
African Journal of Range & Forage Science

ISSN: 1022-0119 (Print) 1727-9380 (Online) Journal homepage: http://www.tandfonline.com/loi/tarf20

# Distribution of the invasive alien weed, Lantana camara, and its ecological and livelihood impacts in eastern Africa

Ross T Shackleton, Arne BR Witt, Winnifred Aool & Corin F Pratt

**To cite this article:** Ross T Shackleton, Arne BR Witt, Winnifred Aool & Corin F Pratt (2017) Distribution of the invasive alien weed, Lantana camara, and its ecological and livelihood impacts in eastern Africa, African Journal of Range & Forage Science, 34:1, 1-11, DOI: 10.2989/10220119.2017.1301551

**To link to this article:** http://dx.doi.org/10.2989/10220119.2017.1301551

Published online: 02 May 2017.

African Journal of Range & Forage Science 2017, 34(1): 1–11
Printed in South Africa — All rights reserved


AFRICAN JOURNAL OF
RANGE & FORAGE SCIENCE
ISSN 1022-0119 EISSN 1727-9380
http://dx.doi.org/10.2989/10220119.2017.1301551

# Distribution of the invasive alien weed, *Lantana camara*, and its ecological and livelihood impacts in eastern Africa

**Ross T Shackleton[1], Arne BR Witt[2], Winnifred Aool[3] and Corin F Pratt[4]**

[1] *Centre for Invasion Biology, Department of Botany and Zoology, Stellenbosch University, Stellenbosch, South Africa*
[2] *Centre for Agriculture and Biosciences International, Nairobi, Kenya*
[3] *National Agricultural Research Organisation, Kampala, Uganda*
[4] *Centre for Agriculture and Biosciences International, Egham, UK*
** Corresponding author, email: a.witt@cabi.org*

***Lantana camara* (lantana) is a major invasive shrub globally, impacting upon biodiversity, economies, ecosystem services, and driving socio-ecological change. The aim of this study was to determine the current and potential distribution of lantana in eastern Africa and its livelihood impacts in one region in Uganda. Data were collected by means of roadside surveys, and then compared with potential distributions based on ecoclimatic models. Household interviews were conducted to understand the impacts of lantana on local livelihoods. Lantana is currently widespread in eastern Africa, and has the potential to spread, especially in Tanzania. According to 40% of respondents, lantana reduced the amount of forage available to livestock by more than 50%, while one-third of those interviewed reported a 26–50% reduction in crop yields. Lantana invasions also cost individual households substantial amounts of money (US$400–500 per annum). Furthermore, lantana reduced the availability of natural resources, such as native medicinal plants, and hindered the movement of people and livestock. Based on the potential distribution of lantana, and its current impacts, we suggest that an integrated management strategy be developed and implemented, including the introduction of additional biological control agents to reduce the negative effects of lantana on local livelihoods.**

**Keywords:** eastern Africa, human well-being, *Lantana camara*, livelihoods, Uganda

## Introduction

Plant species have been moved out of their native ranges into new areas for centuries, both accidentally and intentionally. For example, many plants have been moved to new areas for agriculture, agro-forestry, and ornamental purposes, as well as unintentionally, often concealed in imported goods (Mack 2003). Some of these species naturalise, and a smaller proportion become invasive. Naturalised species are those that have established self-sustaining populations but that do not spread, whereas invasive species are those that have spread, often over substantial distances from where they have become naturalised (Blackburn et al. 2011) and are causing ecological or economic harm and/or having negative health impacts. The spread and dominance of invasive species within their new ranges often leads to negative impacts on people and the environment. Invasive species can, among other things, result in a loss of biodiversity, hinder or even prevent economic development, and reduce the goods and services provided by ecosystems (Pimentel 2002). Biological invasions are now seen as one of the key human-induced components of global change (Brook et al. 2008). Effective management needs to be implemented to prevent or inhibit the spread of established invaders into new areas, and to reduce their negative impacts where they are already widespread and abundant (van Wilgen et al. 2011). Without management, the threat posed by invasive species to people and the environment would be significantly worse. One of the major invasive species globally is *Lantana camara* L. *sensu lato* (Verbenaceae), hereafter referred to as 'lantana'.

### Lantana camara *as a global invader*

Lantana is a widespread and problematic invasive plant with negative effects in over 60 countries globally (Parsons and Cuthbertson 2001). It originates from tropical America and was commonly introduced to other countries around the world, mainly by British colonialists, as an ornamental and/or living fence (Kannan et al. 2013). It is now invasive in many parts of Africa, Asia and Oceania (Bhagwat et al. 2012). The distribution and density of lantana is still increasing in many parts of the world, even in areas where it has been present for many years (Day et al. 2003). Lantana is estimated to have invaded 5 million ha in Australia, 13 million ha in India and 2 million ha in South Africa and is continuing to spread in these countries (Bhagwat et al. 2012).

Lantana has many traits that make it a good invader, including all-year flowering and fruit production in many areas, especially if adequate moisture and light are available; adaptation to long-range dispersal by birds and some mammals; high establishment rates; the ability to coppice; poisonous leaves; high phenotypic plasticity; the ability to hybridise; vegetative reproduction; and allelopathy (Sharma et al. 2005; Priyanka and Joshi 2013). Where it invades, lantana produces dense thickets, which have a negative impact on biodiversity, livestock and people (Day et al. 2003). As the density of lantana increases, species richness decreases, probably as a result of the allelopathic effects and direct competition of this noxious weed (Gentle and Duggin 1998; Chatanga 2007; Bhagwat et al. 2012; Jevon and Shackleton 2015). In Australia, lantana has negative impacts on wildlife (Turner and Downey 2010) and is also highly toxic, contributing to the poisoning of livestock and other animals (Day et al. 2003). If present in croplands it reduces yields and impedes harvesting (Day et al. 2003).

Reliable information about the impacts of major weeds, such as lantana, is required to justify and guide their management (Shackleton et al. 2014). Although understanding of the impacts of invasive species on biodiversity and ecosystem functioning is growing, there is very little information about their impacts (both negative and positive) on human well-being, which is an aspect that this study seeks to address (Shackleton et al. 2007; García-Llorente et al. 2008). In this paper, we present information about the distribution of lantana in eastern Africa, and provide an account of its impacts on smallholder farmers who are largely dependent on natural resources.

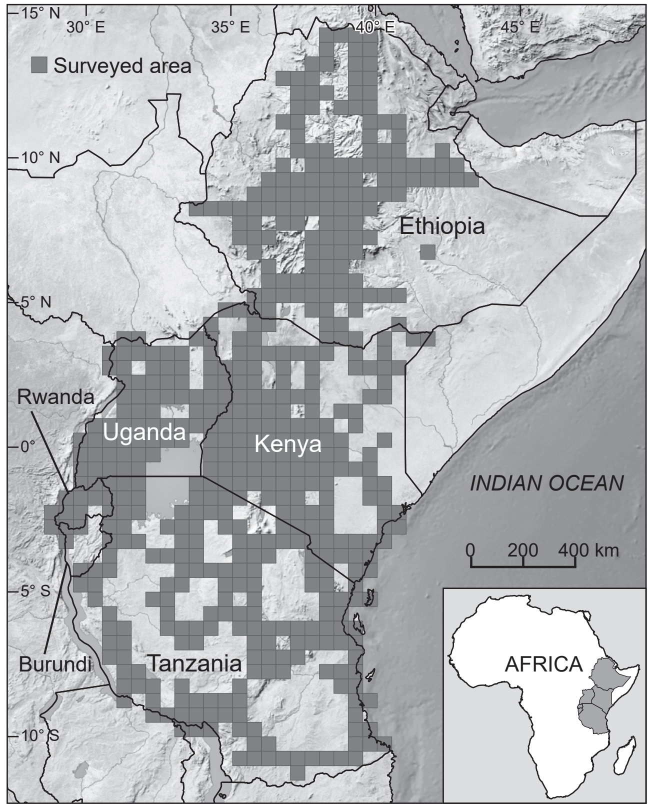


**Figure 1:** Map showing (in half-degree grid squares) the areas surveyed for *Lantana camara* in eastern Africa

## Methods

### *Distribution of* Lantana camara *in eastern Africa*

Broad-scale distribution mapping of naturalised and invasive plants was undertaken across eastern Africa (Figure 1) from 2008 to 2015, based on roadside surveys similar to those undertaken by Henderson (2007), Rejmánek et al. (2016), and Shackleton et al. (2016). Roadside surveys are a cost-effective way of producing a rapid and broad understanding of the distributions of invasive species, especially where current information is scarce or absent. During these roadside surveys, the presence and status of lantana was mapped in Ethiopia, Kenya, Tanzania, Rwanda and Uganda (Figure 2). Insecurity and poor road access in some parts of these countries also limited the extent of surveys.

