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Use of non-timber forest products from invasive alien *Prosopis* species (mesquite) and native trees in South Africa: implications for management

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Abstract

Background: *Prosopis* species have been introduced to many areas outside their native range to provide benefits to local communities. Several *Prosopis* species and their hybrids (hereafter "mesquite") have, however, become naturalised and invasive and now generate substantial costs. Management options are limited because of the complex conflicts of interest regarding benefits and costs. Management policies and strategies must take account of such conflicts, but further insights are needed on the dimensions of uses and impacts before such information can be usefully applied. Current policy in South Africa allows for the growth and use of mesquite in one province, but not in others where its control is mandatory. We report on a study to quantify the direct use and perceptions of non-timber forest products (NTFPs) from mesquite and native trees in South Africa.

Methods: Semi-structures household interviews were conducted with various stakeholder groups to identify what tree products are used, to ascertain amounts used as well as to gauge perceptions of natural resource use between different tree species and use over time.

Results: The direct household use value of native trees was higher than that of mesquite, and local stakeholders attached greater value to products from native trees than from mesquite. Therefore, native trees are and will still be preferentially harvested, and mesquite is unlikely to offer protection to native species by providing an alternative source of products. Mesquite pods do, however, provide valuable additional resources (fodder and medicinal products). The use of both native trees and mesquite is decreasing as the incomes of poorer households rise and as alternative energy sources become available. The benefits and reliance on mesquite are not as high as previously assumed and the impacts from mesquite invasions create large problems for local communities.

Conclusion: This study provides further evidence that the impacts of mesquite exceed the benefits, lending support for a policy to reduce negative impacts.

Keywords: Biological invasions; Conflicts of interests; Cost vs. benefit; Management; Policy; Tree invasions

Background

General introduction

Thousands of plant species have been introduced to new locations by humans, especially during the last three centuries, to serve many purposes (Richardson 2011). Many have naturalised and some have become invasive (Rejmánek and Richardson 2013). Invasive plants often supply benefits to societies in their new ranges, but costs associated with these invasions often increase as the plants spread (Shackleton et al. 2007a; Kull et al. 2011). This typically results in the emergence of complex conflicts of interest, with some stakeholders calling for eradication or control of the invaders, while others promote their continued use (Shaanker et al. 2010; Kannan et al. 2014; Shackleton et al. 2014; van Wilgen and Richardson 2014). Some invasive plant taxa (e.g., *Acacia* and *Pinus* species) are commercially important for forestry and agroforestry (Richardson 2011), while many others (e.g., *Acacia mearnsii*, *Opuntia ficus-indica* and *Prosopis* species) provide useful resources such as fuelwood,

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fodder and fruit, and are important for local livelihoods (Pasiecznik et al. 2001; de Neergaard et al. 2005; Shackleton et al. 2007a, 2011; Richardson et al. 2015). However, these same species also cause substantial costs to local livelihoods and the environment (Shackleton et al. 2014; van Wilgen and Richardson 2014).

Non-timber forest products (NTFPs) are all biological materials other than timber that are harvested from trees for use and sale at the household level (De Ber and McDermott 1989). These include native and introduced species (Cunningham 2001). NTFPs are utilised for subsistence and commercial gain all over the world (Shackleton and Shackleton 2004) and account for 20 % of the incomes of rural poor communities on average and are used by more than 85 % of households in urban areas of southern Africa (Shackleton et al. 2007b; Davenport et al. 2012). The use and trade of NTFPs has potential to be used for poverty alleviation and social upliftment in developing countries in a sustainable way (Shackleton and Shackleton 2004); this includes various initiatives to promote the utilisation of invasive alien species of *Acacia* and *Prosopis* (Choge and Chikamai 2004; Pasiecznik et al. 2006; Shackleton et al. 2007a). The introduction of invasive species can bring benefits by supplying more NTFPs or novel NTFPs, but can simultaneously be detrimental to natural resources, changing traditional patterns of resource use in a positive or negative way (Shackleton et al. 2007a). For example, in South Africa's Eastern Cape province, 90 % of households used invasive alien *Acacia* species (wattles) as their primary heat source, and 19 % of households relied on wattles for cash incomes (de Neergaard et al. 2005). The sale of fruit from invasive stands of *Opuntia ficus-indica* in the Eastern Cape amounted to 9 % of the yearly income of collector's households (Shackleton et al. 2011). In Malawi, *Prosopis* (thereafter "mesquite") provided 44 % of households with an income source (Chikuni et al. 2004), and in India mesquite provided up to 70 % of fuelwood needs for households in arid regions (Pasiecznik et al. 2001; Walter 2011). NTFPs from mesquite such as medicine, fodder, flour alternatives and charcoal, are sold commercially on a large scale worldwide (Shackleton et al. 2014). However, mesquite also generates numerous costs in the same areas, which negatively affect local biodiversity, ecosystem services, economies and local livelihoods (Shackleton et al. 2014).

