International Journal of Biological Sciences and Applications
2015; 2(1): 1-9
Published online January 30, 2015 (http://www.aascit.org/journal/ijbsa)
ISSN: 2375-3811

American Association for Science and Technology


**Keywords**
Azores,
Conservation,
ENFA,
Modelling,
Oleaceae,
*Picconia*

Received: December 19, 2014
Revised: January 24, 2015
Accepted: January 25, 2015

# Distribution and conservation status of the endangered Azorean tree *Picconia azorica*

**José Martins[1], Hugo Costa[2], Orlanda Moreira[1], Eduardo Brito de Azevedo[3], Mónica MT Moura[1], Luís Silva[1, *]**

[1]CIBIO, Centro de Investigação em Biodiversidade e Recursos Genéticos, InBIO Laboratório Associado, Pólo dos Açores, Departmento de Biologia, Universidade dos Açores, 9501-801 Ponta Delgada, Portugal
[2]School of Geography, University of Nottingham, Nottingham, NG7 2RD, UK
[3]CMMG, Centro de Estudos do Clima, Meteorologia e Mudanças Globais, CITA-A, Centro de Investigação em Tecnologias Agrárias, Universidade dos Açores, Rua Capitão João D'Ávila, São Pedro, Angra do Heroísmo, Açores, Portugal

## Email address
josemartins@uac.pt (J. Martins), orlandamoreira@uac.pt (O. Moreira), moura@uac.pt (M. Moura), lsilva@uac.pt (L. Silva), lgxhag@nottingham.ac.uk (H. Costa), edubrito@uac.pt (E. B. de Azevedo)

## Citation
José Martins, Hugo Costa, Orlanda Moreira, Eduardo Brito de Azevedo, Mónica MT Moura, Luís Silva. Distribution and Conservation Status of the Endangered Azorean Tree *Picconia azorica*. *International Journal of Biological Sciences and Applications.* Vol. 2, No. 1, 2015, pp. 1-9.

## Abstract
*Picconia azorica* (Tutin) Knobl. (Oleaceae), an evergreen shrub or small tree, is a top priority species, endemic to the Azores archipelago. It is listed as endangered (EN B1 + 2c; IUCN Red List 2012) and is included in Annex II of the EC Habitats Directive. In this study we aim to: i) estimate the present distribution and abundance of *P. azorica* in the Azores; ii) re-evaluate its conservation status based on the new data; iii) determine environmental factors that might limit its distribution; iv) estimate its potential distribution using Ecological Niche factor Analysis (ENFA); and v) assess the possibilities of reforestation. *Picconia azorica* occurs on a total of 55 $km^2$ (2.2% of the Azores territory), 53% of which is included in Island Natural Parks; 38% of the area is located in Pico Island while in the remaining islands populations are very depauperated with occurrence areas ranging from 9.5 to 0.8 $km^2$. Based on the present area of occurrence and assuming a continuing decline in area of occupancy, extent and/or quality of habitat in the future, following the 2001 IUCN Red List Categories and Criteria, we suggest that *P. azorica* should be considered as Critically Endangered, CR B1ab (i, ii, iii, iv, v). ENFA results showed a medium value for marginality (0.56) and a low value for specialization (1.18), meaning that *P. azorica* habitat breadth is wide and with only a small difference from the average environmental conditions found in the Azores. Around 34% (847 $km^2$) of the land area of the archipelago is potentially suitable as habitat for *P. azorica*. We recommend the reinforcement of the most depauperated and fragmented populations using as guidelines the present results on habitat suitability as well as previous results on propagation and population genetics. *P. azorica* should be also considered as a species with high potential in restoration/reforestation actions in the Azores, particularly at low to medium elevation areas.

## 1. Introduction

Islands are of particular importance for the conservation of global plant diversity.

Although they make up only some 5% of the Earth's land surface, around one quarter of all known extant vascular plant species are endemic to islands (Kreft *et al*., 2008).

The Macaronesian biogeographic region is characterized by a particular flora (Martín *et al*., 2008) and is one of the better explored in the Mediterranean subregions from a biogeographic and conservation perspective. Some of the endemic vascular plants of Macaronesia are among the rarest taxa in Europe (Sjögren, 2000). The Azorean vascular plant flora comprises around 1000 taxa (Silva *et al*., 2010) of which, no more than 300 are considered native and circa 73 are endemic, with 8 plants in the 100 top priority for Macaronesia and 37 in the top priority for the Azores (Martín *et al*., 2008).

