiation received by the slope and regulates the local water and energy regimes, affecting the soil moisture available to the plants (BISPO; VALERIANO; KUPLICH, 2010; FRANKLIN, 2010). In fact, the locations where the *Ocotea odorifera* specimens were found have a predominantly southern orientation, which tends to provide less sunshine. This finding is evidenced by Carvalho (2005), which points out the shadow-tolerance characteristic of the species that, in the juvenile phase, needs shadow to develop.

Conclusion

The potential distribution and possible conservation areas for *Ocotea odorifera* in Curitiba are mainly located in the central-northern region of the city, coinciding with the greater amount of its protected green areas.

Pedology and altitude were the most relevant variables to the species' occurrance, as indicated by the potential distribution model.

Pedology alone was responsible for approximately half of *Ocotea odorifera* environmental suitability.

Therefore, we recommend that pedology should be considered by the municipality during future species' planting plans, in addition to other specific soil features at each planting site.

The study confirmed the preference of the species for higher terrain and the presence of soils of the Latosols and Cambisols classes.

Moreover, we recommend that further studies on the potential distribution of endangered species should use environmental variables with detailed information, aiming a more precise delimitation of priority conservation areas.

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