REPORT

Stakeholder perceptions and practices regarding *Prosopis* (mesquite) invasions and management in South Africa

Ross T. Shackleton, David C. Le Maitre,
David M. Richardson

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Abstract Invasive alien trees impact the environment and human livelihoods. The human dimensions of such invasions are less well understood than the ecological aspects, and this is hindering the development of effective management strategies. Semi-structured interviews were undertaken to investigate the knowledge and perceptions of *Prosopis* between different stakeholder groups. Chi-squared tests, Welch ANOVAs, and Principle Component Analyses were run. Factors such as land tenure and proximity to invasions were especially important for explaining differences in perceptions and practices relating to *Prosopis* among different stakeholder groups. Most respondents were aware of *Prosopis* and considered it to be invasive (i.e., spreading). Costs associated with *Prosopis* were perceived to exceed benefits, and most stakeholders wanted to see a reduction in the abundance of *Prosopis* stands. The mean total cost for the management of *Prosopis* was US\$ 1914 year⁻¹ per farm, where costs ranged from under US\$ 10 to over US\$ 500 per ha based on invasion densities and objectives for control. The findings highlight the need for more effective management interventions.

Keywords Biological invasions · Human perceptions · Indigenous knowledge · Management · Stakeholder perceptions · Tree invasions

INTRODUCTION

Biological invasions impact biodiversity, ecosystem services, and human well-being globally, and further research on invasion dynamics, impacts, and options for management is needed to identify options for sustainable management (Pimentel 2002; Pyšek and Richardson 2010). Research on invasive species is normally approached from

the domain of ecology, and more recently economics. Far less attention has been given to understanding the wider social dimensions of invasions (McNeely 2001; García-Llorente et al. 2008, 2011). Insights on the human dimensions of invasive alien species are essential for effective decision making; in many cases, complex social issues delineate the full suite of benefits and costs associated with invasions (García-Llorente et al. 2008). Research is needed to evaluate stakeholder knowledge, perceptions, practices, awareness, and wants and needs relating to biological invasions (Shackleton et al. 2007; Eiswerth et al. 2011; Kull et al. 2011; Rai and Scarborough 2014). This is particularly important for invasive species that were introduced for specific purposes and where complex conflicts of interest now exist due to the provision of valuable consumptive and nonconsumptive services (Shackleton et al. 2007; Low 2012a; Dickie et al. 2014; van Wilgen and Richardson 2014).

Many invasive alien species such as Australian acacias, *Opuntia ficus-indica* and *Prosopis* provide services such as fuelwood, medicine and edible products to local communities (de Neergaard et al. 2005; Pasiecznik et al. 2006; Shackleton et al. 2007, 2011). In the semi-arid parts of Brazil, the direct-use services provided by invasive species were seen as more important for local communities than those from native species (Dos Santos et al. 2014). *Pinus* spp., *Prosopis*, and other invasive trees are also exploited commercially on a large scale by private companies (Moran et al. 2000; Shackleton et al. 2014). In addition, species like *Acer platanoides*, *Jacaranda mimosifolia*, and *Pinus* are valued for aesthetic and cultural reasons by communities (Foster and Sandberg 2004; Dickie et al. 2014). However, these species also have negative impacts on biodiversity, ecosystem services, and local livelihoods.

Prosopis taxa have been introduced to many parts of the world over past centuries to curb desertification, stabilize soils, and provide services such as fuelwood, fodder, and shade to aid local communities (Pasiiecznik et al. 2001; Low 2012b; Shackleton et al. 2014). As with most invasive alien woody plants around the world (Richardson et al. 2014), *Prosopis* introductions were initially seen as only beneficial to most stakeholders. However, negative perceptions of *Prosopis* grew as its abundance increased, and adverse effects of invasions emerged (Pasiiecznik et al. 2001; Mwangi and Swallow 2005; Maundu et al. 2009; Shackleton et al. 2014).

There is growing evidence of the costs of *Prosopis* invasions on biodiversity, ecosystem services, and the economy in South Africa (Shackleton et al. 2014). This includes reductions in bird and insect species' richness and diversity (Steenkamp and Chown 1996; Dean et al. 2002), *Prosopis* causing increased mortality of *Acacia erioloba* and a reduction in the population stability of native tree species, due to competition for limited resources (Schachtschneider and February 2013; Shackleton et al. 2015), loss of grazing potential (Ndhlovu et al. 2011), impacts on water resources (Dzikiti et al. 2013), and negative impacts on the South African economy (Wise et al. 2012). On the other hand, it is still used for fodder and fuelwood in its invasive range (Wise et al. 2012). However, understanding of the social dimensions of *Prosopis* invasions is poor, and this is thwarting attempts to implement effective management to reduce the costs while, where possible, maintaining some or all of the benefits (Richardson 1998). Key factors that influence human perceptions of invasive alien species generally relate to the abundance of the invader, the services it provides, the time since introduction, the mode of introduction, and many socio-political features of human societies (Shackleton et al. 2007; Kull et al. 2011; Rai and Scarborough 2014).

