Forest Ecology and Management 315 (2014) 211–226

Contents lists available at ScienceDirect

Forest Ecology and Management

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

Potential, realised, future distribution and environmental suitability for *Pterocarpus angolensis* DC in southern Africa

Vera De Cauwer [a,b,*], Bart Muys [b], Rasmus Revermann [c], Antonio Trabucco [b,d]

[a] Polytechnic of Namibia, Department of Land Management, Private Bag 13388, Windhoek, Namibia
[b] University of Leuven, Division Forest, Nature and Landscape, Celestijnenlaan 200E-2411, 3001 Leuven, Belgium
[c] University of Hamburg, Biocentre Klein Flottbek, Department Biodiversity, Ecology and Evolution of Plants, Ohnhorststr. 18, 22609 Hamburg, Germany
[d] Euro-Mediterranean Center on Climate Change, IAFENT Division, Via E. De Nicola 9, 07100 Sassari, Italy

ARTICLE INFO

Article history:
Received 12 October 2013
Received in revised form 20 December 2013
Accepted 23 December 2013
Available online 25 January 2014

Keywords:
Climate change
Ecological niche
Maxent
Pterocarpus angolensis
Southern Africa
Species distribution model

ABSTRACT

The deciduous tree species *Pterocarpus angolensis* occurs in the dry woodlands of southern Africa and grows under a broad range of environmental conditions. It is threatened by overharvesting due to its valuable timber (Blood wood, Kiaat) and by land use changes. Information on the most suitable environmental conditions for the species is often old and anecdotal, while available data on its occurrence refer to range extent and not to distribution. Species distribution models (SDM) could provide more accurate information on distribution and environmental requirements and thereby assist sustainable management of this tree species.

Maxent models were developed to estimate the potential, realised and future distribution of *P. angolensis* and to identify detailed environmental requirements. Occurrences data of the species were sourced from herbaria and other published sources; environmental data from global GIS databases. Relevant environmental predictors were selected through a jack-knife test of the first model runs. The addition of information on competing species, fires and deforestation was tested to determine realised distribution. Model quality was evaluated with an independent presence-absence dataset. The model was projected with two different climate change scenarios to study their effect on the distribution by 2080.

Results show that a potential distribution map can be obtained with good discrimination of the presence of the species (AUC 0.83) and fairly good calibration (correlation coefficient 0.61). Range extent and environmental requirements are more detailed than those described in literature. The distribution of the species is mainly influenced by the amount of summer rainfall, by the minimum temperature in winter and by temperature seasonality. Potential and realised distributions are very similar, with Madagascar as major exception where the species can grow but does not occur. Adding the fire history of the last 13 years or the distribution maps of potentially competing species as predictor variables did not improve the distribution model. It did illustrate that *P. angolensis* is mainly found in areas with annual fire frequency below 45% and that only a few of the tested species show signs of competition. Using a forest cover map improved the realised distribution slightly (Kappa coefficient 0.64). Climate change can decrease the species range considerably, especially in the west, threatening species existence in Namibia and Botswana. On the other hand, the species' occurrence is predicted to increase in Zambia.

1. Introduction

Pterocarpus angolensis DC is a dry woodland tree species belonging to the family of the Fabaceae and can be found in most of tropical southern Africa, including the Miombo woodlands. The tree is intensively harvested for its attractive hardwood and is considered the most important timber tree over much of its range (Boaler, 1966a; Pedro et al., 1955).

Intensive exploitation goes back to the 1950s or earlier in the Democratic Republic of Congo, Tanzania, Zambia and Mozambique (Clarke, 1995; Hauman et al., 1954; Lees, 1962; Timberlake et al., 2010). A few decades later, Von Breitenbach (1973) mentioned that no other African species south of the equator had been exploited on such a large scale. Nowadays, unsustainable harvesting is reported for many areas in the region, although only a few reports are based on research into recruitment rate, growth rate and/or population size structure (Caro et al., 2005; Schwartz and Caro, 2003; Schwartz et al., 2002). The species has the status "Lower Risk/Near Threatened" on the IUCN Red List. As the natural regeneration of *P. angolensis* is reported to be limited in certain parts of the region (Caro et al., 2005; Chakanga, 2000; Dirninger, 2004; von

* Corresponding author at: Polytechnic of Namibia, Department of Land Management, Private Bag 13388, Windhoek, Namibia.
E-mail address: vdecauwer@polytechnic.edu.na (V. De Cauwer).

0378-1127/$ - see front matter © 2014 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.foreco.2013.12.032

Malitz and Rathogwa, 1999; van Daalen, 1991), it is a question if the species' conservation status can be maintained and if the species can remain an important timber resource without forest management interventions.

