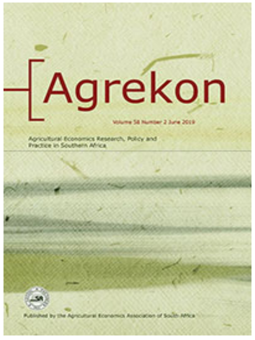

Agrekon

Agricultural Economics Research, Policy and Practice in Southern Africa

ISSN: 0303-1853 (Print) 2078-0400 (Online) Journal homepage: www.tandfonline.com/journals/ragr20

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To cite this article: Luke Humphrey, Gavin Fraser & Grant Martin (2019) The Economic Implications of *Robinia pseudoacacia* L. (black locust) on Agricultural Production in South Africa, Agrekon, 58:2, 216-228, DOI: 10.1080/03031853.2019.1580591

To link to this article: https://doi.org/10.1080/03031853.2019.1580591

Published online: 16 Apr 2019.

AGREKON
2019, VOL. 58, NO. 2, 216–228
https://doi.org/10.1080/03031853.2019.1580591

The Economic Implications of *Robinia pseudoacacia* L. (black locust) on Agricultural Production in South Africa

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ABSTRACT
Robinia pseudoacacia L. (black locust) is an invasive deciduous, broad-leaved tree that has the potential to be widely distributed across South Africa. It has invaded all nine South African provinces. The potential economic impact of *R. pseudoacacia* on agricultural production stems from the tree's ability to reduce the carrying capacity for livestock. This study estimated the potential economic implications of *R. pseudoacacia* on agricultural production in South Africa, specifically the livestock sector. *R. pseudoacacia's* potential distribution was calculated by using a maximum-entropy predictive habitat model, MaxEnt. The distribution of livestock, based on grazing capacity (ha/large stock unit) in South Africa, was then determined. The potential direct economic impacts were estimated by assessing the impact of the potential distribution of *R. pseudoacacia* on the carrying capacity for livestock. The results showed that an infestation of *R. pseudoacacia* has the potential to reduce the total gross margin in the livestock sector by between approximately R135 million and R674 million, dependent on the level of invasion. The potential levels of foregone income and business activity found in this study reaffirm the need to devote resources to develop a viable, economical and effective control.

KEYWORDS
Invasive alien plants; livestock; grazing capacity; MaxEnt; economic impact

JEL CLASSIFICATION
Q15; Q51; Q57

1. Introduction

In many parts of the world, tree invasions have become more widespread in recent decades (Richardson *et al*., 2014) and of all the invasive species, trees are increasingly recognised as one of the largest threats to biodiversity and ecosystem functioning (Rejmánek & Richardson, 2013) and human livelihoods (Shackleton *et al*., 2014). These effects are currently driving the criteria for prioritising efforts for their removal and management (Sieg *et al*., 2010).

The management of invasive trees globally varies from small-scale private initiatives to large-scale national programmes, such as the internationally recognised "working for water" programme in South Africa (Van Wilgen *et al*., 2012; Rejmánek & Richardson, 2013; Brundu & Richardson, 2016). However, the success of tree management also varies dramatically and examples of large scale, long-term controls are limited (Van Wilgen *et al*., 2012; Richardson *et al*., 2014; Kraaij *et al*., 2017). Additionally, as with many introduced invasive tree species, they often provide some form of benefits along with their associated cost, leading to conflicts of interests surrounding their use and or their management (Dickie *et al*., 2014; Van Wilgen & Richardson, 2014), which can compromise management options (Kull *et al*., 2011; Richardson *et al*., 2014). Therefore, investigations into the

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impacts of invasive trees as well as potential conflicts of interest can be used to drive and prioritise management.

In South Africa, the adverse impact of invasive alien plants (IAPs) on water flows have been a prime motivation for prioritisation of trees within South Africa's Working for Water Programme (Le Maitre *et al*., 2016). However, it is increasingly recognised that many invasive trees have other significant impacts that should be considered when prioritising for management. Richardson *et al*. (2014) suggest investigations into a number of impacts, including conflict, control, costs, distribution and economic impacts, to name only a few.