The services that these invasive alien species provide and the costs that they generate have resulted in conflicts regarding their use and management in many developing countries (Low 2012; van Wilgen and Richardson 2014). The introduction of new plants has been labelled as "dangerous aid" as many of these invasive non-native species harm the same communities that were targeted for assistance in the long term (Low 2012). The presumed benefits of these species limit management options and lead to contradictory policies in many developing countries, while costs associated with the invasions continue to rise. For example, in the Northern Cape province, South Africa, mesquite is listed as a "Category 3" invasive "species" which means that the genus may remain in the prescribed area/province, but further planting, propagation or trade is prohibited – expect for the pods from mesquite which are exempted, and may be used on private land. In other South African provinces, mesquite is a "Category 1" invader which means that invasive populations must be controlled (although the regulations do allow for ongoing use of pods) (NEM:BA, 2004; Act No. 10 of 2004: Alien and Invasive Lists 2014) (Department of Environmental Affairs 2014). This means that any trading of products derived from mesquite is illegal in South Africa. Similarly, policy in Kenya states that mesquite should be managed though utilisation to reduce rates of spread and impacts while at the same time benefitting local communities. This policy is controversial as it limits control options; for example biological control is excluded (Shackleton et al. 2014). Such policies that seek to reduce impacts while seeking to benefit communities are widespread in developing countries. The situation is very different in developed countries, where social upliftment does not feature in strategies for dealing with invasive species. In Australia, for example, mesquite is listed as a weed of national significance and legislation does not allow for utilisation (Australian Weeds Committee 2012). Similarly, European regulations issued in 2015 do not make it easy to utilise products from any invasive species (European Union 2014). Utilisation of natural resources is crucial for local livelihoods and social upliftment in developing countries (Shackleton and Shackleton 2004). Sustainable strategies for dealing with "conflict of interest" invasive species must address the relative value of useful invasive species, like mesquite.

The systematic study of the use and perceptions of invasive species relative to native species has been limited (Kull et al. 2011). People use many invasive species simply because they are there, and not to use them would be to forego an opportunity. This is exacerbated if the species provides a resource that is not available from native species (Shackleton et al. 2007a). However, the use and perceptions of conflict invasive species such as Australian acacias differ considerably in different areas (Kull et al. 2011). People often use both native and alien species for the same purposes, and it would be useful to understand the drivers and levels of such usage to develop policies that will minimise harm and maximise benefit. Both native and alien species must be considered when formulating broad conservation aims in rangelands (Milton et al. 2003). On the one hand the alien species could relieve pressure on native species, thus benefiting conservation. On the other hand, however, on-going invasion by the alien species could be very detrimental to native species and to ecosystem services. Furthermore, if the alien species is perceived to be useful, then there would be resistance to the implementation of control from those who benefit from the resource. A better understanding of the level of use, value and dynamics of NTPF uses and perceptions of invasive species is clearly important for formulating effective responses and to guide policy formation and management. The use of NTFPs is usually assumed to be sustainable, allowing for biodiversity conservation and economic development to co-exist (Negi et al. 2011), and this has been proposed for invasive species (Choge and Chikamai 2004). Sustainable outcomes are, however, rare. The situation is inevitably dynamic, with the net benefits that accrue shortly after introduction being steadily eroded as the species invades, resulting in net harm (van Wilgen and Richardson 2014). One needs to consider that even beneficial invasive species can also lead to negative externalities whereas native species do not. Therefore, it is crucial to ensure that the use and perceptions on NTFPs from native and invasive species are incorporated in strategies dealing with invasive species to ensure that the needs of local communities are met while ensuring the conservation of biodiversity and ecosystem services. Mesquite invasions in South Africa provide a good case study for gaining further insights on these issues.

Mesquite in South Africa

Several *Prosopis* species were introduced to a few localities in South Africa in the late 1800s. In the mid-1900s mesquite was widely promoted and planted by the Department of Agriculture as a fodder, fuelwood and shade resource to aid farmers who were struggling with a two-decade long drought in the arid parts of the country (Zimmermann 1991; Poynton 2009). *Prosopis* has since become the second most widespread invasive plant genus in South Africa after Australian acacias (van Wilgen et al. 2012). There is growing evidence that mesquite invasions in South Africa are having profound negative impacts on biodiversity (Dean et al. 2002; Steenkamp and Chown 1996; Schachtschneider and February 2013; Shackleton et al. 2015a, 2015b), ecosystem services (Ndhlovu et al. 2011; Dzikiti et al. 2013) and local livelihoods and economies (Wise et al. 2012; Shackleton et al. 2015c). Wise et al. (2012) estimated that the costs will soon exceed the benefits. Control efforts carried out to date have done little to arrest the rapid spread of invasive populations (van Wilgen et al. 2012). Three seed-feeding biological control agents (*Algarobius prosopis*, *A. bottimeri* and *Neltumius arizonensis*) have been released in South Africa, but have had limited effect. *A. bottimeri* failed to establish, and the other two have not substantially slowed rates of mesquite spread (Zachariades et al. 2011). Although almost 0.5 billion Rand (US$ 50 million) was spent on mechanical and chemical control measures between 1996 and 2008 (van Wilgen et al. 2012) by the state-run Working for Water programme, invasions continue to spread rapidly and the associated negative impacts continue to rise (Wise et al. 2012). Additionally, South Africa's policy for dealing with mesquite highlights the extent to which complexities still exist relating to the use and management of mesquite within South Africa with contradictory policy in different provinces. There is clearly an urgent need for a national mesquite management strategy as there are still conflicting ideas over the use and the benefit supply of the genus and the social and ecological costs it generates within South Africa. However, before more effective management policies can be developed, further insights would be required regarding the relative use, benefits and perceptions of this invasive tree in South Africa as well as to assess if other options are available if mesquite is better managed.

