Forest Ecology and Management 310 (2013) 652–662

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Niche modelling for twelve plant species (six timber species and six palm trees) in the Amazon region, using collection and field survey data

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ARTICLE INFO

Article history:
Received 29 January 2013
Received in revised form 27 August 2013
Accepted 30 August 2013
Available online 7 October 2013

Keywords:
Modelling
Amazon
Field surveys
Herbarium
Timber
Palm

ABSTRACT

Knowledge of the distribution of plant species is essential for planning management and conservation actions, especially for economically important species. Available data on plant species in the Amazon usually do not represent their whole area of occurrence. The most widely used approach to infer predictions on species occurrence is niche modelling, which consists of correlating records of species with environmental conditions in their occurrence areas, generating maps with the potential distribution based on a combination of environmental features suitable for each species. The main objective of this study was to evaluate the ability of modelling to improve knowledge on the distribution of six timber species and six palm trees in the Amazon, and whether these models can benefit from using data from field surveys added to those of biological collections. Models were generated using the Maxent algorithm. All models generated showed a low extrinsic omission rate (TOE) and AUC above 0.75. Areas predicted for timber species were more consistent with empirical knowledge than those predicted for palm trees, probably due to the greater amount of occurrence sites available for timber species, especially after adding data from field surveys. The extent of the predicted area and the Jaccard index were used to compare the maps after insertion of field survey data. There was a large difference in extent just for two species, one timber and one palm, and a reduction in the predicted area for one species, *Swietenia macrophylla*. The application of the Jaccard index resulted in values between 0.41 and 0.65 for timber species, reinforcing that the inclusion of field survey data changed predicted areas. For palms, the similar extent of predicted areas and Jaccard values above 0.80, indicated a subtle difference between maps generated before and after the inclusion of field survey records, probably due to the addition of fewer records. The exception was *Astrocaryum murumuru*, for which the new records increased the extent of the predicted area. The niche models associated with field studies can contribute enormously to increase knowledge concerning the current distribution of species, but new field surveys should be carefully designed to cover wide and undersampled areas. However, it is necessary to consider that this strategy can only be adopted for species with clearly distinctive features, for which field identifications are reliable.

1. Introduction

Knowledge of species distribution is essential for planning management and conservation actions (Ferrier, 2002; Funk and Richardson, 2002; Rushton et al., 2004) and for understanding the ecological and evolutionary determinants of spatial biodiversity patterns (Graham et al., 2006; Ricklefs, 2004). However, determining species distribution still constitutes a challenge, as few occurrence records accurately represent a given distribution, which effectively reflects only dots on a map (Peterson, 2006). Such knowledge becomes more restricted when addressing plant species, due to difficulties in species identification. Correct identifications frequently depend on accessing the canopy and on sampling during the reproductive phenological phase. Some trees only bloom every five or more years (Hopkins, 2007) and for some species, only fertile material incorporated into biological collections provides reliable identifications. It is believed that over 90% of angiosperm species have been described, but the vast majority remain virtually unknown (Heywood, 2001) and many tropical plant species remain undersampled (Prance et al., 2000). The geographical distributions of most tropical plant species are still

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http://dx.doi.org/10.1016/j.foreco.2013.08.064

not well characterised, and in general, data are available for only a few species on a regional scale (Siqueira, 2005).

The Amazon is one of the least floristically known regions. Large gaps in the collection area and the relatively small number of available records in herbaria hinder the accurate mapping of the distribution of many plant species and obtaining a better understanding of their distribution patterns. Thus, the identification of regions of interest for conservation and the most favourable conditions for plant species management is difficult. Using herbarium collection data, Nelson et al. (1990) showed that for the genus *Inga*, collections were concentrated in certain areas. Schulman et al. (2007) also employed herbarium data to analyse the distribution of collection efforts and showed that the situation described by these previous authors has not changed in the last 15 years and that most of the Amazon basin shows no evidence of being botanically explored. There is a strong trend towards concentrating botanical collections in a few areas, resulting in relatively complete checklists only for the small number of better-sampled locations (especially near cities with research institutes), giving the impression that these areas have a greater number of species (Hopkins, 2007).

In the Brazilian Amazon, the three major herbaria hold a total of approximately 594,000 exsiccates, among which 175,000 are deposited in the Agronomic Institute of the North (Instituto Agronômico do Norte – Herbário IAN (2011) (www.cpatu.embrapa.br), 237,000 in the herbarium of the National Institute of Amazonian Research (Instituto Nacional de Pesquisas da Amazônia – Herbário INPA (2011) (http://brahms.inpa.gov.br) and 181,705 in the herbarium of the Emílio Goeldi Museum of Pará (Museu Paraense Emílio Goeldi Herbário MG (2011), resulting in a total collection density for the Brazilian Amazon of approximately one specimen per km^2. Even species considered important for the development of the region are poorly represented in herbaria, as has been shown for the Meliaceae (Martins-da-Silva and Ferreira, 1998) and Lecythidaceae (Santos et al., 2000), based on the analysis of data from the IAN (Embrapa Eastern Amazon - Embrapa Amazônia Oriental) and MG herbaria.