There is an increasing recognition of the effect IAPs have on the agricultural sector (Cullen & Whitten, 1995; Leitch *et al*., 1996; Pimentel *et al*., 2001; Acquaye *et al*., 2005; De Neergaard *et al*., 2005; Eagle *et al*., 2007; Dube, 2010). IAPs have substantial impacts on forage quantity and quality, increasing management costs, imposing land use changes, and thereby reducing agricultural production, output and profitability (Eagle *et al*., 2007). IAPs have the potential to have an impact on the livestock sector, as a reduction in the carrying capacity for livestock disrupts agricultural production. They also pose a threat to livestock production by lowering yield and quality of forage, interfering with grazing patterns, poisoning livestock, restricting access to grazing lands, and increasing costs of managing and producing livestock (Ditomaso, 2000). One such IAP in South Africa, *Robinia Pseudoacacia* L. (Fabaceae), has the potential to have a significant impact on the agricultural sector.

The agricultural sector's significance in South Africa is large because of its potential to create jobs and is a key focus of the New Growth Path (Republic of South Africa, 2013). In South Africa, there are approximately 100 million hectares of agricultural land, of which 72 per cent is used for extensive grazing. Therefore, agricultural land in South Africa is primarily livestock-based (Meissner *et al*., 2013). Livestock production not only contributes substantially to food security in South Africa (Meissner *et al*., 2013), but also forms a critical part of South Africa's socio-economic and socio-political stability (Tibane & Vermeulen, 2014). Furthermore, livestock is the primary driver underpinning sustainable rural agriculture (Palmer *et al*., 2010). The grassland biome is one of the most valuable biomes in South Africa, in terms of agricultural production. Much of the increasing demand for meat and dairy products is supplied from the grassland biome (Boval & Dixon, 2012).

2. *Robinia pseudoacacia*

Outside of its native range, *Robinia pseudoacacia*, an invasive deciduous tree (Cierjacks *et al*., 2013), is often regarded as a problematic invader (Kurokochi *et al*., 2010). Although native to south-eastern USA, the broad-leaved tree has been widely planted and become naturalised elsewhere in temperate North America, Europe, Australia and South Africa (Sheppard *et al*., 2006; Carbutt, 2012) (Figure 1). In South Africa, the plant is listed as a Category 1B invader species under the National Environmental Management: Biodiversity Act 2004 regulations. *Robinia pseudoacacia* are known to have negative environmental and socio-economic impacts.

R. pseudoacacia were introduced into the Eastern Cape Province, South Africa, in the early 1900s (Sim, 1907), spread to 400 separate populations by 2018 and was recorded as growing in all nine provinces. At the end of 2000, the invasive tree was recorded in 110 quarter degree squares (QDS) and was abundant in 14 QDS. By 2015, the tree was recorded in 159 QDS and abundant in 38 QDS, indicating the tree is spreading rapidly to new populations but also within populations (Henderson, 2007; Humphrey, 2016).

The tree is a threat to existing ecosystems as it spreads rapidly from suckering roots and seeds creating monocultures that displace native species (Sabo, 2000). It is a prolific water user, capable of invading pristine environments and its seeds, leaves and bark are toxic to both humans and animals (Kumar, 1992; Sabo, 2000; Van Wyk *et al*., 2002; Sheppard *et al*., 2006; Vanschandevijl *et al*., 2010). Thus *R. pseudoacacia* possess most of the characteristics associated with "weediness" (Sabo, 2000). In South Africa *R. pseudoacacia* is potentially causing extensive negative ecological