This study therefore compares (1) the use of NTFPs from native trees and mesquite by different stakeholders within the invasive range of mesquite in South Africa; and (2) perceptions surrounding mesquite and native tree NTFPs. It is hypothesised that; (1) mesquite is used more than native species due to introduction history and the fact that is it highly invasive and so widespread; (2) the introduction of mesquite has led to the prevision and use of novel resources in the area; and (3) mesquite will be perceived to be more useful than native species by local communities.

Methods

Study site

The study took place in 10 cities, towns and villages across South Africa's Northern Cape province (Fig. 1). This area covers the core of the invasive range of mesquite species in South Africa and represents a cross section of different environmental and socio-political conditions. Invasive stands of mesquite in South Africa comprise a complex mixture of several species and their hybrids (Mazibuko 2012), and we will simply refer to as "mesquite". The study included rural and urban areas and areas with private and communal land tenure. Sampled human settlements included large towns with over 50,000 people (Kimberly and Upington), smaller towns with between 10,000 and 20,000 inhabitants (Calvinia, Carnavon and Prieska), and towns and villages with fewer than 5000 people (Brandvlei, Loeriesfontein, Kenhardt, Mier and Madibeng).

The legacy of apartheid is still clearly reflected in the wealth, education, and distribution of different racial

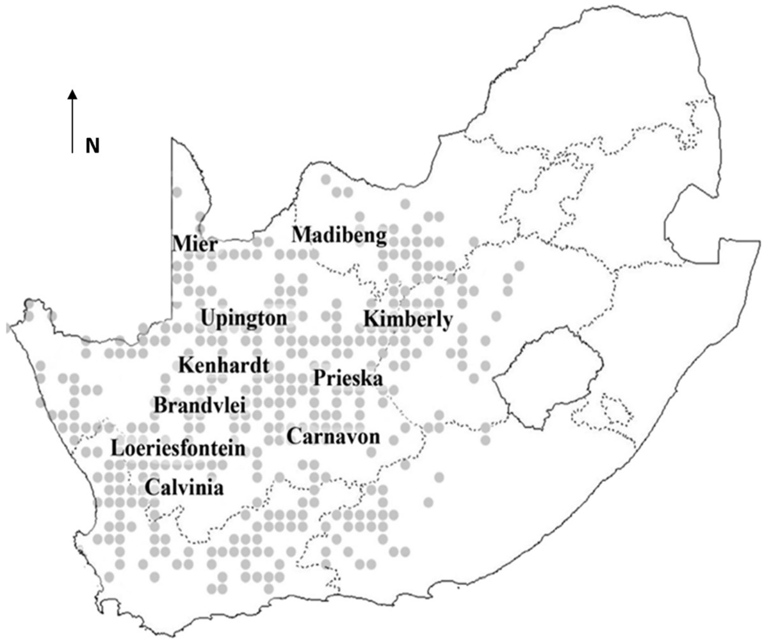

Fig. 1 Locations of the 10 towns in South Africa where interviews were conducted on the use of non-timber forest products from *Prosopis* species (mesquite) and native trees use. Dots represent the occurrence of invasive mesquite stands (Source of Map - Henderson, SAPIA database, ARC-Plant Protection Institute, Pretoria)

groups in the study area (Table 1) (Treiman 2007). Rural land is primarily owned by Whites and is run as game or livestock farms, although there are areas of communal land populated by Black and Coloured (mix-race) communities that were demarcated as "homelands" during the apartheid era. Stark contrasts are evident in urban areas, with moderately affluent suburbs (populated mainly by Whites) and informal settlements ("townships") populated by primarily Black and Coloured residents (Table 1). The economy of the region is based on mining, livestock, game and irrigated crop farming and tourism. The study area is semi-arid to arid, with mean annual rainfall averaging between 150 and 450 mm at different sites and falls within three biomes: the Succulent Karoo, Nama Karoo and Savanna (Mucina and Rutherford 2006).