Among priority species, the genus *Picconia* (Oleaceae) includes two species i) *Picconia azorica* (Tutin) Knobl., locally named Pau-branco, endemic to the Azores where it occurs in all the islands except Graciosa, and ii) *P. excelsa* (Aiton) DC., endemic to Madeira and the Canary Islands. *Picconia azorica* is an evergreen shrub or small tree growing up to 8 m tall, found from sea level up to ca. 660 m, in coastal cliffs, ravines and lava flows as a component of coastal scrubland and medium altitude natural forests (with *Erica azorica*, *Morella faya* and/or *Laurus azorica*) (Silva *et al*., 2009). It was first listed in 1997 on the IUCN Red List as indeterminate, due to the lack of information (Walter and Gillett, 1998); later it was listed as endangered (EN B1 + 2c) on the The World List of Threatened Trees (Oldfield *et al*., 1998) following the IUCN 1994 Categories and Criteria (version 2.3), and kept this conservation status until today (IUCN Red List 2012) indicating that an update is needed (i.e. to the 2001 Categories and Criteria, version 3.1); it is also listed in Annex II of the EC Habitats Directive. *Picconia azorica* was historically used in the Azores for furniture construction and religious statuary since the colonization of the Archipelago. In the past, the major threat affecting *P. azorica* was overexploitation. Gaspar Frutuoso (historian/chronicler, 1522-1591) in his work "Saudades da Terra" reported that *P. azorica* populations were declining in several islands due to human use, and that it was exported from Pico, where the species was more abundant, to the other islands (Frutuoso, 1998). Presently, several threats might be affecting *P. azorica* populations, including habitat degradation, expansion of agricultural land and production forest, competition with alien species and isolation of populations (Cardoso *et al*., 2008; Silva *et al*., 2009).

Recent studies have successfully addressed vegetative and seed propagation (Martins *et al*., 2011, 2012), and population genetics (Martins *et al*., 2013). However, to design effective conservation strategies or recovery plans, information of plant distribution, population number, population size and on the ecological constraints to species establishment are considered as fundamental (Brigham *et al*., 2003). Assessing the spatial distribution of rare and endangered species is essential for efficient conservation management (Margoluis and Salafsky, 1998; Stem *et al*., 2005).

Moreover, in order to increase efficacy in the determination of optimum sites for species recovery, ecological modelling might have an important role by estimating the most suitable habitat. The goal of habitat suitability modelling is to identify areas of habitat suitable for the persistence of a species based on a set of variables describing environmental conditions (Franklin, 1995; Guisan and Zimmermann, 2000; Hirzel and Le Lay, 2008). The ecological niche factor analysis (ENFA) implemented in the software BIOMAPPER by Hirzel *et al*. (2002), is a profile based approach which compares the conditions prevailing on sites with proved species presence with those found across the entire study area. It has been successfully used to model invasive and native species in the Azores (Costa *et al*., 2012, 2013a; Hortal *et al*., 2010). Furthermore, the ENFA provides ecological information on the species, concerning the ecogeographical variables that might be limiting or favouring the species distribution.

This study aims to i) evaluate the present distribution and abundance of *P. azorica* in the Azores; ii) re-evaluate its conservation status, according to IUCN criteria, based on the new data recently made available; iii) determine environmental factors that might limit its distribution; iv) estimate its potential distribution; and v) to assess the possibilities of reforestation. Based on the results of this research and on the work recently performed on propagation and population genetics, conservation guidelines for the establishment of a future recovery plan are discussed.

## 2. Materials and Methods

### 2.1. Study Site

The archipelago of the Azores (36º35'–39º43'N, 24º45'–31º17'W), located at 1300 km from Europe and at 1800 km from North America, it is scattered across 615 km on a WNW–ESE alignment, covering a total land area of 2352 km$^2$. It comprises nine volcanic islands in three main groups: western (Flores and Corvo Islands), central (Terceira, São Jorge, Pico, Faial, and Graciosa Islands), and eastern (São Miguel and Santa Maria Islands). The topography of the islands is characterized by large catchments, ravines, and seasonal water streams, with maximum elevation ranging from 450 m in Graciosa to 2351 m in Pico, with several islands peaking near 1000 m. The Azorean climate is strongly oceanic, with low thermal amplitude, high relative humidity and rainfall throughout the year, and an average annual temperature of 17.5ºC at sea level (Dias *et al*., 2005). The Azores low geological age and the homogeneous oceanic climate of the islands partly explain the lower number of endemic species compared with the neighbouring archipelagos of Madeira and the Canary Islands (Carine and Schaefer, 2010). Several natural plant communities, however, existed prior to human settlement, including coastal and wetland vegetation, meadows, and various types of scrubland and forest (Dias, 1996). Subsequently, the increasing fragmentation of natural plant communities associated with the expansion of monocultural landscapes dominated by intensive pasture and production forests has drastically altered the biodiversity in many areas of the archipelago, leading to the expansion of non-indigenous and invasive species (Silva and Smith, 2006; Silva *et al*., 2008).