The presence of invasive alien plants (including lantana) was noted in half-degree grid cells (~55 km × 55 km; Figure 1), but recorded presence does not imply full coverage, as the whole cell was not necessarily covered in the survey. It would also be extremely difficult and time consuming to record the exact location of every invasive plant seen, especially if it is growing some distance from the road. As such, coordinates, at or within 1 km, of each locality where lantana was found to be present, naturalised or invasive plants were recorded using a hand-held GPS unit (Figure 2). We also noted, in some but not all cases, whether the species was naturalised or invasive, as defined by Blackburn et al. (2011). We assumed that if lantana was not seen within a grid square during our surveys, that it was not present there. As such, it is therefore highly likely that we have under-represented the true distribution of lantana in eastern Africa.

Furthermore, we compared the current distribution of lantana, based on our regional surveys, with a CLIMEX ecoclimatic suitability map for lantana developed by Taylor et al. (2012). CLIMEX is used to assess the potential distribution of an organism based on climatic similarities between areas where an organism occurs, usually its natural or original distribution, and the area of interest, in this case eastern Africa. The climatic input data for the model were obtained from the native range of lantana in Central and South America, as well as from other areas where it had been introduced and become invasive in South Africa and Asia (Taylor et al. 2012). This model was then used to identify areas in eastern Africa that would be ecoclimatically suitable for lantana. We also overlaid maps of current and potential future distribution of lantana onto maps of the protected areas in eastern Africa (IUCN and UNEP-WCMC 2015) to illustrate the threats posed by lantana to biodiversity conservation in the region.

### *Socio-economic study site*

In order to assess the socio-economic consequences of invasion by lantana, we surveyed communities at a smaller scale in the districts of Masindi, Nakasongola and Nakaseke in central Uganda. These districts fall within the 'cattle corridor', a broad zone stretching from south-western to north-eastern Uganda, occupying about 44% of Uganda's total land area (Figure 3). The corridor supports about 90% of the national cattle population, mainly kept by pastoral and agro-pastoral communities (Rugadya n.d.). Many

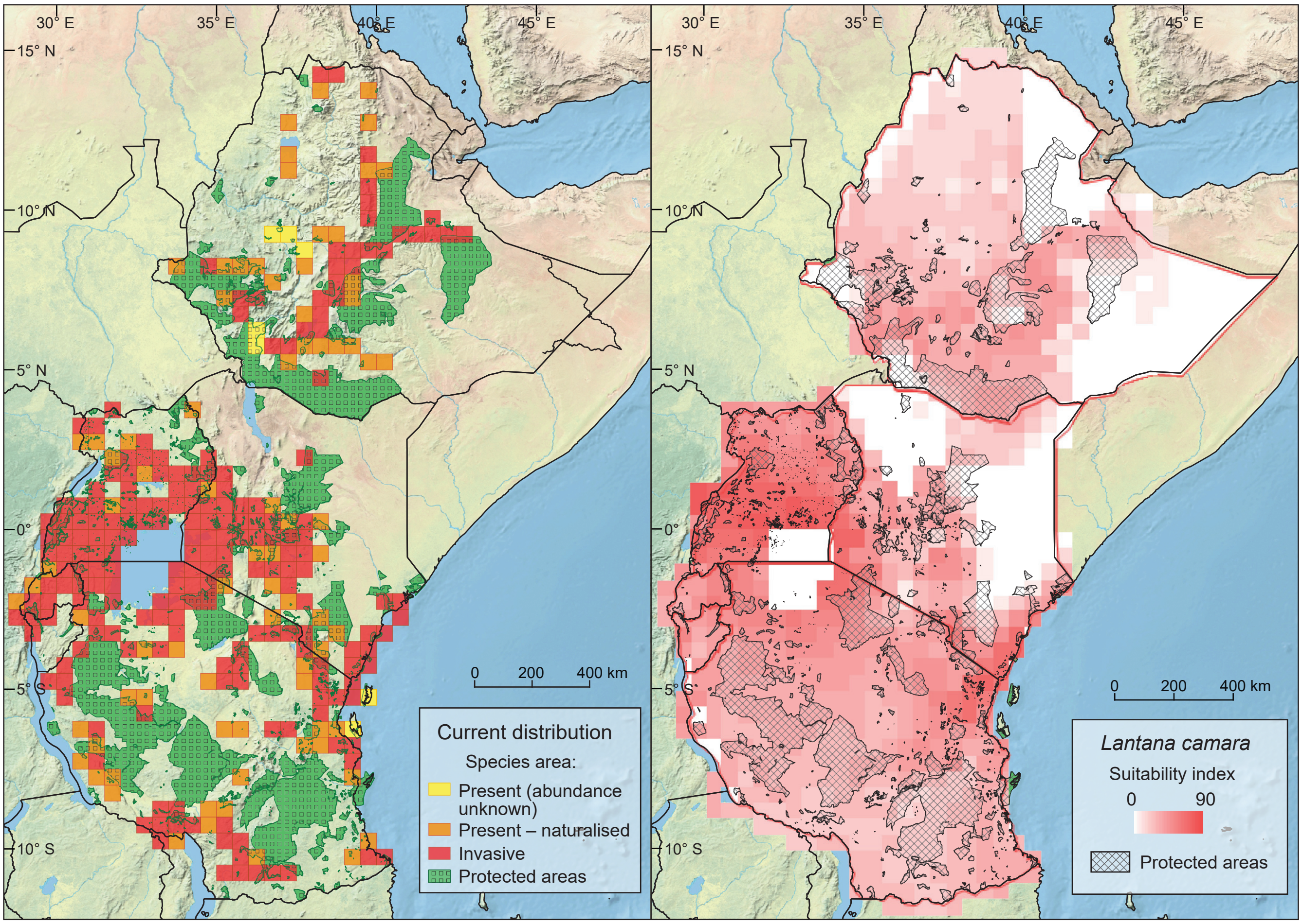


**Figure 2:** Map (left) showing the current distribution of *Lantana camara* in eastern Africa (~55 km × 55 km cells). Red grid cells indicate areas where lantana is invasive (widespread and/or abundant), orange cells where it was present and/or naturalised, and yellow cells where it was recorded with no other information. Protected areas are shown in green (IUCN and UNEP-WCMC 2015). The map (right) shows areas that are ecoclimatically suitable for the establishment of lantana based on a CLIMEX model developed by Taylor et al. (2012) with darker red areas being more suitable

households also practice subsistence cropping (Basalirwa et al. 2013). The area mainly consists of gentle rolling hills and plains and is characterised by dry grass savanna to dry thickets, receiving low and unreliable, but normally bimodal, rainfall (Basalirwa et al. 2013).