Interviews

Semi-structured interviews were conducted with people from four main stakeholder groups - two in rural areas (land-owning farmers, and people living on communal lands) and two in urban areas (affluent suburbs and those living in poor informal settlements). These stakeholders provided a cross section of various groups who utilise natural resources and are influenced by mesquite. The interviews sought to uncover what NTFP products households used, the quantity of used, but also to

Table 1 Demographics (mean ± standard deviation) of the sample populations of the different stakeholder groups interviewed across the study sites. (hh = household)

Stakeholder category	Mean age (yrs)	Gender (% male)	Race group (%)	Education of hh head (yrs)	Mean no. people in hh	Mean no. wage earners per hh	Mean no. state grants per hh	Mean no. state pensions per hh	Modal income bracket (Thousands of Rand/month)
Farmers	53 ± 134	81	Coloured (12) White (88)	13 ± 3	3 ± 1	2 ± 0	0 ± 0	0 ± 0	30-40
Communal rural	47 ± 16	47	Black (25) Coloured (75)	7 ± 4	5 ± 3	1 ± 1	2 ± 1	1 ± 1	0-5
Urban-Affluent	48 ± 13	57	Black (8) Coloured (4) White (88)	14 ± 2	3 ± 1	2 ± 1	0 ± 0	0 ± 0	>40
Urban-Informal	48 ± 33	38	Black (28) Coloured (72)	8 ± 4	5 ± 3	1 ± 1	1 ± 1	1 ± 1	0-5

understand perceptions and trends about the use of NTFPs from mesquite and native trees. Households were selected at random by conducting interviews with all available households on randomly selected streets - although some farmers were located through snowball sampling as many lived in towns rather than on their farms. The head of the household and/or those responsible for the collection of NTFPs were interviewed in their home language (Afrikaans, English, SeTswana, or isiXhosa). A translator was used for interviews in households where interviewees were not conversant in English.

A total of 639 household interviews were conducted across 10 sites between June and September 2014. These included 130 interviews with commercial farmers, 100 in rural communal land villages and 409 in urban areas – (276 in informal settlements, 133 in affluent town suburbs). Farmers were interviewed at all 10 sites. Respondents from urban informal settlements and urban affluent areas were not interviewed at Mier and Madibeng as these areas only had rural villages on communal lands. Sample sizes varied across the stakeholder groups and were based on the demographics of different groups and the availability and ease of access for household interviews (Shackleton et al. 2015a). Farms in the area are widely separated making it costly and time-consuming to do many interviews. Unemployment is high in urban informal areas, so it was possible to conduct interviews throughout the day. In most households in urban affluent areas all the adults in the household worked so interviews could only be conducted for an hour a day in the early evenings and on weekends.

The interviews were semi-structured and comprised three main sections: (1) information regarding the demographics of the respondent household; (2) questions relating to use of mesquite and native trees; and (3) questions relating to perceptions of NTFPs supplied by mesquite and native species, and changes in patterns of use over time. This allowed us to gather information on the products and species utilised, amounts used, and local prices which allowed for the calculation of direct use values.

Field measurements

The key resources obtained from trees included fuelwood, pods used for various products, and fencing poles. For households that had NTFPs at their houses, daily quantities were measured using a spring scale. Many households bought resources from local traders, and indications of amounts bought per time frame were gathered. Local prices were obtained from traders. Quantities that people bought were measured at the local traders. Many households did not have NTFPs available for measurement, but respondents were able to estimate their usage in common units such as donkey carts or bakkie (small truck/utility vehicle) loads per month or year. The contents of twelve bakkie loads and six donkey carts were weighed. This included eight bakkie loads of mesquite, two of *Acacia erioloba* and two of *A. karroo* wood and tree donkey carts of mesquite, two of *A. erioloba* and one of *A. karroo* wood. There were no significant differences in the mean weights of the different species. We standardised the data for wet bakkie loads (which still had fresh bark and were on average a third heavier) to that of dry bakkie loads by subtracting the mean difference between the two. The mean weight of a bakkie load of wood was 422 ± 119 kg. This is lower than the mean of 532 kg for three bakkie loads measured by Twine et al. (2003) - there was high variability based on the type of bakkie. The mean mass of a donkey cart load of wood was 156 ± 66 kg, marginally higher than the average of 132 kg per donkey cart found by Shackleton et al. (2006). Market values for fuel wood, honey and pods used to produce organic medicine were gathered from local traders at each of the study sites. Because there was no market for fodder and fencing poles, a substitute for mesquite pods for fodder -Lucerne pellets - was used (R 3.10 per kg) and the value of native tree fencing poles was substituted for 3 m-long *Eucalyptus* poles (R 40.00 per pole).

Statistics

T-tests were used to compare the total use and value (numerical data) of native tree species relative to mesquite. One-Way ANOVAs and Tukey post-hoc tests were used to compare use and value (numerical data) between different stakeholder groups. Chi-squared tests were used to compare the differences between usage by stakeholder groups and perceptions of mesquite and native species for variables with categorical data. All assumptions for each test were examined before the tests were run. Some groups of products have very small sample sizes precluding statistical analysis.