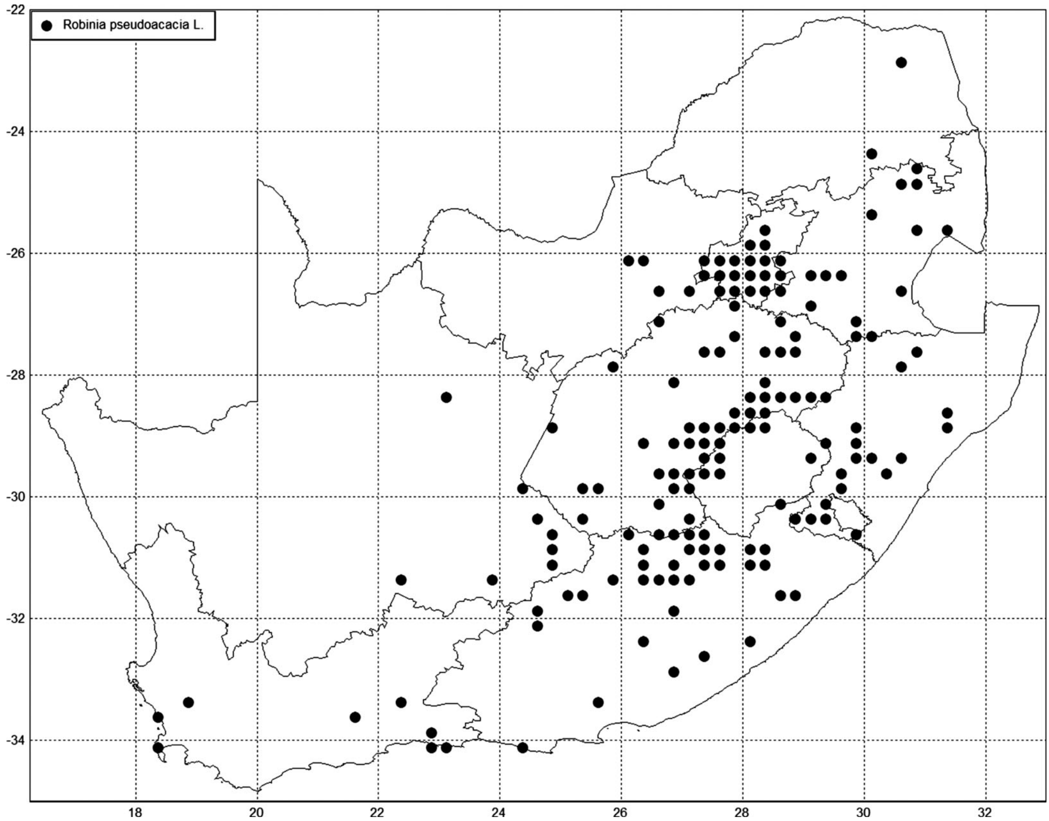

Figure 1. Distribution map of *Robinia pseudoacacia* in South Africa in quarter degree squares as of March 2015. Source: SAPIA (2015).

and economic effects through its impact on native biodiversity (Van Wilgen *et al*., 2001; Carbutt, 2012). The implementation of control measures to combat the spread of *R. pseudoacacia* has proven difficult due to its rapid growth and clonal spread (Akamatsu *et al*., 2014). Considering the economic importance of agricultural production in South Africa, the potential impact *R. pseudoacacia* has on agricultural production needs to be determined. Therefore, the aim of this study is to estimate the potential economic implications of the uncontrolled spread of *R. pseudoacacia* on agricultural production in South Africa. A significant decrease in the value of livestock production will provide an incentive to investigate the use of biological agents to control *R. pseudoacacia* and curtail the potential losses caused by the plant.

3. Bio-economic model

The bio-economic model (Figure 2) was developed to guide research efforts from the biological aspects through to the economic impacts (Leitch *et al*., 1996). To estimate the economic impacts of *Euphorbia esula* L. (Euphorbiaceae) (leafy spurge) infestations, Leitch (1996) used the bio-economic model. The model identified key relationships between the changes in the level of leafy spurge infestation and changes in land output (e.g., carrying capacity for grazing livestock). According to Knowler (2002), economists typically used bio-economic modelling to describe models that have both economic and biophysical components. The model was used to address the relationship(s) that exist between them. More specifically, bio-economic models are capable of simultaneously addressing the various dimensions of an agricultural system (Flichman, 2011).