The area is characterised by overstocking, soil erosion, over-exploitation of plants, low-value grass species and exhausted soils (Mapairwe et al. 2008; NDC and NEMA 2008). Population densities in the area are below the national average, at 41 people km$^{-2}$ (UNDP 2005). Literacy rates are low, around 50%, with low development (Human Development Index of 0.483: ranked 163rd in the world) and high poverty levels (UNDP 2005).

### *Livelihoods survey on local knowledge and perceptions of* Lantana camara

We conducted interviews in 192 randomly selected households in areas with lantana invasions, using semi-structured questionnaires. Surveys were conducted in villages across the three Districts, to obtain a broad representation. All households on randomly selected roads in each village were interviewed with the help of a field assistant with local knowledge. The head of the household or next oldest member of the family was interviewed in their local language. The questionnaires had four sections that covered (1) demographics of the respondent, (2) aspects of his/her knowledge and perceptions about the introduction and spread of lantana, (3) perceptions and knowledge on the negative impacts and benefits of lantana with a particular focus on crop and pasture production and (4) perceptions and practices relating to the management of lantana.

## Results

### *Current and potential distribution of* Lantana camara *in eastern Africa*

Lantana is currently widespread and abundant in areas around Lake Victoria with smaller and localised invasions along the Kenyan coast and large patchy invasions in the foothills of the Ethiopian highlands (Figure 2). The current distribution of lantana largely confirms the potential distribution proposed by the CLIMEX model. For example, based on survey data, lantana was largely absent in northern and north-eastern Kenya, and in eastern Ethiopia, areas that do not match well with ecoclimatic variables suggested by the CLIMEX model to be ideal for the growth and proliferation of lantana (Figure 2). Furthermore, the CLIMEX model indicates that areas around Lake Victoria and along the Tanzanian and Kenyan coasts have very suitable climates, which corresponds to the presence of invasive populations found during roadside surveys. Unsuitable areas in northern Kenya and eastern Ethiopia receive rainfall of less than 500 mm $y^{-1}$. Although a large part of the Ethiopian highlands receives more than 1 500 mm $y^{-1}$, the presence of lantana there may be limited due to low night-time temperatures, which can drop to 5 °C.

Most of Tanzania and northern Uganda are currently uninvaded, but they would appear to be at risk of invasion, because their climates are suitable for the establishment and growth of lantana based on the CLIMEX model. Many protected areas in Uganda have already been invaded, to some degree, and most of those in Tanzania are at risk, including Ruaha National Park, and especially Selous Game Reserve (Figure 2). Since most of southern Tanzania receives rainfall of more than 1 000 mm $y^{-1}$ and experiences moderate temperatures, the climate suitability for invasions there is high. Saadani National Park, along the north-eastern coastline of Tanzania, is also likely to be invaded.

### *Socio-demographic characteristics of the surveyed households*

Of the 192 respondents interviewed, 69% were male, and the mean (±SD) age of respondents was 41 ± 14 years.


**Figure 3:** Map showing the location of Uganda in Africa (inset) and the three districts in Uganda where the socio-economic surveys were undertaken

Most respondents (75%) only had primary school education and the majority were farmers/pastoralists (93%). Households on average consisted of 9 ± 5 people. The vast majority (88%) of households owned livestock. The average (±SD) number of sheep and goats per household was 8 ± 14 (range 0–116) and the mean (±SD) number of cattle was 34 ± 51 (range 0–359), with 93% of respondents grazing their livestock on communal lands within 5 km of their homesteads. Most respondent households were also involved in crop production (85%). Primary crops grown included cassava (33%), maize (32%), sweet potato (16%) and beans (8%). Field sizes ranged between less than 1 ha to over 2.5 ha. Thirty percent of respondents had around 1 ha and 67% had between 1 and 2 ha.

### *Local knowledge on* **Lantana camara** *introduction and presence in Uganda*

All respondents knew what lantana was and what it looked like, with 99% reporting it as being present where they graze their livestock. Most (78%) respondents reported that it has been in their area for more than 10 years. The majority of respondents (95%) did not know why it was introduced, while 5% stated it was brought in as a hedge plant. Locals were of the opinion that lantana was still spreading, with 92% stating that it was increasing in density and extent, while 7% reported that it had decreased in their local area. Respondents reported that it was particularly prevalent around homesteads and nearby grazing lands, along roads, around livestock enclosures, and to a lesser extent near water bodies (rivers, dams and lakes) and in croplands (Figure 4). Invasions in the latter were probably less because farmers are more likely to manage weeds in croplands than elsewhere.

### *Costs and benefits of* **Lantana camara** *invasions*

*General impacts*

Based on comments made by community members, lantana has a significant negative impact on livelihoods

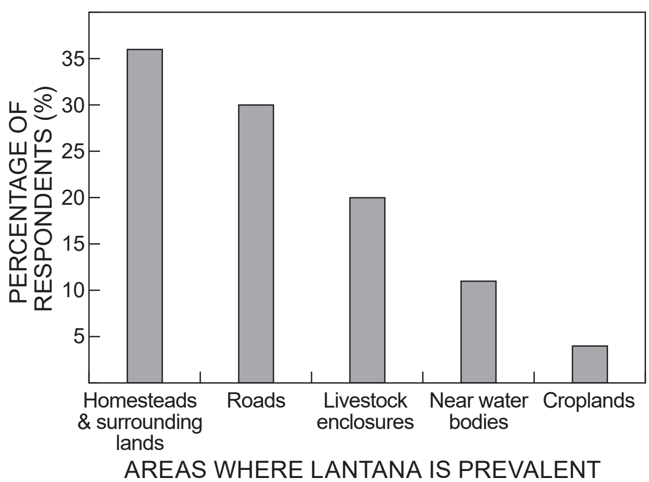


**Figure 4:** Local perceptions of the areas with most prevalent *Lantana camara* invasions. Also an indication of the effectiveness of various management interventions, especially in croplands, and the lack thereof in communal rangelands

**Box 1:** Quotes from villagers on the impacts of *Lantana camara* invasions in Uganda

1. "Lantana is not only a problem to crop production and animals, it is also a big problem to us humans as well. Look at my skin, I have a bruised skin all year round." Local villager in Kirinda village, Nakasongola District.

2. "I have to cut down lantana every three months; if I do not, even my doorstep will be covered in this weed. I am so exhausted I feel like running away from my land." Local villager in Nakasongola District.

3. "I am a victim of lantana in many ways. I used to live in Kagonji village years back but I had to find land here, and relocate my family because my previous land was totally covered in lantana. We had no farmland, grazing land or space for my grandchildren to play. I even feel ashamed telling people that I ran away because of lantana." Local villager in Nakaseke District.

4. "My father sold off most of this land and left just a small piece where the house stands. The land was completely invaded by lantana. In fact, he left and bought a small piece of land 10 km from here. He left us here to see if we can manage to live with these lantana infestations. We are almost giving up ourselves." Local villager in Kamunina village, Nakasongola District.

5. "If the tiny sepals of lantana fall in your eyes, you will only be saved from going blind by a doctor. I think that is why 20 of our cows are blind." Local villager in Kaleire village, Nakasongola District.

6. "I own more than 10 acres of land but live as if I have only 2 acres. The land has become so small because the bulk of it has been rendered useless by lantana infestations." Local villager in Kyeyidula village, Kakoge Sub-county, Nakasongola District.

7. "No crop can out-compete lantana, in fact deforestation is the major reason for the proliferation of lantana in this area. Only those big trees could stand tall against this invader." Village chairman in Nakaseta village, Kakoge Sub-county, Nakasongola District.