Current management interventions for *Prosopis* in South Africa focus on an integrated approach involving mechanical control and chemical control by the national Working for Water program, and biological control (Zachariades et al. 2011; van Wilgen et al. 2012). Although success has been achieved in reducing the density and impacts of invasive stands on a small scale in some areas, the extent and the magnitude of impacts are increasing rapidly (Wise et al. 2012). Between 1996 and 2008, the cover of *Prosopis* in South Africa increased by 35 %, despite the expenditure of R 435.5 million (US\$ 42.7 million) on management (van Wilgen et al. 2012). The release of further biological control agents may be the only cost-effective way of managing *Prosopis* invasions. However, further work in this area has been put on hold due to the conflicts of interest surrounding *Prosopis* use (Zachariades et al. 2011; Wise et al. 2012). A national strategy

for tackling invasive *Prosopis*, along the lines of the one proposed for Australian *Acacia* species in South Africa (van Wilgen et al. 2011), is urgently needed. A key prerequisite for such a strategy is the much improved understanding of the social dimensions of the problem.

In many cases, management strategies have been implemented without due consultation with stakeholders about their perceptions and needs. This has in some cases resulted in conflicts of interest issues relating to livelihood vulnerability and has led to wastage of limited funding (Davis et al. 2011; McNeely 2011; Rai et al. 2012). Focussed social studies can provide valuable insights that are helpful for developing shared goals for management and the means for achieving such goals (Kreuter et al. 2005). However, some social studies on invasive species have only focused on benefits (de Neergaard et al. 2005; Shackleton et al. 2011). Although this is clearly important, costs also need to be considered to provide comprehensive guidelines to inform management interventions. Social studies can also build platforms for improving communication between scientists, managers, and the public (Dangles et al. 2010; Heger et al. 2013). In the case of *Prosopis* invasions in South Africa, better knowledge of the human dimensions could certainly help in highlighting benefits versus costs, exploring new opportunities for effective management, and justifying contentious interventions.

The aims of this study are to (1) elucidate the factors that determine the understanding and perceptions of a woody invasive plant that has both benefits and costs, using *Prosopis* invasions in South Africa as a case study; (2) compare and contrast the knowledge, perceptions and practices relating to *Prosopis* among different stakeholders; and (3) use the information gained to suggest management interventions in the future.

STUDY SITES

The study was conducted at ten locations across the invasive range of *Prosopis* in South Africa (Figs. 1, 2). The area covers the Succulent Karoo, Nama Karoo, and Savanna biomes in the Northern Cape province. The area included sites with private and communal land tenure systems, and towns and villages of different sizes. Kimberly and Upington are the two largest towns in the study area with populations of over 200 000 and 50 000 people, respectively. Calvinia, Prieska, and Carnarvon are small towns with populations ranging from 10 000 to 20 000 people. The other towns and villages have fewer than 5000 people.

Twenty years after the first democratic elections in South Africa, the legacy of apartheid is still strongly reflected in the distribution of different racial groups across the country. Most rural land belongs to Whites and is

Fig. 1 Towns in the Northern Cape province, South Africa, where surveys were conducted to determine human perceptions relating to *Prosopis* invasions. The dots represent the presence of invasive stands of *Prosopis* in South Africa (Source of map Henderson, SAPIA database, ARC-Plant Protection Research Institute, Pretoria)

managed as privately owned commercial farms. There are smaller areas of communal land (including some areas that were demarcated as “homelands” before 1994); these are populated mainly by Black and Colored (mixed race) groups. The primary land use in these areas is subsistence farming. In urban settings, towns are still divided by social–economic status and racial group, with moderately affluent suburbs (comprising mostly Whites) and informal settlements (populated mainly by Black and Colored groups). Sharp contrasts in social and economic status exist between these four main stakeholder groups over the study area (Table 1). The economy of the province is dominated by mining, tourism, and agriculture—fruit and vegetables along perennial rivers—and extensive livestock farming in rangeland areas. The sites provide a representative cross section of the prevailing environmental and sociopolitical conditions across the invasive range of *Prosopis* in South Africa.

MATERIALS AND METHODS

Four key stakeholder groups were identified in the study area: two in rural areas (farmers and villagers living on communal lands) and two in urban areas (people living in poor informal settlements and those living in affluent

suburbs). Semi-structured household interviews were administered with these stakeholder groups not only to ensure that the views of different population groups were considered, but also to explore differences in perceptions, practices, and knowledge regarding *Prosopis* invasions among stakeholder groups. The interviews comprised a mix of closed-ended, open-ended, and ranking questions and had two primary parts: (1) demographic data; and (2) an assessment of perceptions, understanding, practices, and local knowledge relating to *Prosopis* invasions. The latter included questions relating to knowledge of *Prosopis* (e.g., whether it is invasive or not, its benefits, and costs), issues relating to management and the sources of knowledge (if any) regarding *Prosopis* invasions. Household interviews were conducted in a random manner in the home language of the respondents (Afrikaans, English, Tswana, or Xhosa). A translator was used where the respondents were not fully conversant in English. Interviews were directed at the oldest person present at the house.