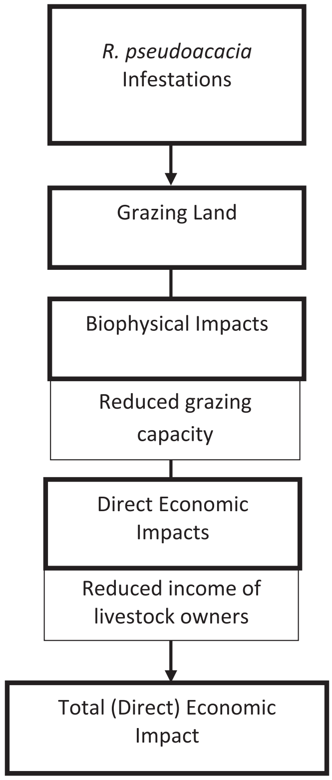

Figure 2. A conceptual bio-economic model of the economic impacts of *Robinia pseudoacacia* infestations. Adapted from Leitch *et al*. (1996).

Figure 2 describes the relationship between the biological aspects and the economic impact if an infestation of *R. pseudoacacia* occurred. This would influence the available grazing capacity in several ways. Firstly, *R. pseudoacacia*'s toxic components would deplete livestock numbers. Secondly, due to the clonal spread, specific areas of the grazing land would become restricted. The biophysical impacts would be a reduction in grazing capacity, ultimately reducing the carrying capacity of an area. The economic impacts of this would result in a reduction in income for livestock owners. In the last stage of the model, the total (direct) economic impact will be determined.

3.1 Potential distribution of R. pseudoacacia

The MaxEnt model (see Appendix for Spatial Distribution Modelling) indicates that the regions of highest suitability for *R. pseudoacacia* are generally distributed towards the eastern portion of South Africa (Figure 3).[1] This includes the Free State and Gauteng provinces, while there is a low probability of establishment of *R. pseudoacacia* into the western portion of the country (largely in the Northern Cape Province). The regions of highest probability coincided with those regions where the IAP had been recorded in the SAPIA database (SAPIA, 2015) and the grassland biome. Most of South Africa's surface water originates from the high-altitude grasslands of South Africa (Turpie *et al*., 2008). The area of highest suitability for *R. pseudoacacia*, the mountain catchments within the grassland biome occupy a mere 8 per cent of the surface area of South Africa but yield 49 per cent of the runoff (Wilson, 1984, cited by Snaddon, 1999). The grassland biome also harbours a rich species, community and ecosystem diversity (Reyers & Tosh, 2003), supplying essential ecosystem services and supporting crop and livestock agricultural activities (O'Connor & Kuyler, 2009).