(see Box 1). Respondents felt strongly that lantana invasions reduced the presence of grasses and shrubs (over 90%) which in turn reduces grazing potential (Table 1, Figure 5) for livestock and wildlife. Furthermore, respondents also said that lantana reduced the availability of, and access to, useful native plants, including valuable medicinal plants, firewood, and plants used in the building of homes and other structures. This is an indication that lantana has negative impacts on plant abundance and diversity, which may also impact on wildlife. Most respondents (79%) said that lantana did have negative effects on wildlife, but some said that the lantana berries benefited birds. Over 95% of respondents felt that lantana also hindered the movement of people and livestock. Dense lantana stands blocked paths and roads, limited access to fields and grazing lands, even making some areas totally inaccessible.

*Negative impacts on livestock and agriculture*

Respondents reported that lantana displaced valuable forage species, hindered stock movement and poisoned their animals (Table 1). Forty percent of respondents reported that lantana had invaded 50–70% of their grazing land. The majority (>90%) said it harmed (poisoned) cattle and sheep. However, 74% said it had no impact on goats. The primary negative effects for livestock included stomach problems, the loss of hair, reduced fecundity, weight loss and general sickness, in some cases leading to death. On average (±SD), households are losing 9 ± 17 livestock per year as a result of lantana invasions, which amounts to a 20% loss in herd size annually, assuming that there is no herd replenishment in that time. It was also reported to have negative effects on crop production, reducing yields of primary crops (maize and cassava) by 26–50% for 40% of respondent households, if not managed effectively (Figure 6). Half of respondents also reported that due to the negative effects on livelihoods, it had resulted in some families having to relocate (Table 1, Box 1).

**Table 1:** Negative and positive impacts of *Lantana camara* invasions on people and the environment (percentage of respondents)

| Impacts of lantana | Negative impacts/ costs | Positive impacts/ benefits | No effect/ don't know |
|---|---|---|---|
| Grass | 99 | 1 | 0 |
| Shrubs | 91 | 9 | 0 |
| Trees | 19 | 0 | 81 |
| Wildlife | 79 | 21 | 0 |
| Useful plants | 98 | 0 | 2 |
| Water | 4 | 0 | 96 |
| Movement | 99 | 0 | 1 |
| Cattle health | 87 | 0 | 13 |
| Sheep health | 86 | 0 | 14 |
| Goat health | 26 | 0 | 74 |
| Drive human relocation | 51 | 0 | 49 |
| Fuelwood | 0 | 16 | 84 |
| Green manure | 0 | 11 | 89 |
| Medicinal plant | 0 | 10 | 90 |
| Hedge plant | 0 | 5 | 95 |

*Benefits*

The majority (57%) of people said lantana was not useful at all. However, a minority of respondents did report they used it as fuelwood (16%), for green manure (11%), and as a medicinal plant (10%), and very few used it for hedging (5%) (Table 1). As mentioned, some (21%) said that lantana benefited wildlife, especially birds that eat the berries.

***Management of* Lantana camara**

Three-quarters of respondents actively managed lantana in grazing lands and all respondents managed it in croplands

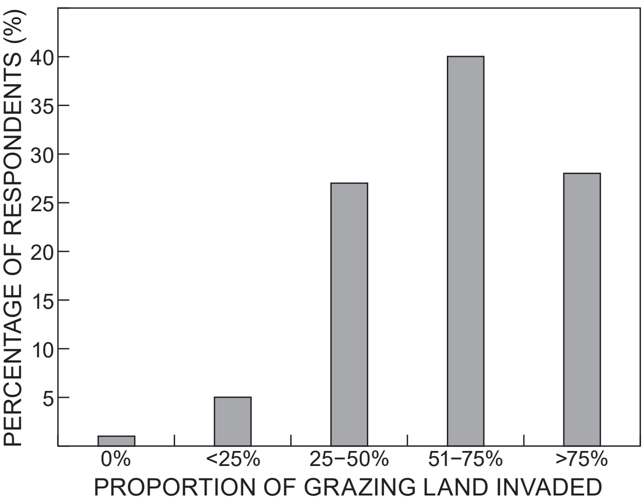


**Figure 5:** Respondents perception on the amount of grazing land invaded by *Lantana camara* invasions

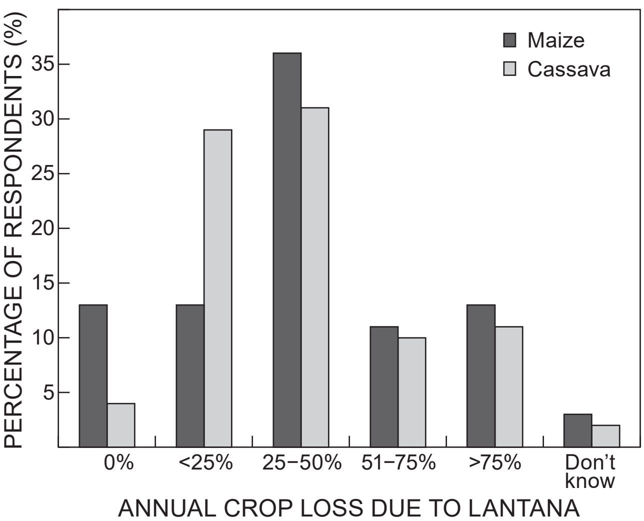


**Figure 6:** Perceptions of local respondents on annual crop losses in maize and cassava as a result of *Lantana camara*

(Table 2). In grazing lands, all respondents slashed lantana in an *ad hoc* manner and 45% also burnt it. In fields, the majority of respondents (over 80%) slashed and hoed lantana, in order to remove it from their fields, while 38% also hand-pulled smaller plants. Respondents did report that invasions were lowest in croplands (see Figure 4), an indication that management interventions in these areas were more effective. Of the people controlling lantana, over 95% said it took them, on average, one week per year to manage it in their fields, with 80% of respondents saying that more than four people assisted them in removing it from their croplands during this time. Sixty-six percent of households paid people to control lantana in their croplands at a cost of US$400–500 per household per year, based on the daily wage rate and the number of labour days reported by the respondent. Overall, 80% of households did not use herbicides in their fields, primarily due to the cost, whereas the remaining households, who did use herbicides, spent approximately US$500 per year. Over 90% of respondents mentioned that if they did not control lantana they would expect crop losses to be between 75% and 100%. All respondents felt strongly that their lives would be better if lantana was not present; even those who had some uses for lantana felt that the negative impacts were greater than the benefits and that native species, displaced by lantana, are more useful.

**Table 2:** Local respondents' practices with regard to the management of *Lantana camara* in rangelands and croplands

| Management of lantana | Respondents (%) |
|---|---|
| Control in rangelands (% yes) | 75 |
| Burn | 40 |
| Slash | 75 |
| Herbicides | 2 |
| Control in croplands (% yes) | 100 |
| Hand pull | 38 |
| Hoe | 96 |
| Slash | 92 |
| Plough | 8 |
| Herbicides | 7 |

## Discussion

### Lantana camara *occurrence*

The field surveys and questionnaires indicate that lantana is widespread in eastern Africa and imposes substantial negative impacts on people and the environment (Table 1, Figures 2, 5 and 7). Furthermore, it has the potential to spread even further within eastern Africa (Figure 2), which would compound the negative impacts recorded so far. Lantana is adapted to grow over a wide range of warm temperate, subtropical and tropical climates (Gujral and Vasudevan 1983), which is why it does so well in most of eastern Africa, especially Uganda. The only factor that appears to be limiting its distribution is low rainfall in the north and north-east of Kenya and eastern Ethiopia, while low temperatures probably inhibit its ability to establish in much of the Ethiopian highlands. Lantana is known to grow best in areas where there is regular rainfall or where soil moisture is available (Swarbrick et al. 1998), but it will not grow well in areas where the temperature drops below 5 °C (Winder 1980).