In total, 639 interviews were conducted across ten sites within the invasive range of *Prosopis* in South Africa (Fig. 1). This included 130 household interviews with commercial farmers, and 409 interviews in urban areas (276 in informal settlements; 133 in affluent town suburbs), and 100 in rural villages situated on communal land. Interviews with farmers were conducted at all ten sites,

Fig. 2 Invasive *Prosopis* species in South Africa: costs, benefits, and management options. **1** Costs of **1a** *Prosopis* encroachment on livestock rangelands; **1b** *Prosopis* thorns that injure humans and animals and damage tires; **1c** *Prosopis* encroaching on urban infrastructure. **2** Benefits: **2a** workers making fuelwood from *Prosopis*; **2b** *Prosopis* being used as a shade and ornamental tree in a rural village; **2c** *Prosopis* pods collected to be milled and fed to livestock. **3** Management options: **3a** Mechanical and chemical clearing of *Prosopis* invasions; **3b** *Algarobius prosopis* (Bruchidae; a seed-attacking insect introduced for biological control); **3c** Fence-line contrast: The farm on the right undertakes annual clearing of *Prosopis*, the farm on the left does not manage *Prosopis*. Photos R.T. Shackleton and J.H. Hoffmann (**3b**)

respondents from urban areas were not included in Mier and Madibeng sites as these areas only had small rural communal land villages. Mier and Madibeng were the only sites where household interviews were administered with people living in rural communal land areas. Sampling numbers differed between different stakeholder groups because of logistical issues of reaching respondents at their homes as well as being based on the population demographics of the different groups. For most areas, there were a very limited number of farmers in the area based on their large farm sizes. Villages occurring in the communal rural land areas were very small, so sample sizes were very limited. More interviews than what were initially planned were conducted with people in urban informal settlements as the interviews at these sites went faster than planned because unemployment was high and most households had someone present throughout the day. Interview times in these communities were therefore not restricted to early evenings.

Chi-squared tests (χ^2) and Welch ANOVAs were used to compare responses between the four different stakeholder groups. Principal Component Analyses were run to assess the relationship between respondents' demographic variables and understanding and perceptions relating to *Prosopis* invasions in South Africa.

RESULTS

Knowledge and perceptions on *Prosopis* invasions

The majority of the sample population were aware of *Prosopis* (Table 2). However, a significantly poorer knowledge of *Prosopis* was found in urban suburbs where 35 % of respondents did not know what *Prosopis* was (Table 2). Knowledge of *Prosopis* was related to town size and proximity to invasions, with people in urban informal settlements and affluent areas in large towns (Kimberly and

Table 1 Demographics of sample population of the different stakeholders interviewed [n = (farmers—133; urban informal—236; urban affluent—130; rural 100)]. hh = household

Stakeholder category	Mean age	Gender (% male)	Ethnic group	Education (mean no. years)	Mean no. people per hh	Mean no. wage earners per hh	Mean no. state grants per hh	Mean no. state pensions per hh
Farmers	53 ± 13.6	80.8	Colored—12 White—88	13 ± 2.8	2.8 ± 1.2	1.8 ± 0.1	0.0 ± 0.0	0.0 ± 0.0
Urban-informal	48 ± 32.6	37.8	Black—28 Colored—72	7.7 ± 3.9	4.7 ± 2.5	0.7 ± 0.7	1.4 ± 1.4	0.6 ± 0.8
Urban-affluent	48 ± 13.2	57.1	Black—8 Colored—4 White—88	14 ± 2.0	2.8 ± 1.2	1.7 ± .6	0 ± 0	0 ± 0
Communal areas	47 ± 15.6	47	Black—25 Colored—75	6.8 ± 4.1	4.5 ± 2.9	0.5 ± 0.6	1.5 ± 1.2	0.7 ± 0.8

Uppington) having a significantly poorer knowledge of *Prosopis* (informal settlements: 78.2 %; affluent areas: 33.7 % of people had no knowledge) compared to a much lower percentage in smaller towns (informal settlements: 2.1 %; affluent areas: 6.0 % not knowing) ($\chi^2 = 96.8$; $df = 1$; $p < 0.001$).

Prosopis invasions were much more prevalent on farms and rural communal areas compared with urban properties. Ninety-four percent of farmers had *Prosopis* on their land, and on average, more people in rural communal areas (61 %) than people in urban areas (29.6 % in informal settlements and 13.45 in affluent suburbs) had *Prosopis* in their gardens. Fifty percent of farmers categorized *Prosopis* as being common on their properties, 22 % had moderate invasions, and 28 % had small *Prosopis* invasions on their farms. On a household level, there were on average 2.4 ± 3.8 *Prosopis* trees in the gardens of people, which had *Prosopis* on their land. A small minority of stakeholders had planted *Prosopis* themselves on their property (Table 2). Most respondents said that *Prosopis* had been on their properties when they arrived there (farmers 45.7 %; informal settlements 40 %; affluent suburbs 68.8 %; and rural communal households 34 %). Approximately a quarter of farmers (27.6 %), and approximately half of households in informal settlements (46.6 %), and rural villages (52 %) reported that *Prosopis* had spread naturally onto their land, but only 6.2 % of households in affluent suburbs held this view. Despite a dislike for *Prosopis* in most stakeholder groups, some urban dwellers (9.8 % informal; 0.9 % affluent) reported a desire to plant *Prosopis* trees on their properties. The most-cited reasons for this were to provide shade and greenery which is lacking in informal settlements. However, many people said any easy-to-grow tree would be acceptable; it did not have to be *Prosopis*.

Prosopis was seen to be spreading on people's properties and in the local environment (Table 2; Fig. 2). People from farms and in rural communal areas supported the

notion of *Prosopis* as an invasive species significantly more than people from urban areas. Many people in urban areas did not know whether or not *Prosopis* was invasive or spreading (10.5 % in informal settlements and 23.6 % in affluent suburbs).

There were contrasts between different stakeholder groups regarding the knowledge of *Prosopis* being invasive. All the farmers (100 %) knew that *Prosopis* is an invasive alien tree. Other stakeholder groups were significantly less aware of this, and people in informal settlements had the least knowledge of this fact (37.1 %) (Table 2).