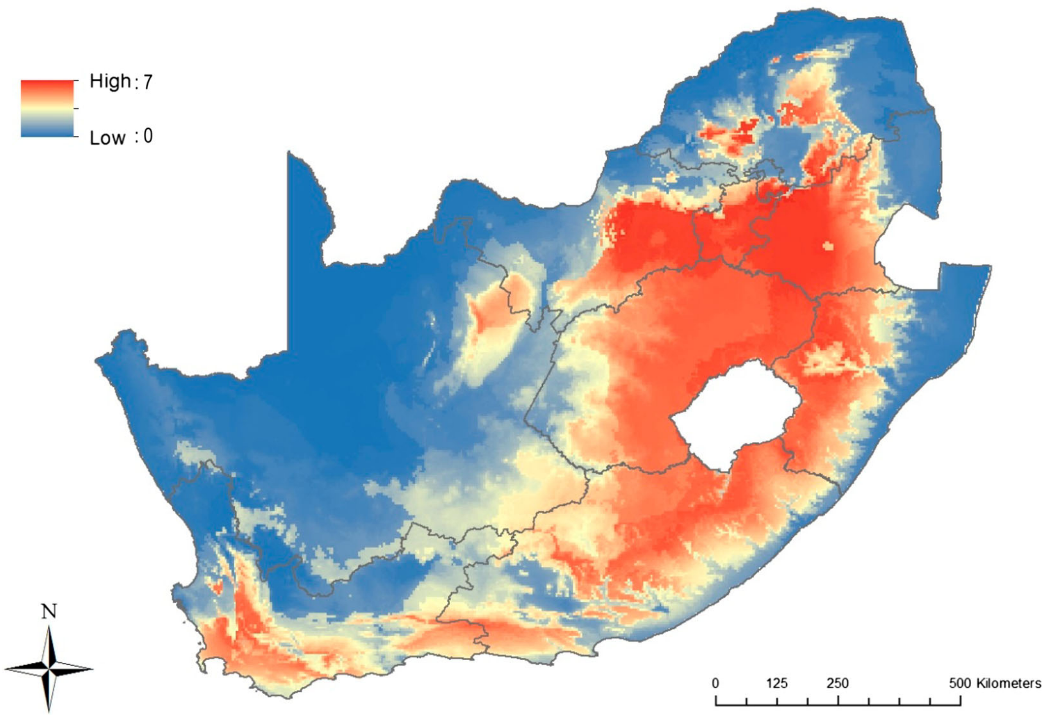

Figure 3. The potential distribution of *Robinia pseudoacacia* in South Africa.

Thus, grasslands are central to the livelihoods and economies for both small-scale/communal and commercial farmers as well as a number of rural communities (Boval & Dixon, 2012).

Areas of moderate probability exist in the north and north-western portions of the Eastern Cape Province, as well as along the south-western coastline. Furthermore, there is a low probability in the northern tip of the country, in the Limpopo province, as well as along the eastern coastline.

Approximately 37.52 per cent or 45 million ha of the total land coverage in South Africa has zero probability for *R. pseudoacacia* establishment (Table 1). Slightly over 25 per cent or 30 million ha of land are vulnerable to low levels of establishment (1–3), with approximately 18 per cent or 22 million ha of land vulnerable to moderate levels of invasion (4 and 5). Although the highest probability of invasion (7) is only 5.95 per cent of total land in South Africa, this represents over 7 million ha of land (mainly within the Gauteng and Free State provinces), which are extremely suitable for establishment. Furthermore, the second highest probability of invasion (6) suggests that approximately 13.10 per cent or almost 16 million ha of land is highly suitable for establishment by *R. pseudoacacia*. Overall, based on the MaxEnt model, *R. pseudoacacia* have the potential for establishment in 62.48 per cent of all land in South Africa.

Table 1. The potential distribution of *Robinia pseudoacacia* in South Africa.

Probability of invasion	Area (ha)	Land cover (%)
0	45 816 900	37.52
1	10 494 600	8.60
2	11 749 000	9.62
3	8 341 620	6.83
4	11 893 400	9.74
5	10 287 300	8.43
6	15 992 000	13.10
7	7 268 170	5.95
Total	121 842 990	

3.2 Estimating the impact of Robinia pseudoacacia *on livestock production*

Estimating the economic impact of infestations requires consideration of both biological and economic parameters (Leistritz *et al*., 1993). A change in an area's agricultural production practices can affect agribusiness firms, local trade and service sectors (Leistritz & Murdock, 1981; Leistritz & Ekstrom, 1986). The potential economic impact of *R. pseudoacacia* on agricultural production stems from the tree's ability to reduce livestock grazing capacity (Bangsund *et al*., 1999). The establishment of the invasive tree restricts access to grazing lands and the seeds, leaves and bark of the tree are toxic to livestock[2] (Kumar, 1992; Van Wyk *et al*., 2002; Vanschandevijl *et al*., 2010). A critical step in estimating the economic impact of an invasion into grazing lands was to estimate the potential reduction in the number of large stock units (LSUs).

The impact of the potential distribution of *R. pseudoacacia* at different invasion probabilities was determined in terms of livestock units (LSUs) in South Africa. In ARC-MAP, the ARC grazing capacity data layer was overlaid with the potential distribution data layer (ARC, 2009). This data provided the impact of the potential distribution of *R. pseudoacacia*, at different invasion probabilities (high, moderate and low), on LSUs in South Africa. However, MaxEnt only predicts the potential distribution of *R. pseudoacacia*, and does not predict the canopy cover of the growth-areas where *R. pseudoacacia* were predicted (at any probability level). According to the MaxEnt model, the cover could range from a single tree to a large infestation. Thus, one could not assume that intermittent patches of *R. pseudoacacia* or a *R. pseudoacacia* monoculture would have the same impact on LSUs (Hirsch and Leitch, 1996). A large infestation of *R. pseudoacacia* would have a greater effect on LSUs, compared with that of a single tree.

