South African Journal of Botany 112 (2017) 283–289

Contents lists available at ScienceDirect

South African Journal of Botany

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

Review

The prognosis for *Ailanthus altissima* (Simaroubaceae; tree of heaven) as an invasive species in South Africa; insights from its performance elsewhere in the world

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ARTICLE INFO

Article history:
Received 24 June 2016
Received in revised form 23 May 2017
Accepted 5 June 2017
Available online xxxx

Edited by T Kraaij

Keywords:
Early detection
Rapid response
Early stages of invasion
Invasive species
Potential distribution
Species distribution modelling
Tree invasions

ABSTRACT

South Africa has a major problem with invasive plant species. Many species have long residence times, are well established, and have large invasive ranges, whereas others are still in the early stages of invasion. Predicting the full extent of invasions for species that have only recently started spreading is important for guiding management strategies. *Ailanthus altissima* is a widespread invasive species in many parts of the world. Although it has had a long residence time in South Africa, it is yet to replicate the extent of invasiveness and major impacts reported for the species in other parts of its adventive range. We mapped the countries in which *A. altissima* has been reported and evaluated the invasion status of the species in each (i.e. the position of the species on the introduction-naturalization-invasion continuum as conceptualized by Richardson and Pyšek, 2012). We then mapped the current distribution in more detail for South Africa. The species is known to be present in at least 51 countries and is invasive in 23 countries. *Ailanthus altissima* is present in all South African provinces except Limpopo and is most common and abundant in the Western Cape, Gauteng, Eastern Cape, and the Free State. We applied species distribution modelling using global distribution data to determine parts of the world, and in particular regions within South Africa, that are climatically suitable for the species. Large parts of Africa are potentially invasible by this species. Seven regions in South Africa were identified as high-risk areas for invasion by *A. altissima*. The species is already far too widespread in South Africa for eradication at the national scale to be feasible. A national strategy for managing the species should focus on: 1) early detection and rapid response in areas identified as climatically suitable and where the species is not already present; and 2) local and regional-scale initiatives based on objective prioritization in terms of feasibility of management success and asset protection.

Contents

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http://dx.doi.org/10.1016/j.sajb.2017.06.007
0254-6299/

1. Introduction

The rise of global trade and long-distance transportation has resulted in an exponential increase in the number of invasive alien species globally (Lockwood et al., 2013). Some invasive species cause ecological and economic damage in invaded ecosystems and threaten biodiversity, human-wellbeing and ecosystem functioning (Pyšek and Richardson, 2010).

Trees were only acknowledged as major invasive species during the early 1980s, but there has been a rapid increase in the number of invasive alien trees, the extent of invasions, and the magnitude and types of impacts in recent decades (Richardson and Rejmánek, 2011; Richardson et al., 2014). A recent global review of invasive alien trees and shrubs listed 751 species from 90 families (Rejmánek and Richardson, 2013).

South Africa has a major problem with invasive alien plant species (Richardson et al., 1997; Henderson, 2007). By 2010, South Africa had at least 8750 introduced plant taxa, of which 660 were recorded as naturalized and 559 as invasive (Wilson et al., 2013). Many are well established while many others are still in the early stages of invasion (Nel et al., 2004; Mgidi et al., 2007). Woody plant species are very well represented in national and regional lists of invasive plant species in South Africa, and species in the genera *Acacia*, *Hakea*, *Eucalyptus*, *Pinus* and *Prosopis* are the dominant invasive plant species in many parts of the country (Richardson et al., 1997). Most of these species have long residence times (>100 years) and have been widely planted in the country (Wilson et al., 2007). Many other alien tree species, some of them also with long residence times, have not yet become widespread invaders. Some of these will probably never become important invaders, but others are likely in the lag phase between introduction and rapid spread that characterizes many invasions. Quantifying this invasion debt (sensu Rouget et al., 2015) is crucial for informing management strategies. Limited resources mean that control efforts need to be carefully prioritized (Nel et al., 2004; Van Wilgen et al., 2011, 2012).