Results

Uses of mesquite and native trees

Fuelwood was the most common NTFP collected or bought for both mesquite and native species (Table 2). The proportion of fuelwood from native species and mesquite varied between stakeholder groups, and fuelwood from native species was used more amongst three stakeholder groups but marginally less by those in Urban Informal settlements who use mesquite slightly more often. Annual household use and the economic value of the use did not differ between mesquite and native trees at a household level. However, total use and value of native species was higher as more households use native species for fuel wood as compared to mesquite. The mean price of fuelwood from native species (R 1.8/kg) was also slightly higher than that of mesquite fuelwood (R 1.4/kg). The overall household direct use value of

Table 2 A comparison of fuel wood use of mesquite and native tree species for different stakeholders. Data are mean ± standard deviation

	Mesquite fuelwood			Native species fuelwood			p-value (mesquite vs. native)		
Stake-holder group	% of hh using	Mean use (kg/hh/yr)	Mean value (R/hh/yr)	% of hh using	Mean use (kg/hh/yr)	Mean value (R/hh/yr)	% of hh using	Mean use (kg/hh/yr)	Mean value (R/hh/yr)
Farmers	54	1648 ± 1650^a	2060 ± 2676^a	85	1784 ± 1892^a	2230 ± 2523^a	0.03	0.630	0.85
Communal rural	48	795 ± 1021^b	930 ± 1229^b	69	860 ± 1110^b	1125 ± 1253^b	0.04	0.17	0.48
Urban - affluent	19	392 ± 259^b	$586 \pm 343_b$	63	339 ± 271^c	641 ± 553^c	0.005	0.39	0.63
Urban - informal	51	539 ± 721^b	$979 \pm 1134_b$	48	528 ± 626^c	1155 ± 1214^b	0.869	0 .09	0.42

Superscript letters = significant differences between different stakeholder groups - Tukey post hoc test. hh = household

native tree fuelwood across all stakeholders was 1.2 times higher than that of mesquite. *Acacia erioloba*, *A. karroo* and *A. mellifera* made up the bulk of native species used followed by *Parkinsonia africana* and *Searsia lancea*. The use of mesquite wood also differed between stakeholder groups (Table 2). Farmers used more mesquite fuelwood than other groups. There was no difference in use and value of mesquite between other groups. Annual use of wood and annual value of fuel wood from native species also differed between different stakeholders (Table 2). Farmers used the most, followed by residents in Communal Rural villages and there were no differences between the urban stakeholder groups who used substantially less than the rural stakeholders.

Mesquite provided more direct-use services than native trees (Table 3). This included the collection of pods for fodder, beer and the manufacture of an organic blood sugar stabiliser marketed as "Manna". Pods were collected by farmers and milled to break the seed, so that they could feed them to livestock while eliminating the risk of spreading the seeds in dung. The collection of pods to produce Manna was restricted to one town (Prieska). Some farmers also collected honey produced from mesquite flowers. Respondents also mentioned that children opportunistically ate the pods from mesquite, but this was not included in the study as children could not be included in the study for ethical reasons. In rural areas numerous native tree species were used to make fencing poles. The value of NTFPs other than fuelwood was approximately 9.4 times higher for mesquite than for native trees. However, fuelwood use overshadowed this and, all together, the value of direct use NTFP products of native trees averaged 1.1 times more than that of mesquite (Tables 2 and 3). Interestingly, no households in Urban Affluent areas used other (besides for fuelwood) NTFPs from mesquite or native tree species (Table 3).

Modes of obtaining NTFP products differed between stakeholder groups for both mesquite and native tree species (Fig. 2). Most farmers and people living in rural communal areas collected products from mesquite and native species themselves, whereas in urban areas most people purchased these products. The proportion of people selling NTFPs was very similar across all stakeholder groups with 2 %–3 % of people selling mesquite and native tree products in Rural Communal areas and Urban-Affluent areas and up to 7 % of respondents selling mesquite products from the Urban-Informal stakeholder group and 7 % of farmers selling native tree species products. Farmers and people from Urban Affluent areas normally had larger-scale operations compared to the more informal trade within the Rural Communal

Table 3 Usage metrics (mean ± standard deviation) for less commonly used non-timber forest products harvested from mesquite and native trees in South Africa. (hh = household)

	Farmers			Communal rural			Urban – informal		
Resource	% of hh using	Mean use (kg or l/hh/yr)	Mean value (R/hh/yr)	% of hh using	Mean use (kg or number of poles/hh/yr)	Mean value (R/hh/yr)	% of hh using	Mean use (kg/hh/yr)	Mean value (R/hh/yr)
Mesquite									
Fodder	3.8	1976 ± 1669	6125 ± 5174	2	200 ± 0	620 ± 0	>1	960 ± 0	2976
Beer	–	–	–	–	–	–	>1	80 ± 28	120 ± 82
Manna	–	–	–	–	–	–	2.2	1013 ± 193	1215 ± 231
Honey	>1	10	700	–	–	–	–	–	–
Native trees									
Fencing poles	–	–	–	4	29 ± 23	1170 ± 912	–	–	–