To combat the problem of the unknown canopy cover of the potential invasion, three canopy cover invasion possibilities were constructed. The possibilities were based on guidelines developed by Le Maitre and Versfeld (1994), which provide for a range of density classes from rare (<0.01 per cent) to closed (100 per cent canopy cover) (Table 2).

Based on the relevant assumptions for each possibility, the total number of LSUs potentially affected by an invasion of *R. pseudoacacia* was determined. The total number of LSUs within each probability of invasion possibilities, which was previously calculated, was multiplied by the canopy cover assumption and the impact on LSUs assumption. This was done for the whole of South Africa as well as for the grassland biome (Table 2).

The potential impact on the gross margin in the livestock sector was estimated, within each probability of invasion scenario. The total number of LSUs within each probability of invasion possibility was multiplied by the gross margin. Gross margins for livestock were obtained from the livestock enterprise budget, compiled by VKB in the eastern Free State. An average gross margin per LSU of R1000 was assumed.[3] Gross margins per LSU vacillated quite significantly, depending on the size and weight of the animals. Therefore, a gross margin of R1000 per LSU was chosen as it represents an average gross margin per LSU.

The potential economic impacts of *R. pseudoacacia* on agricultural production stem from the tree's ability to reduce livestock carrying capacity, due to its poisonous seeds, leaves and bark (Bangsund *et al*., 1999). Meissner et al. (2013) stated that grazing capacity may deteriorate because of an invasion by alien vegetation. A critical step in estimating the economic impact of an invasion into grazing lands is to estimate the potential reduction in the number of LSUs. The total potential number of LSUs within each biome was determined (Figure 4).

Table 2. Summary of the canopy cover invasion possibilities.

Probability of invasion	Canopy cover assumption	Impact on LSU
High (5–7)	>20%	50.0%
Moderate (3–4)	5–20%	25.0%
Low (1–2)	<5%	12.5%

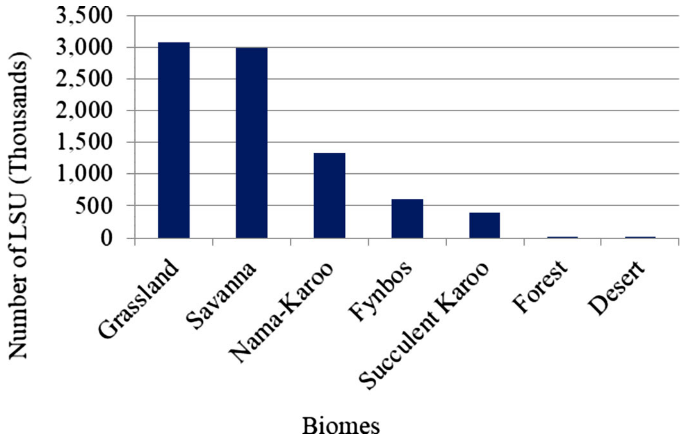

Figure 4. Potential number of LSU's within each of the seven South African biomes.

The results indicate that the grassland biome potentially contains the largest number of LSUs, at slightly over 3 million. This is followed closely by the savannah biome, which potentially contains approximately 3 million LSUs. The nama-Karoo biome contains approximately half the number of potential LSUs of the grassland and savannah biomes. The fynbos and the succulent Karoo biomes contain relatively smaller numbers of potential LSUs of approximately 600 000 and 400 000, respectively. The forest and the desert biomes contain relatively few potential LSUs, relative to the other biomes.

4. Economic Impact of *Robinia pseudoacacia* on livestock in South Africa

Recognising that livestock is an important component in agriculture production in South Africa, the impact of the potential distribution of *R. pseudoacacia*, at different invasion probabilities, on LSUs in South Africa was determined. Table 3 illustrates high (5–7), moderate (3–4) and low (1–2) probabilities of *R. pseudoacacia* invasions and the corresponding potential reductions in the number of LSUs in South Africa.