### *Impacts of* Lantana camara

The majority of poor people in Africa's rural areas are dependent on crop and animal agriculture and other natural resources to support their livelihoods. In Uganda, over 90% of the population is directly or indirectly dependent on agriculture, fisheries, forests, wetlands and other natural resources, which account for 85% of export earnings, with more than 80% of the workforce actively involved in agricultural activities. Most rural households in Africa utilise native plant species for food, medicine, craft, grazing, construction, brewing, commerce, propping and cultural purposes (Eilu et al. 2003). Livestock also play an important role in sustaining rural communities. In Uganda, livestock are ranked as the second or third most important livelihood

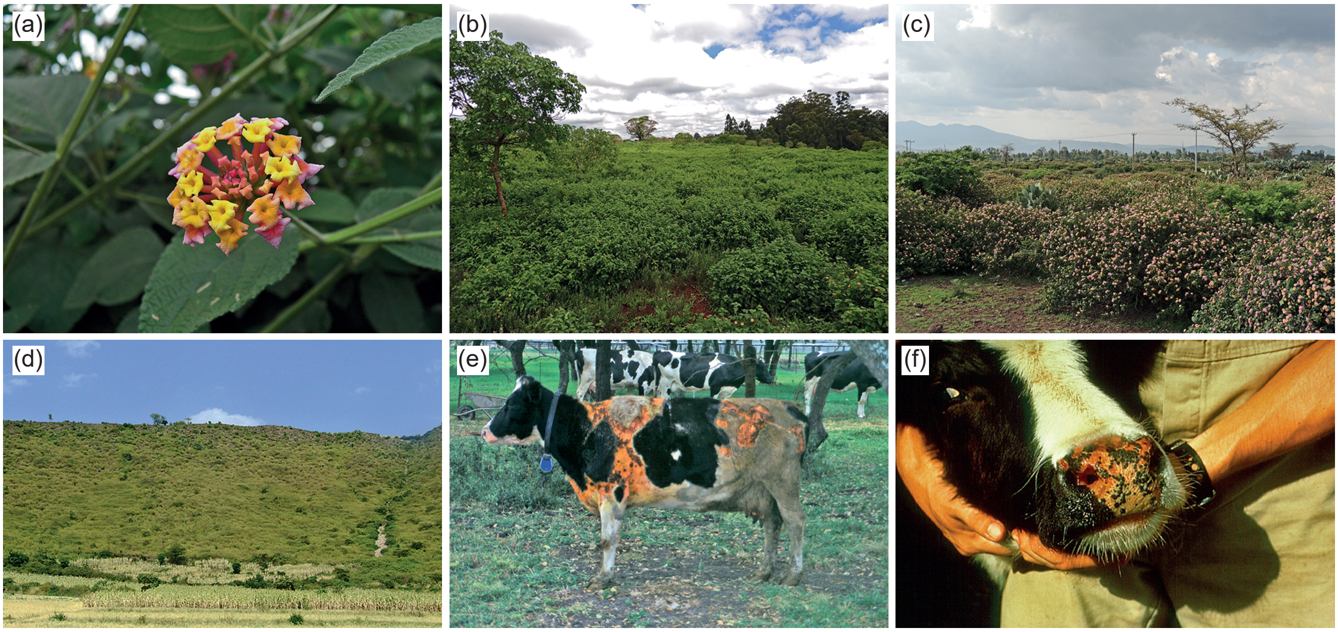


**Figure 7:** (a) *Lantana camara* inflorescence and leaves, (b) *Lantana camara* infestation in Kenya, (c and d) *Lantana camara* invasions in Ethiopia, and (e and f) photosensitivity in cattle that have ingested *Lantana camara*. Photo credits: a–d (ABRW); e (MD Day); and f (Queensland Department of Primary Industries)

source for rural households (Ellis 2000; MAAIF et al. 2010). They provide food and nutrition, work, transport, soil fertility, and economic and social status (Ellis and Freeman 2004; Randolph et al. 2007). In cropping areas, larger animals are not only used for transportation but also draught power for almost a quarter of the total area under crop production worldwide (Devendra 2010). Livestock are also used as 'living savings accounts' because the majority of rural poor don't have access to financial markets, including banks (Freeman et al. 2007). A host of factors have been implicated in the erosion of natural resources on which many of the rural poor in Uganda depend, with the exception of invasive plants.

The findings of this study clearly highlight that lantana invasions have negative effects on rural livelihoods in Uganda, by eroding the natural resource base on which many people depend. The impacts of lantana, as described by those community members interviewed, are supported by the results of scientific studies, which indicate that lantana invasions, among others, have a negative impact on biodiversity, crop and pasture production, and animal health (Day et al. 2003).

Lantana has a negative impact on plant diversity and abundance, by suppressing native vegetation through allelopathy and competition for resources (Gentle and Duggin 1998; Chatanga 2007; Bhagwat et al. 2012; Jevon and Shackleton 2015). In Australia, it is estimated that 275 native plant species are threatened by the presence of this noxious weed (Turner and Downey 2010). There is also growing evidence that lantana has a negative effect on non-timber forest products in India, reducing the abundance of wild bamboos, palms and wild foods through competition (Kent and Dorward 2015). A study in Queen Elizabeth National Park, Uganda, found that lantana reduces the abundance of herbs and grass species, and has a negative effect on the diversity of shrub species (Atuhe 2010).

A reduction in native forage species, as a result of lantana invasions, also contributes to a dramatic decline in livestock carrying capacities (Table 1; Figure 5). In Australia, landowners, incur losses of, on average, US$25.7 $ha^{-1}$ $y^{-1}$ as a result of reduced rangeland productivity (Page 2007). This is exacerbated by the fact that lantana is highly toxic to livestock if consumed (Figure 7). Ingestion of lantana by livestock can cause liver, kidney and gall bladder damage, dehydration and hepatogenous photosensitivity (Black and Carter 1985; Kellerman and Coetzer 1985; Ide and Tutt 1998). Raw photosensitised areas are susceptible to blowfly maggots and bacterial infections, contributing to ill-health. Although respondents in Uganda were in agreement that lantana was toxic to sheep and cattle, many were of the opinion that consumption of lantana by goats did not result in ill-health or death. This is contrary to findings in Kenya, where a number of calves, sheep and East African goats, on zero-grazing, were poisoned when inadvertently exposed to lantana (Munyua et al. 1990). Similar reports from Zimbabwe (Obwolo et al. 1990) and South Africa (Ide and Tutt 1998) have confirmed that lantana is toxic to goats. However, it is postulated that different *L. camara* varieties have different toxin levels (MD Day, Queensland Biosecurity, pers. comm., 2016), which may explain this anomaly. Other than reducing livestock carrying capacities and poisoning livestock, dense thickets of lantana also hinder the movement of livestock and people in Uganda, which has also been documented as a major issue in India and South Africa (Jevon and Shackleton 2015; Kent and Dorward 2015), and has similarly been noted for the invasive shrub *Chromolaena odorata* (Asteraceae) in Tanzania (Shackleton et al. 2016).

A reduction in plant diversity, species composition and vegetation structure can also impact on native animal species. This is supported by our study where most community members reported a reduction in wildlife. It is estimated that in Australia, 24 native animal species are threatened by the presence of lantana (Turner and Downey 2010). There is also evidence suggesting that lantana negatively affects elephant habitats in Asia and reduces bird diversity (Aravind et al. 2010; Wilson et al. 2013), which could have significant negative impacts on tourism. Lantana alters ecosystem processes, such as soil nutrient cycling, and changes fire regimes in natural systems, increasing fire intensities and frequency and facilitating fire penetration into habitats that rarely, if ever, burn, such as woodlands and forests (Day et al. 2003; Hiremath and Sundaram 2005; Berry et al. 2011; Ruwanza and Shackleton 2016).