Accurate information about the distribution and environmental requirements of the species is needed to allow an assessment of the species' status and coordinate protection measures at a national and regional scale. Although a lot of information does exist on *P. angolensis*, it is mainly descriptive or general in nature (Vermeulen, 1990; Von Breitenbach, 1973) or focuses on one country (Banda et al., 2006; Shackleton, 2005; van Daalen, 1991; von Malitz and Rathogwa, 1999). The range extent or the distribution of the species is often summarised as a list of countries, herbaria sample locations or regions were the species can be found (Brummitt et al., 2007; Gillett, 1971; Hauman et al., 1954; Coates Palgrave et al., 1957; Palmer and Pitman, 1972). Existing maps refer to the species' range or extent of occurrence (EOO), not to the area of occupancy (AOO) (Boaler, 1966b; Coates Palgrave, 1983; Van Wyk and Van Wyk, 1997; Von Breitenbach, 1973). Very little information is given on how the maps were compiled; it can be assumed that they are based on collations of existing locality records at the margins of the range, as it is the case for many distribution or range maps in field guides and monographs (Gaston and Fuller, 2009). Therrell et al. (2007) provide the most detailed range map but indicate that the northern limit of the range extent in the Democratic Republic of Congo is uncertain (Fig. 1).

Information on the environmental requirements of *P. angolensis* illustrates that the species tolerates a broad range of environmental conditions, as illustrated in Section 2.1. However, the most suitable environmental conditions within these ranges are not clearly documented.

Species distribution models (SDM) can serve as a tool to produce more precise predictions of the environmental requirements and the geographical distribution than mere species observations, especially for large areas. The models correlate environmental data to species occurrences and sometimes species absences. They are also called ecological niche models (ENM) or species habitat models, although these terms place more emphasis on potential distribution modelling (Elith and Leathwick, 2009; Peterson et al., 2008). Only a minority of SDM or ENM studies focus on the African continent. Cayuela et al. (2009) illustrated that 8% of 123 SDM studies in the period 1995–2007 dealt with African species, and mainly plants from South Africa (4%).

In the past, most SDM's were based on regression models. During the last decade, machine-learning methods have been used increasingly, and shown to outperform traditional regression techniques. This study estimates the potential and realised distribution as well as environmental requirements of *P. angolensis* in southern Africa with the machine-learning algorithm Maxent. Literature on the ecology of the species was reviewed in order to allow a proper interpretation of the results.

Africa is one of the most vulnerable continents to climate change (IPCC, 2007) and forest managers need to consider the potential effects on this important timber species in combination with all other short-term threats to southern Africa's woodlands. Therefore, the SDM for *P. angolensis* was also used to derive the future distribution of the species based on two global climate change scenarios.

2. Methods

2.1. Ecology of P. angolensis

P. angolensis is a deciduous tree that can be found in the mixed miombo or other deciduous woodlands and forests of southern Africa. It is about 10–20 m tall, sometimes reaching a height of 30 m

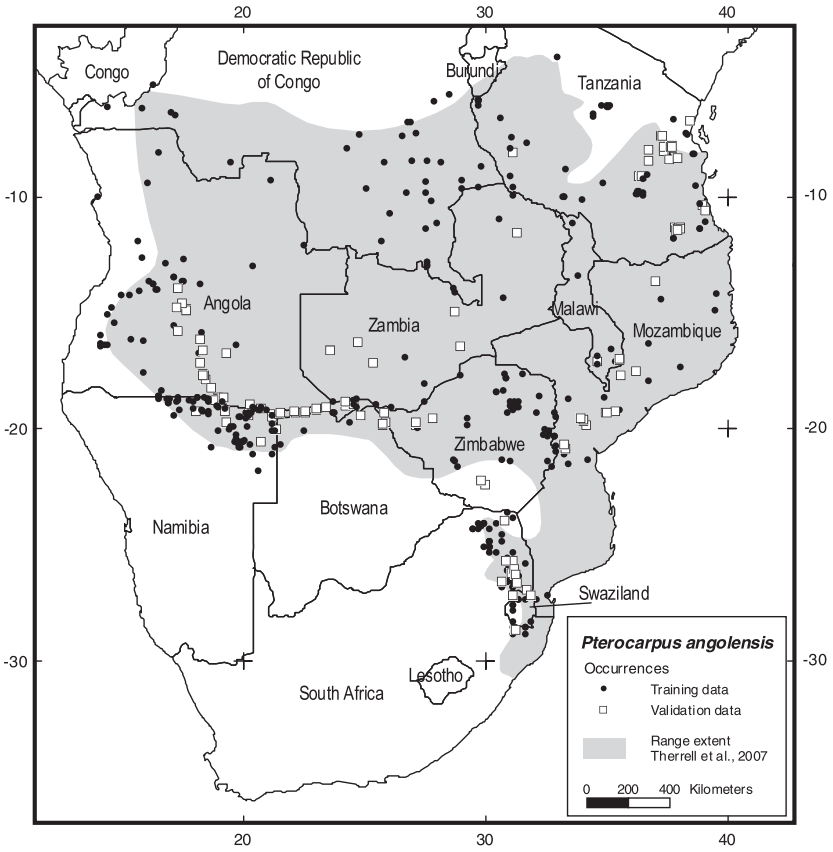

Fig. 1. Approximate range of *Pterocarpus angolensis* (Therrell et al. (2007) based on Boaler (1966b), von Breitenbach (1973) and Coates Palgrave (1983)) and locations of occurrence points used in this study. The northern limit of the current known range extent in the Democratic Republic of Congo is uncertain (Therrell et al., 2007).