Benefits and costs of *Prosopis*

All stakeholder groups considered the costs of *Prosopis* to be greater than the benefits (Figs. 3, 4). Although this sentiment was present across stakeholder groups (Fig. 4), there were significantly different views among stakeholders. More than 90% of farmers and people in rural communal areas viewed *Prosopis* as harmful—much more so than people in urban areas (informal 64.2 % and affluent 50.6 %). Significantly more people from urban informal settlements viewed *Prosopis* as beneficial compared with other stakeholder groups, most likely because invasion densities close to towns and within towns are much lower than in rangelands. Some respondents did not know whether *Prosopis* was beneficial or not (9.7 %)—a substantial proportion of respondents (33.1 %) who held this view resided in urban affluent areas, where awareness of *Prosopis* was lower (Fig. 3). Few respondents recognized any effects of *Prosopis* on their livelihood (6.3 %), with significantly more urban people reporting this compared to other stakeholder groups, largely because urban people lacked first-hand experience/observation of *Prosopis* invasions.

Prosopis was recognized as beneficial to some people in the study area (Fig. 2). In total, 13 types of benefits were reported, the most common being fodder, fuelwood, and

Table 2 Stakeholder responses to questions relating to knowledge and perceptions of *Prosopis* in South Africa

Questions	Farmers	Urban-informal	Urban-affluent	Communal land	χ^2 , df, <i>p</i> value
Do you know what <i>Prosopis</i> is? (also accepted and used local names mentioned above) (% people responding yes)	100	93.5	65.4	100	123.8; 3; 0.001
Do you have <i>Prosopis</i> on your property? (% yes)	94	29.6	13.5	61	224.1; 3; 0.001
Did you plant the <i>Prosopis</i> on your property? (% yes)	1.5	3.5	4.8	3.6	6.4; 3; 0.1
Is <i>Prosopis</i> spreading on your property? (% yes)	96.7	78.2	83.5	98.4	14.1; 3; 0.003
Is <i>Prosopis</i> spreading in the environment around you? (% yes)	100	87.3	74.4	100	149.7; 6; 0.001
If you don't have <i>Prosopis</i> trees on your property would you like to it? (% yes)	0	9.8	0.9	2.1	42.4; 6; 0.001
Did you know <i>Prosopis</i> is an invasive alien tree?	100	37.1	58.3	53	146.0; 3; 0.001

Fig. 3 Stakeholder views of the benefits and costs of *Prosopis* in South Africa ($\chi^2 = 205.1$; df = 12; $p < 0.001$) **Fig. 4** Different views of stakeholder groups on whether costs associated with *Prosopis* are greater than the benefits? ($\chi^2 = 135.8$; df = 6; $p < 0.001$)

shade (Table 3). A small minority of respondents (<5 %) also mentioned other direct and indirect benefits of *Prosopis*, such as honey, local greenery, aesthetic value in towns and gardens, acting as wind breaks, creating privacy for households, and as an ingredient for the brewing of beer/alcohol.

Table 3 Stakeholder views of benefits provided by *Prosopis* (5 % and above) ($\chi^2 = 221.5$; df = 15; $p < 0.001$)

Benefits	Farmers	Urban-informal	Urban-affluent	Communal areas
Fodder	63.1	21.7	23.3	25
Fuelwood	16.2	17	21.8	19
Medicine	1.5	1.1	7.5	0
Shade	16.9	29.3	12.9	26
Children eat pods	0	6.2	0.8	0
Provides jobs	0	6.2	3.8	0

Many farmers mentioned that despite the use of *Prosopis* as a fodder source for livestock, the consumption of pods by livestock facilitated the spread of *Prosopis* on their properties. Some farmers (3.8 %) reported using an alternate feeding strategy that maximizes *Prosopis* fodder benefits while reducing spread. This involved milling pods to powder (breaking up the seeds) prior to providing them as a supplement to livestock (Fig. 2). This is, however, labor intensive and expensive. In the affluent suburbs *Prosopis* was seen as having medicinal benefits. Many respondents reported its use for stabilizing blood-sugar levels in the form of the South African product called “Manna.” This is manufactured from *Prosopis* pods and is popular in affluent communities. Many people in informal settlements highlighted the use of *Prosopis* pods for food, predominantly as snack eaten by children. Eating *Prosopis* pods as an adult carries a negative stigma of being poor. *Prosopis* was seen as promoting local job creation, particularly by respondents in urban informal and affluent suburbs. These jobs included the collection of pods in the Prieska area for the company that produces “Manna,” as well as clearing *Prosopis* as part of the Working for Water program. Although not specifically mentioned by respondents as a form of job creation, there were people in most communities who sold fuelwood made from *Prosopis*, and

Table 4 Stakeholder views of the costs/harm caused by *Prosopis* (5 % and above) ($\chi^2 = 575.4$; $df = 45$; $p < 0.001$)

Negative impacts	Farmers	Urban-informal	Urban-affluent	Communal areas
Reduced Water	75.2	38.4	42	75
Reduces grazing	73.7	11.6	24.8	29
Kills native plant spp.	69.5	11.6	17.3	49
Encroachment and loss of access of land	65.4	23.1	27.1	44
Roots break foundations/houses	3	25	6.8	30
Expensive to control	19.5	0.7	0	0
Makes town/garden dirty	0	14.9	3	1
Reduces property value	13.5	0	0	0
Thorns cause injury to animals and people	5.3	13.8	1.5	45
Roots block bore holes	12	0	0	11
Supports pest animals	9.7	0	0.8	0
Reduces profits	5.3	0	0	0
Thorns cause tire damage	3.8	0	0	8
Blocks pipes	2.3	5.1	5.2	7
Reduces supply of native wood	2.3	2.2	0	11
Impacts farming	0	0	5.2	0

many farmers sold wood to try and recover the costs of clearing—which also led to job creation.