Lantana also has a negative impact on crop production in Uganda, reducing yields of primary crops by 26–50% according to 40% of households interviewed. It is well known that lantana has the ability to outcompete crops, reduce yields and impede harvesting, and harbours crop pests (Day et al. 2003; Sharma et al. 2005; Sharma et al. 2007; Priyanka and Joshi 2013; GISD 2016). Lantana is especially problematic in perennial crops such as coconuts, oil palms, rubber, bananas, citrus, tea and timber plantations (Day et al. 2003; Sharma et al. 2005). This is similar to what has been reported for other invasive shrubs in East Africa, such as *C. odorata* (Shackleton et al. 2016).

Lantana also has other negative social-ecological impacts not mentioned by communities in this study, including increased fire risk, negative impacts on tourism, increased management stress for locals, and decreased aesthetic beauty of landscapes (Page 2007). This study highlights the fact that lantana has limited benefits or uses for a small number of households with much greater costs (Table 1). However, some communities in India are substituting the use of bamboos and other non-timber forest products with lantana, mainly because native plant species have decreased in abundance due to over-utilisation and displacement by lantana itself (Kannan et al. 2014). Despite an over-abundance of lantana, its utilisation is not contributing to an improvement of the lives of those communities affected by invasions, in comparison to those that don't utilise this noxious weed (Kannan et al. 2014).

Although the overall financial costs of lantana invasions, in terms of livestock production, have not been determined for all of Uganda, or more broadly for the eastern African region, they are expected to be substantial, based on data from elsewhere. For example, in Australia, lantana has invaded approximately 2.2 million ha of grazing land, costing the economy US$137.6 million per annum through lost production, livestock loss and sickness. A further US$22.57 million per annum is spent on control costs to reduce the negative impacts (Page 2007). An invasive shrubby vine in Tanzania, *C. odorata*, induced costs of around US$500 per household per year due to livestock death, loss of crops and grazing potential (Shackleton et al. 2016).

### *Management of* Lantana camara

Despite substantial control efforts at a global level, including the use of fire, physical removal, chemical and biological control or a combination of these and other methods, lantana continues to spread in many areas, with further associated costs (Bhagwat et al. 2012). Local communities in Uganda are making an effort to manage lantana, however, it seems to be spreading and could invade significantly more land across eastern Africa (Figure 2). According to the invasive species and livelihoods framework of Shackleton et al. (2007), lantana, based on this Ugandan case study, can be categorised as an undesirable, strongly competitive weed. This means that as it spreads costs will rise, increasing the vulnerability of local communities. This highlights the fact that management efforts need to be improved and better coordinated to prevent further negative impacts on people and the environment and reduce spread into uninvaded areas so local communities are not subjected to these negative impacts.

Despite the pessimism expressed by Bhagwat et al. (2012), that lantana control is a 'battle lost', there have been numerous successes in the management of lantana (Swarbrick 1986; Day et al. 2003; Babu et al. 2009; Witt et al. 2012), an indication that coordinated national and regional approaches to control can be effective. For example, van Wilgen et al. (2012) estimated that a combination of mechanical, chemical and biological control reduced the lantana invasion in South Africa by 50%, albeit at a substantial cost, with over US$17.8 million being spent between 1995 and 2008. The greatest benefits have accrued from biological control, with a benefit:cost ratio of 34:1 (van Wilgen et al. 2004), and this is prior to the introduction and establishment of additional effective and host-specific agents. However, at a global level, biological control of lantana has had mixed successes, with no one agent providing substantial control over large areas and many failing to establish (Broughton 2000; Zalucki et al. 2007). In South Africa, 13 biological control agents have established, but control is variable across the numerous varieties or biotypes that are present (van Wilgen et al. 2012) because biological control agents show preferences for one or more biotypes (Day et al. 2003). This is probably why biological control of lantana has been so successful in Hawaii and the Solomon Islands, where only one lantana variety is present (Day et al. 2003).

In South Africa, two agents, *Aceria lantanae* Cook (Eriophyidae) and *Ophiomyia camarae* Spencer (Agromyzidae) are improving control in frost-free areas on some varieties of lantana (Urban et al. 2011); *Telonemia scrupulosa* Stål (Tingidae) has provided good control in subtropical regions and *Uroplata girardi* Pic (Chrysomelidae) has been beneficial in coastal areas (Baars and Neser 1999), with other agents providing negligible control or appearing to have an impact at a few sites only. In Australia, *Teleonemia scrupulosa*, *Calycomyza lantanae* (Frick) (Agromyzidae), *Uroplata girardi* and *Octotoma scabripennis* Guérin-Méneville (Chrysomelidae) have become abundant and are controlling lantana invasions to some extent, by reducing their photosynthetic potential and as a result also impacting on flower and fruit production (Day and Neser 2000). Most recently, there has also been increased damage by *Ophiomyia camarae* and *Falconia intermedia* Distant (Miridae) in northern Queensland, Australia (MD Day, Queensland Biosecurity, pers. comm., 2016).

Factors such as climatic mismatches, issues with mass rearing and parasitism of released agents have largely hindered highly effective biological control of this noxious weed in South Africa and elsewhere (Urban et al. 2011). However, there have been some obvious successes, with some agents significantly reducing the spread and density of lantana wherever they have established. At a global level, biocontrol may have been more successful, but the lack of concerted long-term efforts and sustainable funding has often resulted in the release of suboptimal agents: agents that were easier to test and mass rear and not necessarily the most damaging. In addition, in Uganda, no official releases of biocontrol agents for the control of lantana have been made in the last 50 years, despite the availability of some effective agents in South Africa and Australia.

Although control through utilisation and acceptance of areas dominated by this weed as novel ecosystems has been touted (Bhagwat et al. 2012; Kannan et al. 2014), it will not provide respite to those communities affected by this weed. Lantana is a low-value plant, with very few worthwhile or profitable uses; it is obvious that the costs of invasions, as shown in this study, far outweigh any benefits that may accrue from its use. It also needs to be recognised that the supply of lantana far exceeds demand and, as such, this is not a viable or effective management strategy at the landscape level (Kannan et al. 2016). Utilisation, as a management strategy on its own or in isolation, is highly controversial in relation to other control approaches (Shackleton et al. 2014) and should not be promoted for lantana in eastern Africa.

To ensure human well-being and biodiversity conservation through control of lantana, concerted efforts need to be made to build additional awareness of the negative effects of lantana in this region. This should include further research, as has been done in Australia, on the losses to grazing and impacts on crop production (Page 2007) and biodiversity (Turner and Downey 2010). In addition, research into the development and implementation of best management practices, appropriate for conditions in eastern Africa, needs to be undertaken. Countries in the region also have to consider introducing additional biological control agents; agents that have been released elsewhere and have proven themselves to be effective. Related to this, renewed efforts, at a global level, to initiate additional research on potential biological control agents would be beneficial; a well-funded programme extending over 10–20 years could lead to the selection of more effective agents, which once established, could offer long-term and sustainable control.

In order to be more effective in our efforts to manage lantana in eastern Africa, we need to develop and implement coordinated national and regional integrated management strategies, which need not only include biological control, but also programmes to increase awareness and develop capacity. In most cases, it is not the control interventions that are flawed, but rather the inability of people to implement them effectively. If we fail to implement long-term strategies for the control of lantana in the region, its ongoing spread will lead to further biodiversity loss and increased poverty levels. Conflict over access to natural resources is bound to increase as the natural resource base on which millions of people depend is eroded by lantana invasions.