In 2007 the regional network of protected areas was reclassified (Calado *et al*., 2009) resulting in two units (the Island Natural Parks and the Azores Marine Park) and five categories of protected areas (Natural Reserve; Natural Monument; Habitats or Species Management Protected Area; Protected Landscape; Resource Management Protected Area). The terrestrial areas classified under the system in each Island compose the Island Natural Park, covering 24.1% of the land surface of the Azores.

## 2.2. Species Data

*Picconia azorica* presence data were obtained from two field surveys: (i) from a random sampling performed in 2001 (described in Silva and Smith, 2006) whose data are included in ATLANTIS, which is a regional species database of 500 m grid-based spatial incidence information for around 5000 species (see Borges *et al*., 2010 and the Azorean Biodiversity Portal at http://www.azoresbioportal.angra.uac.pt/); and (ii) from a systematic survey performed in 2008 in all the islands where the species occurs. Both data sources were merged at 500 m spatial resolution. As a result, we used 221 occurrences recorded across the Azores. To avoid an overestimation of the area of occurrence we only included the data available in Atlantis with the highest accuracy level as well as the data collected in the above mentioned survey. Data used in the analysis is represented in figure 1.

## 2.3. Conservation Status

Based on the estimated number of individuals and on the distribution area, we analyzed the conservation status following the criteria listed on version 3.1. IUCN Red List Categories and Criteria (2001) (second edition). Since long term monitoring is not available, we used mainly criteria based on area of occurrence and area of occupancy as well as on the number of populations. We estimated the proportion of the distribution located inside the Island Natural Parks (INP) and thus under some type of legal protection.

## 2.4. Ecogeographical Variables

We used ecogeographical variables (EGV) of climate, topography and land cover. Climatic variables were selected from the CIELO Model developed by Azevedo (1996). In CIELO Model, a raster GIS environment of 100 m spatial resolution is used to model local scale climate variables relying on limited available data from synoptic coastal meteorological stations. More information on the CIELO Model is available in Azevedo *et al*. (1999) or through the CLIMAAT project in Azevedo (2003). We submitted the annual average of the minimum, maximum, mean and range values of temperature, relative humidity and precipitation to principal component analyses (PCA) since most of them were highly correlated. We held the first two components for temperature (TPC1-2) and relative humidity (RHPC1-2) and the first one for precipitation (PPC1), explaining 99.67, 99.98 and 90% of the original variables' variance.

For topography, we used a digital elevation model (ALT) available in the CIELO Model database and derived new information from it with a GIS (ESRI® ArcGIS™ 9.3): slope (SLP), summer hillshade (HS), winter hillshade (HW), flow accumulation (FLOW) and curvature (CURV). Hillshade is a simulation of the lighting conditions on the surface dictated by the topography and the position of the Sun. We considered either the summer or the winter solstices. Flow accumulation is the accumulated water flow from all cells flowing into each downslope cell, considering the surface as impervious. Curvature is the second derivate of the surface, thus finding flat, convex and concave areas.

Finally, land cover data was also obtained from the CIELO Model database. The land cover classes were sorted in the following order to define an ordinal land cover variable (OLC), from "like forest" to "unlike forest": (1) forest, (2) natural vegetation, (3) pastureland, (4) agriculture, (5) barren/bare areas and (6) urban/industrial areas. All the EGV were resampled to 500 m to match the occurrence data.