The types and the average number of benefits listed differed significantly between the various stakeholder groups ($p < 0.001$) (Table 3). Only fuelwood and shade were commonly mentioned across all stakeholder groups. Fodder was mentioned on average three times more by farmers than other stakeholders, and the fact that *Prosopis* invasions led to job creation and that *Prosopis* provides edible products was mentioned most by respondents from informal settlements. The use of *Prosopis* to produce the blood-sugar medicine was mentioned mainly by people residing in urban affluent areas.

In total, 28 different costs associated with *Prosopis* were mentioned (Table 4; Fig. 2). The most common costs mentioned were negative impacts on water supply and grazing potential, loss of native species (including grass, shrubs, and trees), problems with encroachment, and transformation of land (Table 4). Further complaints (less than 5 %) relating to *Prosopis* included death of livestock, increased livestock illness, allergies and asthma, changing of the taste of water, a reduction in wool quality, flooding caused by it blocking river systems, and damage to power lines. *Prosopis* was also seen as aesthetically displeasing, responsible for giving children stomach problems (after

pod ingestion), providing refuge for criminal activities, and killing of garden plants. The high costs associated with managing invasions, and the difficulty of removing *Prosopis* trees (as they coppice profusely) were also seen as problematic costs associated with the tree.

One farmer grew up with *Prosopis* invasions along a small river on their farm, and mentioned the first time he ever saw the river flow was after *Prosopis* stands were cleared from along its banks after he inherited the farm. Many different stakeholders noted that dense thickets caused loss of access to recreational areas in urban areas and loss of access to rivers and grazing areas in rangelands. *Prosopis* thorns were seen as problematic across all stakeholder groups as they injure livestock and people and puncture car tires. Many people mentioned that the thorns were poisonous and caused infections. All stakeholders mentioned problems associated with the deep-penetrating root systems of *Prosopis* trees; these block bore holes, block, and burst underground water pipes, and cause buildings to crack and break when the roots shift foundations.

Prosopis had negative economic impacts for farmers, including high costs for control, loss of profits, and decreases in the value of farms. The costs of clearing can exceed the purchase price of the land. One farmer mentioned that it costs R 5000 per ha to clear *Prosopis* on land that he purchased for R 1500 per ha.

Farmers mentioned that *Prosopis* thickets benefitted problem animal species such as jackals (which eat lambs), aardvarks and porcupines (which break water pipes), baboons and feral pigs (which cause general damage). On the other hand, one farmer noted an increase in populations of the native kudu *Tragelaphus strepsiceros* due to *Prosopis* invasions, which he considered a benefit. *Prosopis* was seen to reduce the abundance of native tree species such as *Acacia erioloba* and *A. karroo* (both important fuelwood species). The grazing potential of land has also been reduced by *Prosopis* through the reduction of grasses and Karoo shrubs. In urban areas, *Prosopis* caused gardens and the city streets to become ‘dirty’ due to leaf and podfall in the dry season.

The reported cost categories ranged from those associated with single trees causing problems at a household level (blocking water pipes, cracking foundations, growing into power lines, making gardens dirty) to those at a landscape level (biodiversity loss, encroachment of land, loss of grazing, water uptake). Chi-squared tests revealed that the types of costs and number of costs listed differed significantly between different stakeholder groups ($p < 0.001$). People in rural areas, farms, and communal areas were able to identify more costs (3.8 and 3.3 per interviewee) compared with people in urban informal settlements (1.6) and people in affluent urban areas (1.4).

Prosopis management

The majority of farmers (88 %) implemented some form of management to control *Prosopis* invasions (Table 5; Fig. 2). The most common techniques included manual cutting and herbicide application to stumps. However, some farmers rented earth-moving machinery to dig up invasive *Prosopis* trees, while others applied only a foliar herbicide and burnt the bases of large trees. Despite the presence of biological control agents (seed-feeding beetles), many farmers regarded the control method as ineffective. No respondents purposefully used the control-through-utilization approach, although many farmers did use the wood from felled trees to partly cover the costs of clearing. Others collected pods to add to feed for livestock. Some suggested that creating large-scale industries to produce paper or bio-energy could improve control as it would introduce a large-scale demand for *Prosopis*. However, high transport costs to and from remote areas was viewed as a potential problem for rolling out such enterprises.