There are three broad approaches to managing invasive species: 1) prevention of introductions; 2) eradication of small isolated invasions; and 3) management of established populations through containment, impact reduction or value addition (Wilson et al., 2013). Although preventing the entry of invasive species is the most effective way of limiting the impacts associated with invasive species, limited resources are allocated to prevention in most parts of the world (Wilson et al., 2013). It is thus important to detect invasions early and implement control measures rapidly to prevent widespread impacts (Wilson et al., 2013). Identifying suitable areas for invasion will improve search efficiency, reduce costs, and enable early detection of populations before they spread. In South Africa this approach has been applied to the invasive tree species *Acacia stricta* (Kaplan et al., 2014) and *Melaleuca parvistaminea* (Jacobs et al., 2014).

There is much to learn about the invasive potential of a given species in a particular area by examining the invasion ecology of the species elsewhere (e.g. Richardson et al., 2008, 2015). Besides dealing with current widespread invasive species, it is also important to identify invasive species that have become major weeds globally (especially in regions with similar climatic and environmental conditions to those that exist in the area in question) but which have not yet replicated such levels of invasion. This paper focusses on assessing the biogeography, distribution and habitat suitability of *Ailanthus altissima*, a tree native to China which has been introduced to many parts of the world (Kowarik and Säumel, 2007). The species is currently a widespread invasive species throughout Europe (Kowarik and Säumel, 2007; Cabra-Rivas et al., 2016) and the United States, particularly in urban areas (Albright et al., 2010). Its distribution and invasion status in other regions to which it has been introduced have been less thoroughly assessed. This paper reviews the distribution and status of *A. altissima* following its introduction to areas outside its native range globally and assesses its current and potential status in South Africa. Current invasion foci of *A. altissima* in southern Africa are identified and predictions are made regarding its potential range in the country.

2. Methods

2.1. Study species

Ailanthus altissima Mill. Swingle (Simaroubaceae; tree of heaven) is a deciduous, dioecious tree species that is native to China which has been introduced to all continents except Antarctica (Kowarik and Säumel, 2007). The species has many characteristics typical of successful invasive species (Knapp and Canham, 2000) including prolific seed production, rapid juvenile growth that often forms dense impenetrable stands (Burch and Zedaker, 2003), a tolerance for harsh weather conditions and high levels of atmospheric pollution (Lawrence et al., 1991), and the ability to resprout vigorously after disturbance (Kowarik, 1995; Kowarik and Säumel, 2007; Constán-Nava et al., 2010). It is a popular ornamental plant in urban areas in many parts of the world and has also been widely used for roadside restoration (Kowarik and Säumel, 2007; Constán-Nava et al., 2010). In its adventive range *A. altissima* is most abundant in urban areas where it mainly occurs in disturbed sites, degraded fields, and along roads and water courses (Kowarik and Säumel, 2007; Constán-Nava et al., 2010).

2.2. Assessment of the global distribution of Ailanthus altissima

A global map was created in ArcMap 10.3.1 to show the countries in which *A. altissima* is native, introduced, naturalized and invasive. Distribution data were collated from many sources. The Global Biodiversity Information Facility (GBIF), Centre for Agriculture and Biosciences International (CABI), the Global Invasive Species Database (GISD) and Delivering Alien Invasive Species Inventories for Europe (DAISIE) were the primary sources of data. Data were also sourced from a search of the literature and the internet. After editing to remove obviously incorrect localities (e.g. from the ocean) the final data set comprised 11,462 localities.

The term 'invasive' is often used loosely in the literature dealing with alien plant species (Pyšek et al., 2004); this is certainly the case for the data sources and publications dealing with *A. altissima*. It was therefore difficult to discern the invasion status of *A. altissima* at all localities in its adventive range [i.e. the position of introduced populations on the introduction-naturalization-invasion continuum as conceptualized by Richardson and Pyšek (2012)]. We categorized all data points following the criteria proposed by Pyšek et al. (2004) and Richardson et al. (2011) as follows: "native" (within the native range); "introduced" (all records outside the native range where there is no evidence of naturalization or invasion); "naturalized" (where there is evidence of localized