## 2.5. Modelling

The Biomapper 4.0 software (Hirzel *et al*., 2007) was used to run the modelling approach based on the ecological-niche factor analysis (ENFA). ENFA compares the distribution of locations where the focal species was identified to a reference set in the multidimensional space of EGV previously selected to run the analysis. From this comparison, the so-called global marginality and specialization coefficients are calculated. The former is interpreted as the difference between the conditions used by the focal species and the average conditions available in the study area. Most often it ranges from zero to one and a large value means the species lives in a very particular habitat. The specialization describes the narrowness of the species niche and any value exceeding unity indicates some form of specialization. In mathematical terms, the comparison is analogous to a PCA, but here the first factor is calculated so that accounts for all the marginality of the species and the following factors so as to maximize the specialization not explained in the first factor. Consequently, the resulting ENFA factors have an ecological meaning and enables for modelling the species habitat suitability (HS) for the whole study area through an *environmental envelope* technique. This technique is conceptually very close to the niche theory and it consists in delineating, in the space of the EGV used, the hypersurface that circumscribes all suitable conditions for the species. As a result, HS is expressed in a continuous raster map of HS scores ranging from 0 to 100. These HS scores do not equal 'true' probabilities of species presence but relative likelihood of species presence (for a full description of the ENFA, see details in Hirzel and Arlettaz, 2003; Hirzel *et al*., 2002, 2006).

The continuous Boyce Curve (Hirzel *et al*., 2006) was used for the evaluation of the results. This is a threshold-independent method based on only presence data and estimates how much the modelling results differ from random expectation, which is assumed to be a measure of the quality of the model. A good HS model produces a monotonically increasing curve. The continuous Boyce Curve was calculated within a *k*-fold cross-validation procedure, thus defining averaged curves and dispersal measures. Finally, the continuous Boyce curve was also used to reclassify the continuous HS scores produced by ENFA into discrete classes of suitability as this is more honest and practical (Liu *et al*., 2005). Following guidelines from Hirzel *et al*. (2006) and Costa *et al*. (2013a), three classes of suitability were created: not suitable, moderately suitable, and highly suitable (Figure 2).

# 3. Results

## 3.1. Present Distribution and Abundance

Several populations of *P. azorica* are presently depauperated in four of the archipelago islands, namely: São Miguel, where only one population is known, besides some scattered individuals; Terceira with a few residual populations composed of scattered individuals; Faial with only one population, besides scattered individuals; and Corvo, with a very fragmented population composed of sub-populations with ca. 20 to 30 individuals, separated by pasture and agricultural fields.

The area of occurrence of *P. azorica* was estimated in 55 km$^2$, which represents 2.2% of the total land area of the archipelago (Table 1). The largest area of occurrence by *P. azorica* is located in Pico Island, which represents 38% of the total species distribution (Table 2). Other important populations are found in São Jorge, Santa Maria and Flores, while São Miguel, Faial, Corvo and Terceira, with occurrence areas ranging from 0.8 to 3.5 km$^2$, include the most depauperated populations (Table 1).

***Table 1.*** *Distribution of Picconia azorica in the Azores. Area of occurrence in the Azores (number of 500 x 500 m cells, extension in km$^2$ and percentage of island surface) and portion of the area within Island Natural Parks. Data from, ATLANTIS data base, considering only the highest level of precision to avoid overestimation.*

| Island | Total Area | | | Area inside INP | | | Island | |
|---|---|---|---|---|---|---|---|---|
| | cells | km$^2$ | % | cells | km$^2$ | % | cells | km$^2$ |
| Corvo | 8 | 2.0 | 9.3 | 7 | 1.8 | 87.5 | 86 | 22 |
| Faial | 10 | 2.5 | 1.3 | 9 | 2.3 | 90.0 | 753 | 188 |
| Flores | 27 | 6.8 | 4.3 | 23 | 5.8 | 85.2 | 622 | 156 |
| Graciosa | 0 | 0.0 | 0.0 | 0 | 0.0 | 0.0 | 274 | 69 |
| Pico | 83 | 20.8 | 4.4 | 31 | 7.8 | 37.4 | 1897 | 474 |
| Santa Maria | 38 | 9.5 | 8.6 | 28 | 7.0 | 73.7 | 440 | 110 |
| São Jorge | 38 | 9.5 | 3.5 | 6 | 1.5 | 15.8 | 1094 | 274 |
| São Miguel | 14 | 3.5 | 0.4 | 10 | 2.5 | 71.4 | 3152 | 788 |
| Terceira | 3 | 0.8 | 0.2 | 3 | 0.8 | 100.0 | 1700 | 425 |
| Total | 221 | 55.3 | 2.2 | 117 | 29.3 | 52.9 | 10018 | 2505 |

Approximately half (53%) of the area of occurrence is located inside INP. In general, high proportions of the area of occurrence are located within INP (above 74% in six of the islands), however in Pico and São Jorge, where the most representative areas of *P. azorica* are located, only 37 and 16% of the area is covered (Table 1).