Expenditure on the management of *Prosopis* was highly variable and was based on invasion densities and goals of management. Expenditure to prevent establishment of invasions in the un-invaded camps was in some cases lower than R 100 per ha and for the removal of moderate-to-dense invasions, farmers estimated they were paying R 600–2500 per ha using manual cutting and herbicide application and over R 5000 per ha using excavators. The annual average costs of control implemented by farmers was high with a mean of expenditure of R 20 667 ± 12 024 (R1 = US\$ 11.3—November 2014) per farm per annum. Annual expenditure on the management of *Prosopis* was also highly variable, ranging from R 750–2000 per farm per annum, and was spent either on maintaining access roads and water points on densely invaded farms, or doing annual clearing to prevent the establishment of *Prosopis* on farms with sparse invasions. Attempts to achieve local eradication of moderate and dense *Prosopis* invasions resulted in expenditure ranging from R 40 000 to R 180 000 per farm per annum. One farmer mentioned that

the South African National Roads Agency offered to clear *Prosopis* on his farm in return for road-building material from his farm. They had spent almost R 500 000 clearing approximately 20 ha of dense invasion using earth-moving machinery (this figure was not included in the average cost of control calculation).

The proportion of respondents controlling *Prosopis* in other stakeholder groups was significantly lower than for farmers. Respondents from the other stakeholder groups mainly uprooted *Prosopis* seedlings, and some trimmed or felled trees when they got too big. Most people uprooted and trimmed trees themselves. People in the affluent group employed gardeners to do this, with costs averaging R 50 per annum.

The majority of respondents from all stakeholder groups wanted to see a decrease in the abundance of *Prosopis* in their area (Table 5). Most people wanted Working for Water program to clear their land; this view enjoyed significantly more support from people from rural communal areas than from other groups. Their main reasons being that this reduced the negative impacts of *Prosopis* and helped in reducing the personal costs of clearing. However, many farmers objected to letting Working for Water teams on their land as they saw them as ineffective. Examples included the late application of herbicides after cutting, over-dilution of herbicides, and clearing outside the growing season which results in the herbicide not being taken up by the *Prosopis* trees. These trees then coppiced which led to increased density of invasions. Farmers also noted that the piecemeal clearing technique employed by Working for Water often left patches of *Prosopis* between cleared areas and was ineffective in the long term, as there was a source of seed to reinvade cleared areas. Furthermore, many farmers expressed concerns about theft of stock and equipment, apparently by Working for Water teams. The mistrust in the efficiency of the Working for Water program from farmers has resulted in many land-owners preferring to clear *Prosopis* invasions themselves. A number of respondents in urban areas did not want *Prosopis* trees to be removed from their properties,

Table 5 Stakeholder perceptions, views and practices related to the management of *Prosopis* invasions in South Africa

Questions	Stakeholder groups				χ^2 , df, <i>p</i> value
	Farmers	Urban-informal	Urban-affluent	Communal areas	
Do you control <i>Prosopis</i> on your property? (% yes)	87.8	21.3	17.6	46.6	103.9; 3; 0.001
Average annual cost of control? (Rand)	20 667 ± 12 024	0	50 ± 22	0	8.3; 3; 0.001
Would you like to see a decrease in <i>Prosopis</i> population densities in your area (environment)?	100	92.8	100	99	4.3; 3; 0.23
Would you be happy for the Working for Water program to clear <i>Prosopis</i> on your property? (% yes)	73.4	73.9	67.4	94	90.7; 6; 0.001

although they were happy to see them removed from rangelands. Many respondents reported they would only be happy for *Prosopis* trees to be removed from urban areas if these were replaced with other trees by the government.

Factors relating to the knowledge of *Prosopis*

The majority of respondents observed the benefits and costs of *Prosopis* first hand. However, various other knowledge resources were reported by the respondents. Most people who did not gain knowledge from personal experience, gained knowledge on *Prosopis* through interacting with local farmers, and people employed by Working for Water. Others learned about *Prosopis* at their places of work and at school. A small percentage of people also mentioned that they had learned about *Prosopis* invasions via the media. Prominent sources were a short documentary on the national environmental TV show “50:50” and adverts for “Manna” as a blood-sugar-stabilizing product. Farmers who do not have *Prosopis* on their land said they have observed and heard about the benefits and costs at quarterly meetings of farmers associations. The origin of the knowledge on the benefits and impacts of *Prosopis* differs significantly between the stakeholder groups ($p < 0.001$) (Table 6). In general, farmers and people in rural communal areas experienced benefits and costs first hand, whereas people in urban areas learned about the benefits and costs from other people (farmers and Working for Water staff) and the media. Those who lived nearer to

invasions also had a better knowledge of the benefits and costs relating to the invasions.

The principal component analysis revealed that there were no strong relationships between demographic variables (age, education level, and gender) and people’s knowledge and perceptions of *Prosopis*. There are, however, strong relationships between knowing what *Prosopis* is and knowing whether it is spreading, knowing that it causes impacts, and wanting *Prosopis* to be managed better.

DISCUSSION

Factors shaping knowledge, perceptions, and practices of *Prosopis* invasions

There is still much to be learned about factors that influence knowledge, perceptions and practices relating to biological invasions (García-Llorente et al. 2008). One framework suggests that the abundance of invasions is the dominant factor influencing perceptions (Shackleton et al. 2007). Other factors such as biophysical characteristics of the local environment, potential uses, growth form of the plant, mode of introduction, social context of the area (socioeconomic status, local policies, and land tenure), and familiarity with the invasive species clearly also shape perceptions and use of invasive aliens (Kull et al. 2011; Rai and Scarborough 2014). Aesthetic values relating to invasive species have also been found to influence the perceptions of invasions (Dickie et al. 2014), and were highlighted to a limited extent in our results. Using *Prosopis* invasions as a case study has highlighted that there are substantial differences in knowledge, perceptions, and attitudes toward *Prosopis* between different stakeholders in South Africa

Knowledge of *Prosopis* is more superficial in urban areas where impacts of invasions do not directly influence people’s livelihoods and where there is less first-hand experience of invasions. Many people in urban areas only knew about *Prosopis* through engaging with people who have first-hand experience (farmers and farm workers) and via the media (Table 6). This highlights that proximity to invasions played an important role, with people in urban areas away from large-scale invasion being less knowledgeable. Town size played a role regarding knowledge of *Prosopis* invasions—individuals in smaller towns were more knowledgeable. This is most likely due to these communities being closer knit, allowing people to gain knowledge of *Prosopis* by interacting with farmers; such interactions are less common in larger cities like Kimberly and Upton.