In the 1970s, the largest field survey of the Brazilian Amazon was performed, referred to as the RADAMBRASIL Project, in which approximately 2000 hectares (ha) were sampled, and all trees with a circumference at breast height (CBH) of greater than or equal to 100 cm (diameter at breast height (DBH) > 32 cm) were included. As the survey aimed to estimate timber volumes, it did not include palm trees. Recently, the data from approximately 3000 sites of this field survey were digitised and made available to the academic community (<>), initiating a series of new analyses and interpretations regarding the distribution patterns of the flora of the region (Emilio et al., 2010; ter Steege et al., 200. Other more sporadic field surveys have been conducted under different projects within scientific institutions. These data are seldom used to improve the understanding of plant species biogeography.

The major difficulties in using field survey data are that such data are not always widely available, such as herbarium collection data, and species are not always recorded during their fertile phase. Thus, reliable species identification is possible only for a limited number of species. However, for species for which identification is relatively reliable, field survey data might represent a relevant type of data input for improving knowledge concerning their distribution.

In recent years, the most common approach that has contributed to a better understanding of species distribution is niche modelling. This type of modelling consists of correlating primary data from species records with the environmental conditions of their areas of occurrence and generating maps showing the potential distribution based on the combination of favourable environmental characteristics for each species. Several different techniques have been employed for niche modelling (Funk et al., 1999; Guisan and Zimmermann, 2000; ter Steege et al., 2000) to obtain potential species distributions, with different goals. These algorithms have been widely adopted to estimate areas where a species was not recorded but is probably present. Depending on the algorithm applied, presence-only or presence-absence data can be used. Models based solely on presence-only data, despite being considered less efficient by some authors (Graham et al., 2004; Hijmans et al., 2000; Huettmann, 2005; Reese et al., 2005; Soberón and Peterson, 2005), are easier to obtain, either through taxonomic reviews or using scientific collections. Presence–absence data can only be collected through field studies and their availability is usually much more restrictive.

Species of economic interest, such as timber species and palm trees, are among the first to experience a decrease in their stocks when adequate strategies for management and conservation are not defined. Logging in the Amazon is highly selective and the species with the greatest commercial value are the most heavily exploited (Barros and Veríssimo, 1996; Kitamura, 1994; Lisboa, 1989; Uhl and Vieira, 1991). The present knowledge concerning the occurrence of these species is more empiric than scientific, and for most timber species, there are no published maps of their distribution. Although these commercial species might reach high densities in some areas, if harvest is conducted over their entire area of occurrence, difficulties in replacing stocks or searching for matrices with distinct genetic traits might occur, leading to their extinction or quality impoverishment. Thus, knowledge concerning distribution is an essential first step to evaluate the effects of exploitation. Palm trees constitute a group of plants with multiple uses, as they can be used for food (fruits and palm hearts) and for the production of edible and fuel oils; in addition, the seeds and fibres are used for handicrafts and their leaves (straw) can be used to cover houses (Wallace, 1853). The exploitation of palm trees might affect the whole individual (extraction of palm hearts), part of it (removing leaves and fibres) or only the collection of fruits and seeds, and a better understanding of the distribution of these species would aid the design of strategies for their management, including assessment of their potential for commercial exploitation. In this study, we aimed to assess the viability of obtaining accurate distribution maps through modelling for six timber species: *Cedrela odorata* L. (Meliaceae); *Hymenolobium excelsum* Ducke (Fabaceae); *Manilkara huberi* (Ducke) Chevalier (Sapotaceae); *Mezilaurus itauba* (Meissn.) Taubert ex Mez (Lauraceae); *Swietenia macrophylla* King (Meliaceae), and *Handroanthus impetiginosus* (Mart. ex DC.) Mattos (Bignoniaceae); and six palm trees: *Astrocaryum aculeatum* G. Mey.; *Astrocaryum murumuru* Mart.; *Attalea maripa* (Aubl.) Mart.; *Euterpe oleracea* Mart; *Mauritia flexuosa* L., and *Oenocarpus bacaba* Mart. in the Amazon. The species were selected based on their relatively reliable identification in the field, economic importance, and data availability. However, despite being well-known species, the number of records of these species in botanical collections is irregular. For this reason, models were generated using data from biological collections and from field surveys performed both by RADAMBRASIL (1968–1978) and as part of research projects.

Therefore, the major goals of the present study were as follows: (1) to estimate areas of occurrence of the target species based on niche models; (2) to compare model outcomes with the known extent of occurrence of the species to evaluate whether the obtained results are consistent; (3) to examine whether the addition of field survey data provides a relevant contribution to modelling; and (4) to propose more effective strategies for field surveys to increase knowledge regarding the distribution of the studied species and other species of economic interest.