## 3.2. Conservation Status

According to our data and following the 2001 IUCN Red List Categories and Criteria version 3.1, *P. azorica* should be considered as Critically Endangered – CR B1ab(i,ii,iii,iv,v) based on: extent of occurrence estimated to be less than 100 km$^2$ (B1), and estimates indicating severely fragmented or known to exist at only a single location (a); and continuing decline, observed, inferred or projected, in any of the following (b): (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals.

## 3.3. Potential Distribution

ENFA results revealed a medium value for marginality (0.557) and a low value for specialization (1.181). This means that *P. azorica* habitat differs little from the average environmental conditions in the Azores and that its habitat breadth is wide. These results show considerable adaptability of *P. azorica* to the different ecological conditions found in the Azores.

The importance and role played by each EGV in *P. azorica* distribution is expressed by the correlations between the EGV and the ENFA factors (Table 2).

***Table 2.*** *Correlations between the EGV and the ENFA factors. Factor 1 is the marginality factor, which explains 100% of the marginality and 28% of the specialization. Factors 2 and 3 are specialization factors, which explain the remaining specialization in decreasing amounts (in brackets). Only the first three factors are shown for practical reasons. (+) Species was found in locations with higher values than average; (-) Means the reverse. A larger number of symbols indicates higher correlation. (*) Species was found occupying a narrower range of values than available. The larger the number of asterisks, the narrower the range. No symbol indicates a very low correlation.*

| EGV | Factor 1 (11%) | Factor 2 (23%) | Factor 3 (18%) |
|---|---|---|---|
| RHPC1 | ++++++ | ****** | ****** |
| TPC1 | - - - - - | ******* | ******* |
| SLP | ++++ | * | |
| OLC | - - - | | * |
| ALT | - - - | | * |
| TPC2 | - | * | ** |
| CURV | - | | |
| HW | + | * | ** |
| FLOW | - | ** | *** |
| PPC1 | | * | * |
| RHPC2 | | | |
| HS | | * | * |

The most important variables for *P. azorica* distribution are those more correlated with the marginality factor (factor 1), namely the relative humidity, temperature and slope. High positive correlation between the marginality factor and both the principal component of the relative humidity (RHPC1) and the slope (SLP) indicate that *P. azorica* is more likely to occur in steep locations with relatively low levels of relative humidity although with relatively large annual amplitude. A high negative correlation between the principal component of the temperature (TPC1) and the marginality factor indicates that *P. azorica* is more likely to occur in areas characterized by high temperature with low annual variation. This is in agreement with the negative correlation found with altitude (Table 2). Also, *P. azorica* is clearly associated with forest-like areas since a negative correlation was found with the type of soil use (low values of OLC corresponded to forest-like habitats while high values corresponded to forest-unlike habitats). In terms of specialization, the most relevant EGV were the TPC1 and RHPC1 since they present the highest correlation scores with the first two specialization factors (factors 2 and 3). This means that *P. azorica* is present in a relatively narrow range of conditions as regards both these variables, namely temperature and relative humidity.

Based on these results, ENFA modelled the potential distribution for *P. azorica* throughout the Azores (Figure 1). We divided the potential habitat of *P. azorica* into not suitable, moderately suitable, and highly suitable (Figure 2). Around 34% of the total area of the archipelago is suitable as habitat for *P. azorica* (Table 3). Santa Maria and Faial showed the highest percentage of suitable area (75% and 54% respectively) while in the remaining islands 20 to 40% of the available area is suitable as potential habitat, with the exception of Graciosa Island which has a much reduced suitable area (Table 3).

## 4. Discussion

Presently the area of occurrence of *P. azorica* corresponds to around 2% (55 km$^2$) of the total area of the Archipelago. Compared to other endemic species this is a considerable area, clearly above other native trees like *Prunus azorica* (23.5 km$^2$), and only exceeded by widespread species like *Laurus azorica* (563 km$^2$), *Erica azorica* (685 km$^2$) and *Juniperus brevifolia* (361 km$^2$) (Corvelo, 2010).

