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Towards a national strategy to optimise the management of a widespread invasive tree (*Prosopis* species; mesquite) in South Africa

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ABSTRACT

Invasive stands of *Prosopis* (mesquite) cover over 6 million ha of South Africa and could invade over 56 million ha. These invasive stands have major impacts on biodiversity, local livelihoods and ecosystem services. We applied several methods to develop an objective basis for a national strategy to prioritise and guide the management of *Prosopis*. Decision trees were used for assigning different control objectives (prevention of spread to unoccupied areas, local eradication, containment and asset protection) to each of the 234 local municipalities in the country. Priority assets that require protection in densely invaded areas were identified, ranked and mapped (in order of importance: water source areas, biodiversity hotspots, and areas with high agricultural and rangeland potential). Available control methods were compared in terms of costs, effectiveness, and potential to create employment. Biological control and more mechanised approaches were identified as important and the role of control-through-utilisation requires urgent research. Scenario development suggests that integrated control would be most effective. Strategic guidelines for improving the management of *Prosopis* were produced. These guidelines discuss key needs and objectives for management, targets, time frames, indicators and monitoring programs, research needs and spatially prioritized management areas. Although the strategy proposed in this paper is specific to *Prosopis* in South Africa, the principles will be useful in other regions where *Prosopis* species are invasive, and more generally for other widespread invasive tree taxa.

1. Introduction

1.1. General introduction

A small proportion of species moved by humans to new regions become naturalised, and some of these become invasive - leading to negative impacts on biodiversity, ecosystem services and human well-being in many parts of the world (Pimentel, 2011; Jeschke et al., 2014). Biological invasions are an important component of human-induced global change, along with other factors such as habitat transformation and climate change (Vitousek et al., 1997). Managing invasive species is often complicated and challenging as many invaders can simultaneously provide benefits and cause negative impacts within a given area, resulting in conflicts of interest regarding their use and management (Brown and Sax, 2004; Shackleton et al., 2007; Kull et al., 2011; van Wilgen and Richardson, 2014; Woodford et al., 2016). This makes understanding the various social, ecological, ecosystem related and economic aspects of invasions, and the implications of these invasions for different stakeholders, important for guiding best-management practices. Such a holistic and integrated understanding requires a transdisciplinary approach that transcends knowledge systems and incorporates different actors to develop plans and solutions acceptable to a diversity of key stakeholders (Max–Neef, 2005; Kueffer, 2010; Angelstam et al., 2013).

The negative impacts of many invasive species have led to the initiation of control programs across the world sometimes referred to as investing in ecological infrastructure or natural resource managment. Some notable initiatives include the Weeds of National Significance (WONS) program in Australia (Thorp and Lynch, 2000; Australian Weeds Committee, 2012.), the Working for Water (WfW) program in South Africa (van Wilgen and Wannenburgh, 2016), and the U.S. Department of Agriculture's invasive-species clearing program in the USA (USDA, 2010). Article 8 (h) of the Convention on Biodiversity also requires signatory countries to take steps to manage invasive alien species. Furthermore, the EU Regulations 1143/2014, brought into effect in January 2015, seek to comprehensively manage invasive species to reduce their impacts on biodiversity, ecosystem services and human well-being in Europe (details in Brundu and

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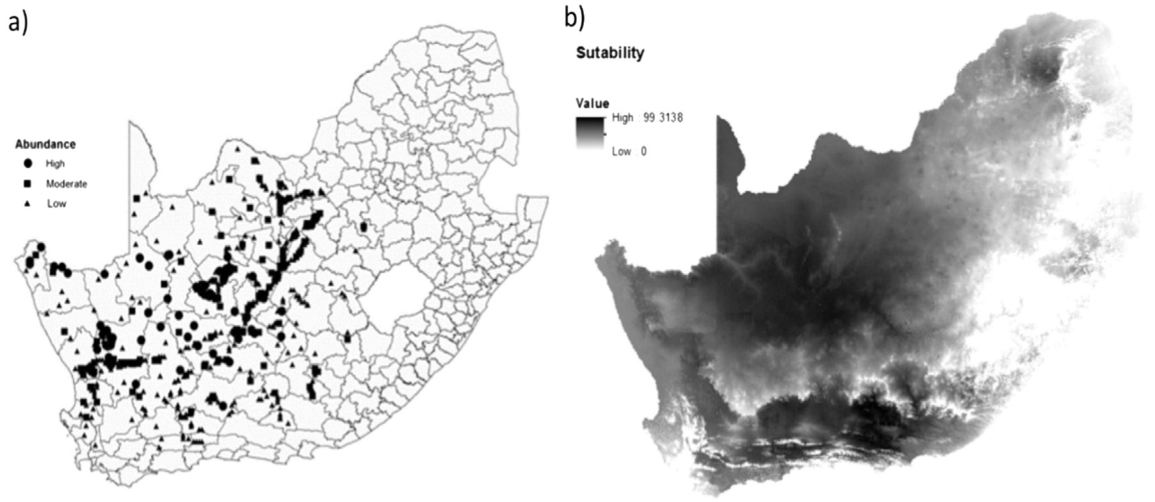

Fig. 1. (a) Distribution of *Prosopis* spp. in South Africa (Sources: SAPIA database – L. Henderson; Van den Berg, 2010; Shackleton et al., 2015a, 2015b); (b) Climatically suitable areas for *Prosopis* spp. in South Africa based on Mgidi (2004).