*Acknowledgements* — We acknowledge support from the DST–NRF Centre of Excellence for Invasion Biology (CIB). During the writing of the paper ABRW was supported as a CIB Fellow. RTS acknowledges additional support from Stellenbosch University through 'Consolidoc' funding through the office of the Vice Rector: Research, Innovation and Postgraduate Studies. Preparation of this paper was partially funded by the CABI Development Fund, which is supported by contributions from the Australian Centre for International Agricultural Research, Australia, the UK's Department for International Development, and others. The JRS Biodiversity Foundation provided support for the invasive plant surveys and production of the distribution maps, which were produced by Tim Beale. Baseline data for the development of the CLIMEX map was provided by Andrew McConnachie. Michael Day kindly reviewed previous drafts.

## References

Aravind NA, Rao D, Ganeshaiah, KN, Shaanker RU, Poulsen JG. 2010. Impacts of the invasive plant, *Lantana camara*, on bird assemblages in Male Mahadeshwara Reserve Forest, South India. *Tropical Ecology* 51: 325–338.

Atuhe G. 2010. The distribution of *Lantana camara* and its impact on plant species diversity in Queen Elizabeth National Park. MSc thesis, Makerere University, Uganda.

Baars JR, Neser S. 1999. Past and present initiatives on the biological control of *Lantana camara* (Verbenaceae) in South Africa. *African Entomology Memoir* 1: 21–33.

Babu S, Love A, Babu CR. 2009. Ecological restoration of lantana-invaded landscapes in Corbett Tiger Reserve, India. *Ecological Restoration* 27: 467–477.

Basalirwa NA, Majaliwa JGM, Otim-Nape W, Okello-Onen J, Rubaire-Akiiki C, Konde-Lule J, Ogwal-Byenek S. 2013. Nature and dynamics of climate variability in the Uganda cattle corridor. *African Journal of Environmental Science and Technology* 7: 770–782.

Berry ZC, Wevill K, Curran TJ. 2011. The invasive weed *Lantana camara* increases fire risk in dry rainforests by altering fuel beds. *Weed Research* 51: 525–533.

Bhagwat SA, Breman E, Thekaekara T, Thornton TF, Willis KJ. 2012. A battle lost? Report on two centuries of invasion and management of *Lantana camara* L. in Australia, India and South Africa. *PLoS ONE* 7: e32407.

Black H, Carter RG. 1985. Lantana poisoning of cattle and sheep in New Zealand. *New Zealand Veterinary Journal* 33: 136–137.

Blackburn TM, Pyšek P, Bacher S, Carlton JT, Duncan RP, Jarošík V, Wilson JRU, Richardson DM. 2011. A proposed unified framework for biological invasions. *Trends in Ecology and Evolution* 26: 333–339.

Brook BW, Sodhi NS, Bradshaw CJA. 2008. Synergies among extinction drivers under global change. *Trends in Ecology and Evolution* 23: 453–460.

Broughton S. 2000. Review and evaluation of lantana biocontrol programs. *Biological Control* 17: 272–286.

Chatanga P. 2007. Impact of the invasive alien plant species, *Lantana camara* (L.) on native vegetation in northern Gonarezhou National Park, Zimbabwe. MSc thesis, University of Zimbabwe, Zimbabwe.

Day MD, Neser S. 2000. Factors influencing the biological control of *Lantana camara* in Australia and South Africa. In: Spencer NR (ed.), *Proceedings of the X International Symposium on Biological Control of Weeds, 4–14 July, Montana State University, Bozeman, Montana, USA*. Bozeman: Montana State University. pp 897–908.

Day MD, Wiley CJ, Playford J, Zalucki MP. 2003. *Lantana: current management, status and future prospects. ACIAR Monograph* no. 102. Canberra: Australian Centre for International Agricultural Research.

Devendra C. 2010. *Small farms in Asia: revitalising agricultural production, food security and rural prosperity*. Kuala Lumpur: Academy of Sciences Malaysia.

Eilu G, Obua J, Tumuhairwe JK, Nkwine C. 2003. Traditional farming and plant species diversity in agricultural landscapes of south-western Uganda. *Agriculture, Ecosystems and Environment* 99: 125–134.

Ellis F. 2000. *Rural livelihoods and diversity in developing countries*. New York: Oxford University Press.

Ellis F, Freeman HA. 2004. Rural livelihoods and poverty reduction strategies in four African countries. *Journal of Development Studies* 40(4): 1–30.

Freeman AH, Thornton PK, van de Steeg JA, McLeod A. 2007. Future scenarios of livestock systems in developing countries. In: Rosati A, Tewolde A, Mosconi C (eds), *Animal production and animal science worldwide. WAAP Book of the Year 2006*. Wageningen: Wageningen Academic Publishers. pp 219–232.

García-Llorente M, Martín-López B, González JA, Alcorlo P, Montes C. 2008. Social perceptions of the impacts and benefits of invasive alien species: implications for management. *Biological Conservation* 141: 2969–2983.

Gentle CB, Duggin JA. 1998. Interference of *Choricapia leptopetala* by *Lantana camara* with nutrient enrichment in mesic forests on the central coast of NSW. *Plant Ecology* 136: 205–211.

GISD (Global Invasive Species Database). 2016. Species profile: *Lantana camara*. Available at http://www.iucngisd.org/gisd/species.php?sc=56 [accessed 10 December 2016].

Gujral GS, Vasudevan P. 1983. *Lantana camara* L., a problem weed. *Journal of Scientific and Industrial Research* 42: 281–286.

Henderson L. 2007. Invasive, naturalised and casual alien plants in southern Africa: a summary based on the South African Plant Invaders Atlas (SAPIA). *Bothalia* 37: 215–248.

Hiremath AJ, Sundaram B. 2005. The fire-lantana cycle hypothesis in Indian forests. *Conservation and Society* 3: 26–42.

Ide A, Tutt CLC. 1998. Acute *Lantana camara* poisoning in a Boer goat kid. *Journal of South African Veterinary Association* 69: 30–32.

IUCN (International Union for Conservation of Nature and Natural Resources) and UNEP-WCMC (United Nations Environment Programme's World Conservation Monitoring Centre). 2015. The World Database on Protected Areas (WDPA). Available at http://www.protectedplanet.net [accessed 20 October 2016].

Jevon T, Shackleton CM. 2015. Integrating local knowledge and forest surveys to assess *Lantana camara* impacts on indigenous species recruitment in Mazeppa Bay, South Africa. *Human Ecology* 43: 247–254.

Kannan R, Shackleton CM, Krishanan S, Shaanker RU. 2016. Can local use assist in controlling invasive alien species in tropical forests? The case of *Lantana camara* in southern India. *Forest Ecology and Management* 376: 166–173.

Kannan R, Shackleton CM, Shaanker U. 2013. Reconstructing the history of introduction and spread of the invasive species, *Lantana*, at three spatial scales in India. *Biological Invasions* 15: 1287–1302.

Kannan R, Shackleton CM, Shaanker RU. 2014. Invasive alien species as drivers in social-ecological systems: local adaptations towards use of *Lantana* in southern India. *Environmental Development and Sustainability* 16: 649–669.

Kellerman TS, Coetzer JAW. 1985. Hepatogenous photosensitivity diseases in South Africa. *Journal of Veterinary Research* 52: 157–173.

Kent R, Dorward A. 2015. Livelihood responses to *Lantana camara* invasion and biodiversity change in southern India: application of an asset function framework. *Regional Environmental Change* 15: 353–364.

MAAIF (Ministry of Agriculture, Animal Industry and Fisheries, Uganda), Uganda Bureau of Statistics, Food and Agriculture Organization of the United Nations, International Livestock Research Institute, and World Resources Institute. 2010. *Mapping a better future: spatial analysis and pro-poor livestock strategies in Uganda*. Washington, DC: World Resources Institute.