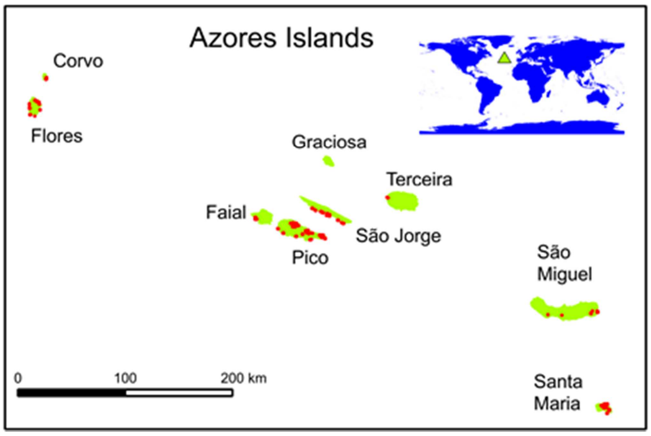


***Figure 1.*** *Location of the Azores Archipelago. Distribution of Picconia azorica in the archipelago (red dots). Data from ATLANTIS data base, only the records with the highest precision level were considered in order to avoid overestimation of the area of occurrence.*

More than one third of the area of occurrence of *P. azorica* is located on Pico, the second largest island in the Archipelago and geologically the youngest, with fields of recent lavas, poor soils, and thus a smaller agricultural occupation and a lower population density, with vast natural areas (Dias *et al*., 2005). Other data indicate a higher occurrence area for *P. azorica* (Corvelo, 2010) however, based in our extensive field work and on the collected data we considered it to be most likely inaccurate, leading to an overestimation of the total area of occurrence. As an example, an occurrence area of 140 km$^2$ is given for Flores, for a total Island area of around 156 km$^2$, meaning that almost all of the territory would include the presence of *P. azorica*. This, according to our field observations, corresponds to an overestimation of the area of occurrence.

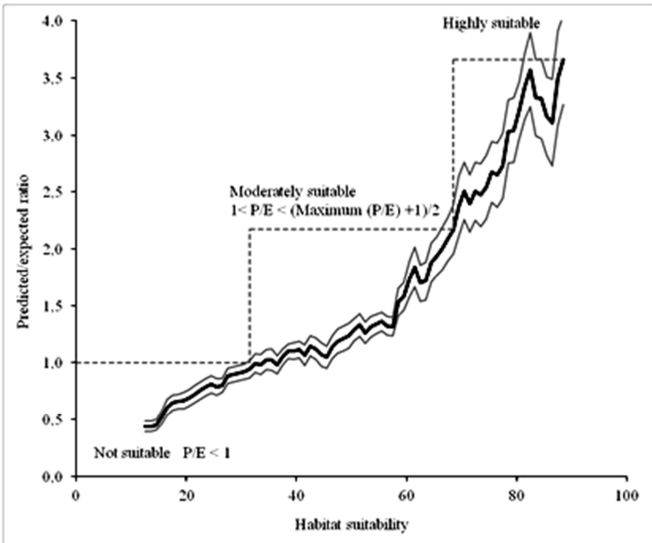


***Figure 2.*** *Results of the ENFA applied to model Picconia azorica distribution in the Azores. The graph shows the average continuous Boyce curve and the 95% confidence intervals. The X axis is the HS value (habitat suitability) calculated by the model. The Y axis is the ratio between the values of occurrences of P. azorica predicted by the model (P) and the expected value if the distribution of occurrences of P. azorica was random (E). The higher the P/E ratio, the better is the model. The continuous Boyce curve was the basis for reclassifying the model to discrete classes: i) cells with HS between 0 and 16, not suitable; cells with HS between 16 and 78, moderately suitable; and iii) cells with HS between 78 and 100, highly suitable.*

Regarding the conservation status, following the most recent criteria, we suggest an upgrade of the conservation status from Endangered to Critically Endangered. This was largely based on the area of occurrence, estimated to be less than 100 km$^2$, and on field observations indicating the general occurrence of small and severely fragmented populations. Also, if no effective conservation actions are undertaken, we expect a reduction in the area of occurrence of the species and in the quantity and quality of the habitat, due to the expansion of invasive alien species like *Pittosporum undulatum*, the most important woody invasive species in the Azores (Lourenço *et al*., 2011).

In fact, *P. undulatum* has been shown to have present and potential distributions which largely coincide with those estimated for *P. azorica*, although being much wider (Costa *et al*., 2012; Lourenço *et al*., 2011). The ecological preferences of *P. azorica* largely coincide with those of *P. undulatum* and *Morella faya*, a native species, such as low to medium elevation, relatively high temperature and low relative humidity. Also, our results showed that both *P. azorica* and *P. undulatum* occur in forest like areas, with similar land uses (Costa *et al*., 2012). By contrast, *P. azorica* potential habitat differs from the habitat defined as potentially more suitable for *Prunus azorica*, a native species more likely to be found at higher altitudes and at more humid locations (Moreira *et al*., in press). Therefore, in the absence of effective conservation measures, it is very likely that *P. azorica* populations will still decline due to the expansion of invasive alien species, even inside INP (Costa *et al*., 2013b), but also due to changes in plant communities associated to anthropogenic disturbance (Marcelino *et al*., 2013).