Table 6 Where people gained their knowledge on the benefits and costs of *Prosopis* (Benefits: $\chi^2 = 306.1$; df, = 14; $p < 0.001$) (Costs: $\chi^2 = 203.2$; df = 18; $p < 0.001$)

How you gained knowledge on <i>Prosopis</i>	Stakeholder groups			
	Farmers	Urban-informal	Urban-affluent	Communal areas
<i>Benefits</i>				
Observed	97	88.7	47.7	89.4
Farmers association	3	0	0	0
Farmers	0	11.4	45.3	10.6
Work place	0	0	4	0
Media	0	0	3	0
<i>Costs</i>				
Observed	93	59.4	49	70.8
Farmers	5.3	20.9	39	10
Farmers association	1	0	0	0
Media	0.8	2.4	10.2	0.8
Work place	0	0.8	3.8	0
Working for water	0	16.5	0	17.5
School	0	0	2.8	0.8

Population demographics had no clear influence on knowledge and perceptions of *Prosopis*. However, other social-context factors such as land tenure led to differences in perceptions and practices regarding the management of *Prosopis*. A significantly higher percentage of private land owners actively managed *Prosopis* compared with respondents living in communal areas (Table 5). Although 75 % of people in rural communal areas considered *Prosopis* to be harmful, and 99 % of people would like to see populations controlled, no one was involved in any form of management besides clearing seedlings from their gardens. This may be not only because they are very poor and cannot afford to clear *Prosopis* themselves, but also because people are not sufficiently strongly motivated to manage invasions as they feel that such interventions should be undertaken by government. Tenure rights—where people did not want to invest in clearing land they did not own—were also important. In Kenya, many people in communal areas cleared *Prosopis* in small agricultural fields that were considered their “own” and most respondents viewed that it was their duty to do it, although many mentioned government assistance would be appreciated (Mwangi and Swallow 2005). The majority of respondents in Kenya (60 %) believed that it was the government’s responsibility to remove *Prosopis* from communal land (rangelands), but 40 % believed that it should be a combined effort involving government, NGOs, and local communities (Mwangi and Swallow 2005).

Knowledge, perceptions, and practices relating to *Prosopis* invasions in South Africa

All stakeholder groups felt that *Prosopis* had more negative impacts/costs than benefits in the study area (Table 4). The key benefits of *Prosopis* that are recognized are its provision of fodder, shade, and fuelwood. Some benefits listed by respondents were not commonly mentioned in the literature on *Prosopis* from other parts of the world, including: making beer, job creation, medicinal value, and aesthetic beauty. On the other hand, communities in other parts of the world highlighted uses of *Prosopis* that were not mentioned in our survey. These included its use for construction poles, charcoal, fencing, improving soils, wood carving/timber, bio-char, and making ropes (Chikuni et al. 2004; Mwangi and Swallow 2005; Kazmi et al. 2009). Many noted that the benefits were less in dense invasions because the trees in dense stands produce fewer pods and remain in a shrub form, making utilization difficult because people and livestock are unable to penetrate these thickets (Shackleton et al. 2014). Most of these benefits can be substituted by native species such as *Acacia karroo*, *Searsia* spp. (used for fuelwood and shade), *A. erioloba*, and *A. mellifera* (used for fuelwood, shade, and fodder).

The production of the blood-sugar pills is an exception to this, although a decrease in tree densities could allow for greater pod yields. In Kenya, the loss of native species due to encroachment by *Prosopis* has led to the loss of many specific services provided by these species such as palms that are used for thatching and weaving (Stave et al. 2007).

Some novel issues relating to costs/negative impacts were also raised. These included factors such as *Prosopis* roots breaking infrastructure, the fact that the presence of *Prosopis* invasions reduces the property values of farms, and that leaf and pod falling in the dry season makes gardens and town streets untidy and “dirty.” Communities in other parts of the world have mentioned that *Prosopis* invasions caused cracks in the ground, increased the prevalence of malaria, and reduced crop yields (Mwangi and Swallow 2005).

Most respondents believed *Prosopis* to be spreading. This is in agreement with other sources that have shown that *Prosopis* invasions in the Northern Cape province increased from approximately 128 000 ha in 1974 to 1.5 million ha in 2007, and that the extent increased by around 8 % per annum from 1974 to 2007 (Van den Berg 2010; van Wilgen et al. 2012). This will increase costs and reduce benefits, thereby increasing human vulnerability in the future (Shackleton et al. 2007; Wise et al. 2012). Most people (98 %) would like to see *Prosopis* populations reduced in the study area (Table 5). This is slightly higher than in Kenya where 85–90 % of the respondents would like *Prosopis* to be eradicated (Mwangi and Swallow 2005)—although some people with *Prosopis* in their gardens did not want *Prosopis* removed. There were also numerous issues raised regarding the efficiency and reliability of the government-run program that co-ordinates invasive plant clearing—Working for Water. Farmers are making substantial investments every year to manage *Prosopis* on their land (Table 5). The average costs of manual cutting and poisoning when done by farmers were generally lower than those of the Working for Water program which range from R 130 per ha in sparsely invaded areas to R 5340 per ha under dense invasions (Wise et al. 2012).