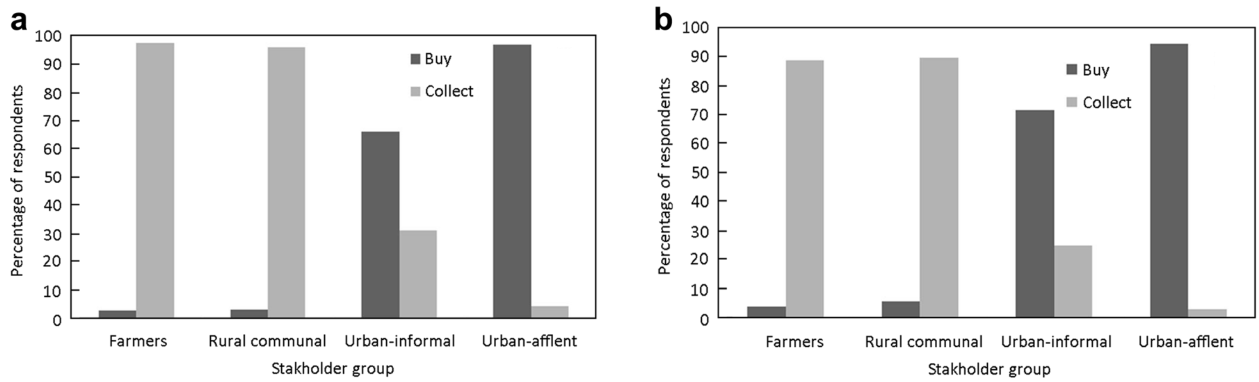

Fig. 2 Methods of securing non-timber forest products from (**a**) mesquite – ($\chi^2 = 255.8$; $p < 0.0005$) and (**b**) native species ($\chi^2 = 235.2$; $p < 0.0005$) for four stakeholder groups in South Africa

areas and Urban Informal areas and employed labourers to do the work, thus creating valuable jobs.

Perceptions and trends over time

In general, most households viewed the products provided by mesquite as inferior to native species – particularly in the case of fuelwood (Fig. 3). There were several reasons for this, including that mesquite wood does not generate as much heat or form coals as well as many native species; mesquite logs have smaller diameters than those from native species; mesquite has thick thorns that some people consider poisonous, making it relatively difficult to harvest and utilise; when the mesquite wood is slightly wet it produces an unpleasant smoke, and the most commonly mentioned reason was that the wood is rapidly powdered by a boring insect as it dries (which means that large quantities of wood cannot be stored for long periods) (Table 4). A small percentage of respondents preferred mesquite to native species, because it produces a highly nutritious fodder; invasive mesquite stands are often closer and more accessible to towns

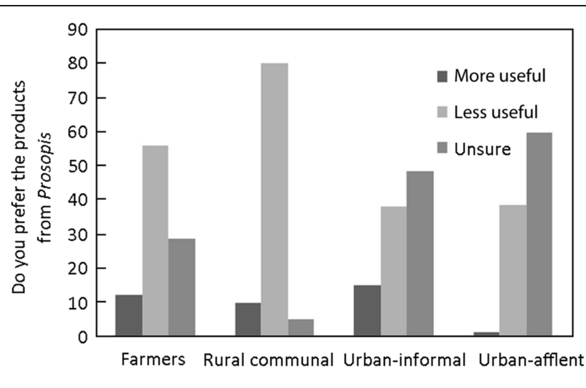

Fig. 3 Perceptions on the usefulness of non-timber forest products supplied by mesquite compared to native tree species in South Africa ($\chi^2 = 189.3$; $p < 0.0005$)

(making wood collection cheaper and faster); and some households make beer out of the pods (Table 4). Another reason for preferring to use mesquite was because the wood could easily be collected from debris left by government-sponsored clearing projects. Many people in the Urban Affluent stakeholder group were unsure whether mesquite products were better than native tree products and had no particular preference (Fig. 3).

In general, most stakeholders were either using the same amount of mesquite or native tree species, or have decreased their use of fuel wood over the last 10 years (Fig. 4). The primary reasons for reduced use – particularly in Urban-Informal settlements and in Rural Communal villages – is the recent electrification of these areas, and increased incomes through grants enabling many people to move to alternative energy sources such as electricity and gas. Only a small proportion of people in all stakeholder groups have increased their use of mesquite or native trees for NTFPs. Reasons for increased use include: bigger families driving a greater demand for wood, and the lower cost of fuel wood compared to electricity. Some people have increased their use of mesquite compared to native trees as the mesquite has spread rapidly making the wood are more accessible. Some farmers have also increased their use of mesquite as they are making more effort to control it and so use the wood of trees that have been cut down. Most people in Urban-Affluent areas used the wood primarily for barbeques, a strong tradition in the area, and are using about the same amount of wood as in the past.