Richardson (2016)). Although some countries have produced high-level management strategies for dealing with invasive species, many lack species-specific plans and strategies. These management strategies are highly important to yield successful results (Downey, 2011). Australia has plans for 20 species under their WONS program (Thorp and Lynch, 2000) program, and South Africa has case-study examples for Australian *Acacia* species and *Parthenium hysterophorus* invasions (van Wilgen et al., 2011; Terblanche et al., 2016). Other management strategies have been structured around functional groups that share similarities in terms of impacts and management responses (Paynter et al., 2003; Gosper and Vivian-Smith, 2009) and approaches that focus on particular pathways of introduction or area-specific interventions (Lee and Chown, 2009). But globally many areas and species still lack specific management plans.

The lack of strategic planning and objective prioritisation for specific species and land areas has reduced the effectiveness of large-scale invasive species management programs such as WfW (van Wilgen et al., 2012a; van Wilgen and Wannenburgh, 2015; Shackleton et al., 2016). The requirements for managing invasive species in South Africa are set out in general terms in the National Environmental Management: Biodiversity Act (NEM: BA, 2004) and are given effect in the regulations on invasive species in terms of this act (DEA, 2014). For example, the Act stipulates that all organs of the state must prepare plans for eradication, control and monitoring of listed invasive species, and that strategies must be produced for dealing with invasive species that have significant negative impacts (DEA, 2014). However, different species or groups of species require different types of information and different management approaches to be effective.

Numerous approaches have been used for developing strategies to guide the management of invasive species, including area- and pathway-based approaches, risk assessments, impact assessments and spatial planning and prioritisation (Downey et al., 2010; van Wilgen et al., 2011). Prioritisation of invasive species based on the associated risks and impacts is widely recognized as being crucial for effective large-scale planning of interventions (Pheloung et al., 1999; Robertson et al., 2003; Downey, 2010; Downey et al., 2010). Despite such recognition, these approaches have rarely been applied (Roura-Pascual et al., 2009, 2010; Grice et al., 2011; Forsyth et al., 2012; Le Maitre et al., 2015). Objective spatial prioritisation (ranking of land areas by importance) must be done to guide management and to optimise the allocation of limited funds (van Wilgen et al., 2012a). Various methods have been used for spatial planning; these include decision trees and multi-criteria decision-making analysis (MCDA) methods such as Analytic Hierarchy Process (AHP) (Grice et al., 2011; Forsyth et al., 2012; Le Maitre et al., 2015). Decision trees have been used to assign management approaches to different areas, for example for prevention of spread to unoccupied areas, local eradication, containment, and asset protection (Grice et al., 2011; Le Maitre et al., 2015). There is a range of options for containment and asset protection, including different combinations of mechanical and chemical control, control through utilisation, biological control and cultural control. Each option has its advantages and disadvantages, making stakeholder involvement in assessing wants and needs essential (van Wilgen et al., 2011; Shackleton et al., 2014). Multi-criteria decision analysis (MCDA) provides a tool for prioritising areas for control when there are multiple objectives and divergence and contestation in stakeholder agendas relating to management (Saaty, 1990; Forsyth et al., 2012). AHP is useful for reaching consensus regarding management options among different stakeholders. It also facilitates transdisciplinary engagement (Angelstam et al., 2013), which is crucial in cases where invasive species generate conflicts of interest (Saaty, 1990; Forsyth et al., 2012). This paper therefore aims to use various approaches to develop strategic guidelines to better manage widespread *Prosopis* invasions in South Africa.

1.2. Prosopis in South Africa

1.2.1. History, distribution and impacts

Prosopis species were introduced to many parts of the world over the past two centuries and are now naturalised or invasive in over 100 countries and islands (Shackleton et al., 2014). Numerous *Prosopis* species were introduced into South Africa from the Americas in the late 1800s and were widely distributed to farms in the arid interior of the country in the mid-1900s to provide fodder, fuelwood and shade (Poynton, 2009). *Prosopis* became naturalised and later invasive, and now a hybrid swarm involving numerous species (Mazibuko, 2012) is the second most widespread invasive plant genus in South Africa after *Acacia* (Henderson, 2007). Invasive stands occur throughout the arid and semi-arid interior of South Africa at varying levels of abundance (Fig. 1a). *Prosopis* occurs within the boundaries of 61 of the 234 municipalities in the country, across almost half the country (Fig. 1a). Past surveys estimated that *Prosopis* covers 1.8 million ha of South Africa (83% in the Northern Cape) (Versfeld et al., 1998; Van den Berg, 2010). Using compounded annual spread rates of 8% pa (Van den Berg, 2010) and the latest distribution records, we estimate that invasions currently cover over 6 million ha in South Africa (43% of which is in the Northern Cape). *Prosopis* could potentially invade up to 56 million ha (63% of which would be in the Northern Cape) in the future based on