According to our modelling results, around 34% of the total area of the archipelago, which corresponds to 852 $km^2$, is suitable as habitat for *P. azorica*. This is a very significant area when compared to the 55 $km^2$ where *P. azorica* presently occurs, and presumably an estimate of the area of occurrence previous to human settlement, five centuries ago, since, according to the historic descriptions, the islands were initially covered with dense forests (Dias *et al*., 2005). This also shows that the species is not at equilibrium with the environment, similarly to what was found for another native tree, *M. faya* (Costa *et al*., 2012). Since we assume that the past distribution was wider than the present distribution, we might have not included all the favourable habitats in the ENFA. Therefore, the potential distribution might be underestimated.

Our study revealed that Santa Maria and Faial show the highest proportions of suitable areas as habitat for *P. azorica*, with 75% and 54% respectively. Graciosa, on the contrary, showed 97% of its territory as not suitable for *P. azorica* (Table 3). Since we found medium marginality and low specialization, this unexpected result might be a consequence of two confounding sources: i) since no *P. azorica* is presently found in Graciosa, no sample of sites with favourable environmental conditions was available for the ENFA, although they might eventually be present; and ii) a correlation with land use showed that *P. azorica* tends to occur in forest-like habitats, a type of land cover uncommon in Graciosa.

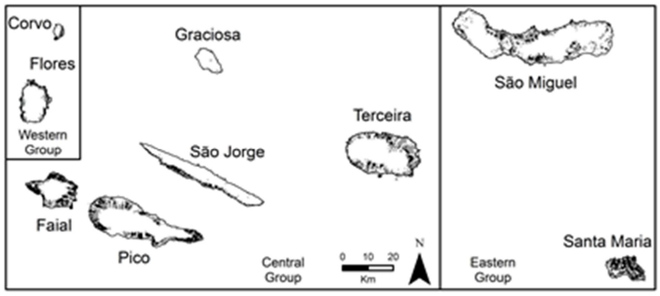


***Figure 3.*** *Results of the ENFA applied to model Picconia azorica distribution in the Azores. Habitat suitability: black, highly suitable area; grey: moderately suitable area; white: area not suitable.*

In some of the islands large percentages of the territory where *P. azorica* occurs are covered by INP. However in the two islands (Pico and São Jorge) with the largest areas of occurrence, most of that area is located outside INP (Costa *et al*., 2013b). Considering that the main threats presently pending upon Azorean species include anthropogenic disturbance, changes in land use and invasion by aliens species (Cardoso *et al*., 2008; Marcelino *et al*., 2013; Silva *et al*., 2008), even within INP (Costa *et al*., 2013b), the survival of individuals outside INP is by no means warranted. This might also lead to the extinction of severely fragmented populations, as in Corvo Island, which has shown an interesting distinctive genetic pattern (Martins *et al*., 2013).

***Table 3.*** *Area potentially suitable for Picconia azorica in the Azores, based on the results of the ENFA. Area of habitat (number of 500 x 500 m cells, extent in $km^2$ and percentage of island surface) potentially suitable (moderately or highly suitable) or not suitable for the occurrence of P. azorica in the Azores. Habitat suitability classes as defined according to the shape of the continuous Boyce curve (see Figure 2).*