Discussion

Many previous studies of NTFP use from invasive alien plants have focused only on the use value of a single species and provided no comparisons with usage of native species (Chikuni et al. 2004; de Neergaard et al. 2005; Shackleton et al. 2007c; Shackleton et al. 2011). Such a comparison is important to illustrate the potential value invasive species can provide but also gives insight into the other alternatives

Table 4 Views of different stakeholders (% of respondents) on the negative ($\chi^2 = 4.05$; $p = 0.29$) and positive ($\chi^2 = 11.5$; $p = 0.0006$) aspects of mesquite non-timber forest product provision as compared to those supplied by native trees

	Negative				Positive		
Stakeholder group	Bad smoke	Poor quality wood	Thorns	Turns to dust	Fodder	Make beer	More accessible
Farmer	1.8	31.1	19.8	37.0	11.3	–	1.8
Rural Communal	4.6	25.8	24.2	38.5	7.0	–	3.0
Urban - Affluent	–	53	6.3	40.1	–	–	1.6
Urban - Informal	7.3	25.7	28.6	28.8	10.7	1.1	3.7

and the potential opportunity costs of their use. This study has shown that the direct use and value of resources provided by an introduced "wonder plant" which has now become a major invader - mesquite - is not as high as high as that of native trees in the arid parts of South Africa. This suggests that the benefits provided by mesquite are not as high as previously assumed, and with rising costs associated with spreading invasions, management interventions to reduce the extent and density of mesquite are becoming increasingly justifiable.

Findings in relation to hypotheses

(1) We hypothesised that mesquite would be used more than native species. Our findings indicate, however, that native species – particularly *Acacia* species - provide higher value for direct household use to local stakeholders than mesquite provides (Tables 2 and 3). The bulk of this use is for fuelwood which is the most commonly utilised NTFP in other parts of South Africa as well (Twine 2005; Davenport et al. 2012). This suggests that mesquite is less useful than previously assumed. It also means that the pressure on native tree populations remains high as they are still being utilised and are being displaced by invasive mesquite (Schachtschneider and February 2013; Shackleton et al. 2015b, 2015c).

(2) We hypothesised that the introduction of mesquite would lead to the provision and use of novel resources in the area, which it has, as mesquite provides a greater diversity of products than native trees in the study area. The most important novel resource is pods which are valued for fodder and to a smaller extent for the production of an organic medicine and brewing alcohol (in one town) (Table 3). This study did not quantify the value of consumption of pods by livestock in rangelands, although this is high (Wise et al. 2012). However, any assessment of the value of pods as fodder would have to factor in the loss of grazing where mesquite invades (Ndhlovu et al. 2011), as well as the role of livestock in spreading mesquite seeds in their dung (Shiferaw et al. 2004).

(3) We hypothesised that the natural resources provided by mesquite would be preferred to those of native trees. However, our findings indicate that the majority of stakeholders prefer native trees over mesquite and see products of native species as superior (Fig. 3). This is mainly because the wood quality of mesquite is perceived as poor for the reasons highlighted in Table 4, and fuel wood is the most widely used NTFP in the area. In Ethiopia when production of charcoal was legalised in an attempt to control mesquite through utilization, locals substituted mesquite with native *Acacia tortilis* and *A. nilotica* because these native species

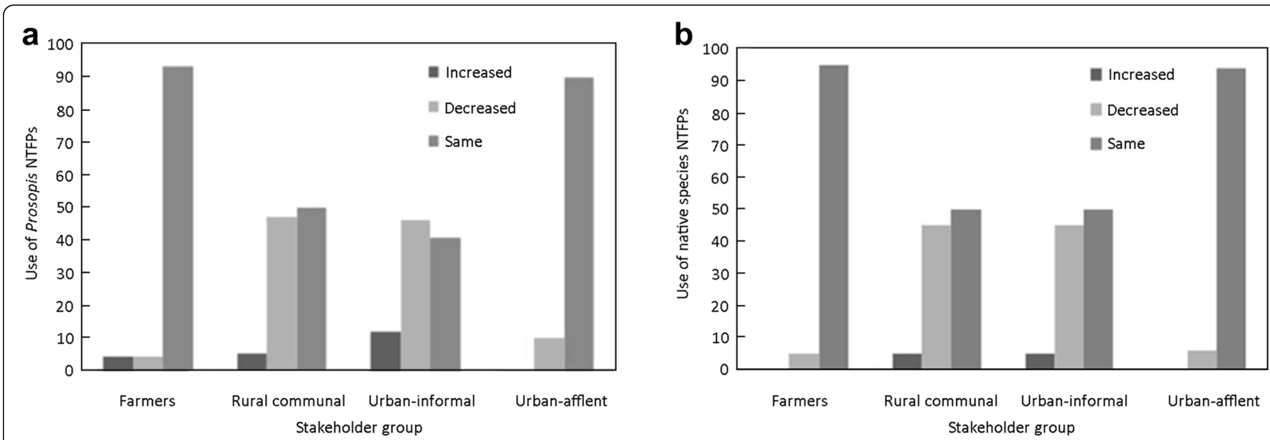

Fig. 4 A comparison of the use of (**a**) mesquite ($\chi^2 = 130.0$; $p < 0.0005$) and (**b**) native species ($\chi^2 = 111.5$; $p < 0.0005$) since the year 2000 in South Africa