Mack RN. 2003. Global plant dispersal, naturalization, and invasion: pathways, modes and circumstances: In: Ruiz GM, Carlton JT (eds), *Invasive species: vectors and management strategies*. Washington, DC: Island Press. pp 3–30.

Mpairwe D, Mutetikka D, Kiwuwa GH, Owoyesigire B, Zziwa, Peden D. 2008. Options to improve livestock-water productivity (LWP) in the cattle corridor within the White Nile sub-basin in Uganda. In: Humphreys E, Bayot RS, van Brakel M, Gishuki FN, Svendsen M, Wester P, Huber-Lee A, Cook S, Douthwaite B, Hoanh CT, Johnson N, Nguyen-Khoa S, Vidal A, MacIntyre I, MacIntyre R (eds), *Fighting poverty through sustainable water-use*, vol. II. Colombo: CGIAR Challenge Program on Water and Food. pp 61–64.

Munyua SJM, Njenga MJ, Karitu TP, Kimoro C, Kiptoon JE, Buoro IBJ. 1990. A note on clinical-pathological findings and serum enzyme activity in sheep, goats and Friesian calves with acute *Lantana camara* poisoning. *Bulletin of Animal Health and Production in Africa* 38: 275–279.

NDC (Nakasongola District Council) and NEMA (National Environment Management Authority). 2008. Nakasongola District Environment Policy. Available at http://www.nemaug.org/district_policies/Nakasongola_Dist_Env_Policy.pdf. [accessed 5 October 2016].

Obwolo MJ, Odiawo GO, Goedegebuure SA. 1990. Clinicopathological features of experimental *Lantana camara* poisoning in indigenous Zimbabwean goats. *Zimbabwe Veterinary Journal* 21: 1–7.

Page A. 2007. Economic impact of lantana on the Australian grazing industry. Final report to Queensland Department of Natural Resources and Water. Available at http://weeds.ala.org.au/WoNS/lantana/docs/60_Lantana_Grazing_EIA_Final_Report_(b).pdf [accessed 16 August 2016].

Parsons WT, Cuthbertson EG. 2001. Common lantana. In: Parsons WT, Cuthbertson EG (eds), *Noxious weeds of Australia*. Melbourne: CSIRO Publishing. pp 627–632.

Pimentel D (ed.). 2002. *Biological invasions: economic and environmental costs of alien plant, animal and microbe species*. New York: CRC Press.

Priyanka N, Joshi PK. 2013. A review of *Lantana camara* studies in India. *International Journal of Scientific and Research Publications* 3: 1–8.

Randolph TF, Schelling E, Grace D, Nicholson CF, Leroy JL, Cole DC, Demment MW, Omore A, Zinssta J, Ruel M. 2007. Role of livestock in human nutrition and health for poverty reduction in developing countries. *Journal of Animal Science* 85: 2788–2800.

Rejmánek M, Huntley BJ, Le Roux JJ, Richardson DM. 2016. A rapid survey of the invasive plant species in western Angola. *African Journal of Ecology* 55: 56–69.

Rugadya MA. n.d. Pastoralism as a conservation strategy: Uganda country paper. Available at http://cmsdata.iucn.org/downloads/uganda_country_study.pdf [accessed 10 October 2016].

Ruwanza S, Shackleton CM. 2016. Effects of the invasive shrub, *Lantana camara*, on soil properties in the Eastern Cape, South Africa. *Weed Biology and Management* 16: 67–79.

Shackleton CM, McGarry D, Fourie S, Gambiza J, Shackleton SE, Fabricius C. 2007. Assessing the effect of invasive alien species on rural livelihoods: case examples and a framework from South Africa. *Human Ecology* 35: 113–127.

Shackleton RT, Le Maitre DC, Pasiecznik NM, Richardson, DM. 2014. *Prosopis*: a global assessment of the biogeography, benefits, impacts and management of one of the world's worst woody invasive plant taxa. *AoB Plants* 6: plu027.

Shackleton RT, Witt ABR, Nunda W, Richardson DM. 2016. *Chromolaena odorata* (Siam weed) in eastern Africa: distribution

and socio-ecological impacts. *Biological Invasions*. DOI: 10.1007/s10530-016-1338-4.
Sharma GP, Raghubanshi AS, Singh JS. 2005. *Lantana* invasion: an overview. *Weed Biology and Management* 5: 157–165.
Sharma OP, Sharma S, Pattabhi V, Mahato SB, Sharma PD. 2007. A review of the hepatotoxic plant, *Lantana camara*. *Journal of Scientific and Industrial Research* 37: 313–352.
Swarbrick JT. 1986. History of the lantanas in Australia and origins of the weedy biotypes. *Plant Protection Quarterly* 1: 115–121.
Swarbrick JJ, Willson BW, Hannan-Jones MA. 1998. *Lantana camara* L. In: Panetta FD, Groves RH, Shepherd RCH (eds), *The biology of Australian weeds*. Melbourne: RG and FJ Richardson. pp 119–140.
Taylor S, Kumar L, Reid N. 2012. Impacts of climate change and land-use on the potential distribution of an invasive weed: a case study of *Lantana camara* in Australia. *Weed Research* 52: 391–401.
Turner PJ, Downey PO. 2010. Ensuring invasive alien plant management delivers biodiversity conservation: Insights from an assessment of *Lantana camara* in Australia. *Plant Protection Quarterly* 25: 102–110.
UNDP (United Nations Development Programme). 2005. Uganda human development report 2005. Linking environment to human development: a deliberate choice. Kampala: UNDP. Available at http://hdr.undp.org/sites/default/files/uganda_2005_en.pdf [accessed 20 August 2016].
Urban AJ, Simelane DO, Retief E, Heystek F, Williams HE, Madire LG. 2011. The invasive '*Lantana camara* L.' hybrid complex (Verbenaceae): a review of research into its identity and biological control in South Africa. *African Entomology* 19: 315–348.
van Wilgen BW, de Wit MP, Anderson HJ, le Maitre DC, Kotze I M, Ndala S, Brown B, Rapholo MB. 2004. Costs and benefits of biological control of invasive alien plants: case studies from South Africa. *South African Journal of Science* 100: 113–122.
van Wilgen BW, Dyer C, Hoffmann JH, Ivey P, Le Maitre DC, Moore JL, Richardson DM, Rouget M, Wannenburgh A, Wilson JRU. 2011. National-scale strategic approaches for managing introduced plants: insights from Australian acacias in South Africa. *Diversity and Distributions* 17: 1060–1075.
van Wilgen BW, Forsyth GC, Le Maitre DC, Wannenburgh A, Kotzé JDF, van den Berg E, Henderson L. 2012. An assessment of the effectiveness of a large, national-scale invasive alien plant control strategy in South Africa. *Biological Conservation* 148: 28–38.
Wilson G, Desai AA, Sim DA, Linklater L. 2013. The influence of the invasive weed, *Lantana camara* on elephant habitat use in Mudumalai Tiger Reserve, southern India. *Journal of Tropical Ecology* 29: 199–207.
Winder JA. 1980. Factors affecting the growth of lantana in Brazil. PhD thesis, University of Reading, UK.
Witt ABR, Day MD, Urban AJ, Sankaran KV, Shaw R. 2012. Lantana: the battle can be won. *Biocontrol News and Information* 33(2): 13N–15N.
Zalucki MP, Day MD, Playford J. 2007. Will biological control of *Lantana camara* ever succeed? Patterns, processes and prospects. *Biological Control* 42: 251–261.

Received 7 November 2016, revised 20 February 2017, accepted 25 February 2017
Associate Editor: Liz Trenchard