| Island | Not suitable | | | Moderately suitable | | | Highly suitable | | | Suitable | | | Island | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | cells | $km^2$ | (%) | cells | $km^2$ | (%) | cells | $km^2$ | (%) | cells | $km^2$ | (%) | cells | $km^2$ |
| Corvo | 50 | 12.5 | 58.1 | 22 | 5.5 | 25.6 | 14 | 3.5 | 16.3 | 36 | 9.0 | 41.9 | 86 | 22 |
| Faial | 343 | 85.8 | 45.6 | 220 | 55.0 | 29.2 | 190 | 47.5 | 25.2 | 410 | 102.5 | 54.5 | 753 | 188 |
| Flores | 453 | 113.3 | 72.8 | 98 | 24.5 | 15.8 | 71 | 17.8 | 11.4 | 169 | 42.3 | 27.2 | 622 | 156 |
| Graciosa | 267 | 66.8 | 97.5 | 7 | 1.8 | 2.6 | 0 | 0.0 | 0.0 | 7 | 1.8 | 2.6 | 274 | 69 |
| Pico | 1228 | 307.0 | 64.7 | 420 | 105.0 | 22.1 | 249 | 62.3 | 13.1 | 669 | 167.3 | 35.3 | 1897 | 474 |
| Santa Maria | 109 | 27.3 | 24.8 | 158 | 39.5 | 35.9 | 173 | 43.3 | 39.3 | 331 | 82.8 | 75.2 | 440 | 110 |
| São Jorge | 872 | 218.0 | 79.7 | 134 | 33.5 | 12.3 | 88 | 22.0 | 8.0 | 222 | 55.5 | 20.3 | 1094 | 274 |
| São Miguel | 2267 | 566.8 | 71.9 | 696 | 174.0 | 22.1 | 189 | 47.3 | 6.0 | 885 | 221.3 | 28.1 | 3152 | 788 |
| Terceira | 1040 | 260.0 | 61.2 | 518 | 129.5 | 30.5 | 142 | 35.5 | 8.4 | 660 | 165.0 | 38.8 | 1700 | 425 |
| Total | 6629 | 1657.3 | 66.2 | 2273 | 568.3 | 22.7 | 1116 | 279.0 | 11.1 | 3389 | 847.3 | 33.8 | 10018 | 2505 |

According to Silva *et al*. (2009), most of the Azorean endemic vascular plants require recovery plans including reinforcement of depauperate populations, using appropriate propagation methods, the establishment of ex situ populations, and in some cases genetic studies. Recovery plans for endangered species are presently common in other Macaronesian Islands (DRF, 2012; Gobierno de Canarias, 2012a,b). Based in our results, strong conservations measures should be directed to *P. azorica*, including: i) the reinforcement of highly depauperated and fragmented populations, namely those in São Miguel, Terceira, Faial and Corvo Islands; ii) restoration of natural habitats, through an effective management of alien species, particularly in São Jorge and Pico Islands and where the largest *P. azorica* populations are located (see Costa *et al.*, 2013b, for examples); and iii) the eventual revision of the INP in Pico and São Jorge in order to minimize the area of *P. azorica* outside the park boundaries, and thus more vulnerable.

The maintenance of sufficient genetic variability within and among populations is one of the principal goals of conservation planning since the existence of variability is the only way to assure long-term species survival and to accommodate new selection pressures brought about by environmental change (Barrett and Kohn, 1991; Kim *et al.*, 2005). Thus, in population reinforcement projects plants should be obtained by seed germination in order to maintain the genetic variability. Although *P. azorica* can be propagated by air layering, it is a species which favours sexual reproduction since an adult tree can produce thousands of seeds with viability close to 100% (Martins *et al.*, 2011, 2012). Further, the arbitrary translocation of individuals between islands should be avoided in order to preserve the genetic identity and structure of the most differentiated populations (Martins *et al.*, 2013), thus seeds obtained from each population should be used to their own reinforcement.

Since extensive areas are potentially suitable as habitat for *P. azorica*, particularly at low and medium altitudes, this species should be readily considered in the restoration of areas for conservation as well as in areas designed to function as buffers for the protection of water lines and lakes. Considering the potential distribution estimated for Santa Maria, *P. azorica* should be clearly used as one of the community structuring species in the restoration of degraded areas, particularly those which presently show only a reduced plant cover or are heavily invaded by alien species. Thus, the considerable potential of *P. azorica* for occupying a more extensive area than that corresponding to its present distribution, clearly makes it a potential candidate for reforestation actions in the Azores islands, particularly at low and medium elevation. However, extreme care should be taken in the design of those actions, in order to avoid further genetic admixture derived from unplanned reforestation measures.

Undoubtedly, *P. azorica* has the potential to regain the important ecological role in the structure and dynamics of arborescent plant communities that it most likely played, prior to the human settlement in the Azores.

## Acknowledgements

This study was funded by DRCTC (Direcção Regional da Ciência Tecnologia e Comunicações, Azores) and was part of Project VERONICA and Project DEMIURGO. Hugo Costa was supported by a scholarship from CIBIO/INBIO and by Project Woody Biomass included in the global Green Islands project supported by the Azorean Government and MIT Portugal. The Authors would like to thank the technicians from the Azorean government which supported field surveys.

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