produced larger boles, had smaller spines and were easier to harvest, and because there were perceptions that the smoke from mesquite was poisonous (A. Witt: unpublished data). This provides another example illustrating that native species are favoured over mesquite, and highlights that planting alien species is unlikely to replace the use of native species, or to protect them. The supply of pods (a novel resource) from mesquite was the main reason why a small percentage of respondents preferred mesquite over native trees. Mesquite fuelwood was also favoured not because of its quality but because it could more easily be accessed. This has been noted elsewhere; for example, wood from *A. mearnsii* was perceived to be of lower quality than native species in the Eastern Cape of South Africa, but because it was more abundant close to villages it was used more (Shackleton et al. 2007a). Different perceptions relating to the use of natural resources of invasive species therefore often relate to their abundance, proximity, novelty, social contexts, factors surrounding introductions, cultural preferences and the opportunity costs of not using them (Shackleton et al. 2007a; Kull et al. 2011).

Use patterns and perceptions

Most previous studies have assessed patterns of use within defined socio-economic groups (Twine et al. 2003; Shackleton et al. 2007c; Paumgarten and Shackleton 2009; Davenport et al. 2012; Thondhlana et al. 2012), and not between groups. Our study revealed that use patterns, methods of obtaining the resources, and use over time varied between stakeholders within different social-economic and land tenure contexts (Tables 2 and 3; Figs. 2, 3 and 4). We found that those living closer to invasions (farmers and people in rural communal land villages) mainly collected the NTFPs themselves, whereas people in urban areas relied more on purchasing these resources. People living in more rural areas also used a higher value of NTFPs compared to those in urban areas. Interestingly, the traditionally poorer stakeholders are moving away from use of fuelwood (Fig. 4) as they adopt alternative energy sources such as electricity, gas and paraffin. The decreasing reliance on natural products has also been highlighted in other parts of South Africa, and has been linked to increased electrification and increased incomes especially through state grants and pensions (Shackleton et al. 2013). However, other sources suggest that the use of NTFPs, especially on a commercial scale, is increasing in some areas (Twine 2005). Those in wealthier stakeholder groups still use similar amounts of NTFPs as there is a strong culture of using wood for barbequing.

Benefits vs. costs

Wise et al. (2012) estimated that mesquite invasions were providing a net benefit to local communities in South Africa, but that a net loss will result shortly as mesquite trees continue to spread. Although mesquite is providing about half of the farmers in the Northern Cape with a mean direct-use value R 2 000 per annum, the mean expenditure of farmers to control mesquite is over R 20 000 per farm per annum (Shackleton et al. 2015a). Mesquite invasions have also led to numerous other social, ecological and economic costs such as negative impacts on water, grazing potential, biodiversity and infrastructure that have not been fully valued (Ndhlovu et al. 2011; Dzikiti et al. 2013; Shackleton et al. 2015a, 2015c). This suggests that mesquite invasions in South Africa generate more costs than benefits. Some argue that mesquite invasions play a positive role in that they reduce the use and pressure on native trees (Food and Agriculture Organisation FAO 2004). However, mesquite invasions are having large-scale negative impacts on native tree population stability, abundance, density and mortality in South Africa (Schachtschneider and February 2013; Shackleton et al. 2015b, 2015c) and natives are still being harvested in preference to mesquite. Native trees will therefore decline as mesquite stands become more widespread and dense, possibly more so than as a result of direct harvesting. In Kenya, mesquite is negatively impacting populations of native species that supply specialised NTFPs, e.g., a palm (*Hyphaene compressa*) used for weaving and thatching (Stave et al. 2007).

Conclusion

This study, focussing on invasive mesquite species, illustrates the benefit of understanding the conflicts of interest caused by invasive species within the developing world, and how understanding natural resource use is important for informing policy and management. We suggest that similar studies in other parts of the world would help to highlight the relative values of the resources provided by invasive species and to determine whether invasive alien species provide any unique resources that may be affected by management. Our study has shown that people preferentially use native species over mesquite and are decreasing their reliance's on natural resources from trees in general. It also highlights that alternative native species are available, if mesquite was substantially reduced through more effective management. Current policy in South Africa is attempting to simultaneously maximise benefits and minimise harm, but this approach is likely to lead to growing negative impacts and continued spread. It would be better to base policy direction on overall net benefit or loss. Wise et al. (2012) predicted that a situation of net losses would arise soon, and that the magnitude of the net loss would grow rapidly as mesquite continues to spread. It would therefore appear to be better to adapt policy and treat mesquite as an undesirable invasive species everywhere (category 1), and consider using more damaging biological control agents (not only seed-attacking insects).

Competing interests
The authors declare that they have no competing interests.

Authors' contributions
All authors conceived the study. RTS collected the data, performed statistical analysis. All authors helped to draft manuscript. All authors read and approved the final manuscript.

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