Implications for management

The results have highlighted that there is demand for increased and improved control of *Prosopis* in South Africa and that the conflicts of interest are not as pronounced as was previously thought. Local respondents considered the costs of *Prosopis* to outweigh the benefits. This is because of the obvious negative effects that the invasions have on livelihoods, and because the benefits from utilization are low when *Prosopis* forms dense thickets (Shackleton et al. 2014).

Respondents identified the need to monitor Working for Water operations more closely and to prioritize management interventions to improve management success and effectiveness in the long term. Farmers suggested that tax subsidies or subsidies on herbicides would help them manage *Prosopis* better. This suggestion is being implemented in other areas of South Africa (Gamtoos Water 2013).

The results from our study showed that there is need for more cost-effective methods to reduce the costs of *Prosopis* invasions and to reduce the financial burden of control for farmers and the Working for Water program. This need could be met through the use of biological control (Zachariades et al. 2011; van Wilgen et al. 2012; Wise et al. 2012). Research into biological control was halted in the past due to conflicts of interest around the use of *Prosopis*. However, the substantial rates of spread and high levels of costs from *Prosopis* invasions warrant resumption of research on this topic (Zachariades et al. 2011). To date, biological control of *Prosopis* in South Africa has been poor, with one agent failing to establish, and the other two having minimal effects on the rate of spread of *Prosopis* (Zachariades et al. 2011). There are other biological control agents, such as an *Evippe* species, which have reduced *Prosopis* invasion densities in Australia (van Klinken 2012) which could also be effective in South Africa (Zachariades et al. 2011). Effective biological control agents could reduce stand densities (and the rate of spread), which would make utilization easier and thus raise the benefits of *Prosopis* in the long term (Zachariades et al. 2011).

Further research is also needed to explore the feasibility of promoting large-scale use of *Prosopis* to utilize benefits from *Prosopis* and increase employment, while at the same time reducing the costs and spread of invasions (Choge and Chikamai 2004; Kazmi et al. 2009). For example, Kenya is in the process of setting up regional power plants that will be fueled with *Prosopis* biomass and there is scope for large scale charcoal production (Shackleton et al. 2014). Many respondents suggested that *Prosopis* invasions are important for job creation.

Improving awareness and encouraging farmers with sparse *Prosopis* invasions to control them before they become dense could also help these land owners to save money and prevent the spread of *Prosopis* in the long term. There is also need for targeted awareness programs in urban areas, where knowledge about *Prosopis* is lacking. Information on local invasive species should be incorporated in the school syllabus. A key requirement for reducing the costs of *Prosopis* invasions and more effective and improve management is a national strategy—similar to the one implemented in Australia or the one suggested for invasive Australian *Acacia* species in South Africa (van Wilgen et al. 2011; Australian Weeds Committee 2012).

Using multiple-stakeholder participatory approaches to create this strategy would help in reducing the conflicts and aid in developing a holistic plan that considers all the needs and concerns of all stakeholders.

CONCLUSIONS

Citizens in rural areas—living on commercial farms and in villages situated on rural communal lands—had greater knowledge on aspects relating to *Prosopis* invasions than people living in towns and cities. Perceptions, knowledge, and practices relating to *Prosopis* differed between stakeholders and were linked to the social context of the stakeholder groups such as land tenure, economic status, and town/city size. No clear link was found between knowledge and perceptions of *Prosopis* and demographic variables such as age, gender, and education level. Most people believed that *Prosopis* invasions in South Africa were causing more harm than benefit, and numerous negative impacts were mentioned. Most stakeholders were of the view that *Prosopis* is spreading and that densities of invasive populations in South African need to decrease to reduce costs. The costs of control are currently high for farmers and the Working for Water program, and there is need not only to look into new methods of management but also to make current management more effective. Biological control or mass scale utilization could help us improve control in the future.

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AUTHOR BIOGRAPHIES

Ross T. Shackleton (✉) is a PhD student at the Centre for Invasion Biology, Stellenbosch University (<http://academic.sun.ac.za/cib/>). His research interests include biological invasions and environmental management.

Address: Centre for Invasion Biology, Department of Botany and Zoology, Stellenbosch University, Private Bag X1, Matieland 7602, South Africa.

e-mail: rossss@sun.ac.za; rtshackleton@gmail.com

David C. Le Maitre is a Plant Ecologist based at the Council for Scientific and Industrial Research (CSIR) in Stellenbosch. His research interests include conservation biology; invasion ecology, and catchment hydrology.

Address: Centre for Invasion Biology, Department of Botany and Zoology, Stellenbosch University, Private Bag X1, Matieland 7602, South Africa.

Address: Natural Resources and the Environment, CSIR, P.O. Box 320, Stellenbosch 7599, South Africa.

David M. Richardson is the Director of the Centre for Invasion Biology based at Stellenbosch University. His research focusses on the ecology and management of invasive species, especially trees.

Address: Centre for Invasion Biology, Department of Botany and Zoology, Stellenbosch University, Private Bag X1, Matieland 7602, South Africa.