The results suggest that at a high probability of invasion, there would be a reduction of approximately 1.9 million LSUs. At moderate and low probabilities of invasion, there would be reductions of approximately one million LSUs each.

However, MaxEnt only predicts the potential distribution of *R. pseudoacacia*, and does not predict the canopy cover of the invasion. To combat the problem of the unknown canopy cover of the potential invasion, canopy covers were estimated, and three canopy cover scenarios were constructed.

Based on our canopy cover and impacts on LSUs assumptions, the total number of LSUs that could potentially be impacted by an invasion of *R. pseudoacacia* was estimated at different invasion probabilities (Table 4). This allowed for a more accurate and realistic estimation.

The results suggest that at a high probability of invasion, *R. pseudoacacia* has the potential to affect 961 359 LSUs (assuming a dense canopy cover of >20% and a reduction of LSUs by 50%). This represents just less than one third of the total number of LSUs within the grassland biome

Table 3. The impact of the potential distribution of *Robinia pseudoacacia* on LSUs in South Africa.

Probability of invasion	Number of LSU
High (5–7)	1 922 717
Moderate (3–4)	1 047 292
Low (1–2)	1 037 499

Table 4: Number of LSUs potentially impacted by an invasion of *Robinia pseudoacacia* in South Africa, based on the relevant assumptions.

Probability of invasion	Number of LSUs impacted
High (5–7)	961 359
Moderate (3–4)	261 823
Low (1–2)	129 687

(see Figure 4). At a moderate probability of invasion, the invasive tree has the potential to affect 261 823 LSUs (assuming a medium canopy cover of 5–20 per cent and a reduction of LSUs by 25%). Lastly, at a low probability of invasion, the invasive tree has the potential to affect 129 687 LSUs (assuming a light canopy cover of <5 per cent and a reduction of LSUs by 12.5%). These figures for the number of LSUs affected in the three probability zones assume that the total area in each of the zones is invaded. However, it is unlikely that each of the zones will be totally invaded by *R. pseudoacacia.* To determine the impact of the potential invasion, in monetary terms, three scenarios were developed to cover high (50%), moderate (25%) and low (10%) levels of invasion (Table 5).

Using the worst-case scenario, with an invasion rate of 50 per cent in the three zones, the impact on the total gross margin of the livestock sector of approximately R676 million per annum. It was estimated that an invasion at a moderate invasion level (25%) could potentially cause a reduction in gross margin in the livestock sector of approximately R338 million per annum and a low invasion level (10%) could potentially cause a reduction in total gross margin in the livestock sector of approximately R130 million per annum. This suggests that the uncontrolled spread of *R. pseudoacacia* has the potential to have significant economic implications on the South African agricultural industry.

As the grassland biome is the most likely biome to be invaded, the same scenarios used for the determination of the economic impact of *R. pseudoacacia* on the country can be used for the grassland biome. In monetary terms, the impact of the potential invasion of *R. pseudoacacia* at a high invasion rate on LSUs in the grassland biome, could potentially cause a reduction in total gross margin in the livestock sector of approximately R410 million. At moderate and low invasion rates, the potentially reduction in total gross margin in the livestock sector would be R205 million and R82 million respectively. This means that approximately 60 per cent of the reduction in total gross margin would be incurred on the grassland biome.

5. Discussion

The spread of *R. pseudoacacia* has the potential to cause extensive damage to the agricultural sector, specifically to livestock as seen in the study. Although this study only looked at one element – the impact on grazing capacity – the potential economic impacts are significant. There remains a role for public intervention to control *R. pseudoacacia,* as this will yield public benefits for a diverse array of other natural resource service flows negatively impacted by *R. pseudoacacia* (Eagle *et al*., 2007). Thus, to prevent the potential negative impacts from occurring, a solution to the problem is needed.

Mechanical and herbicidal control methods have proven to be unsuccessful, as seen in the literature (Brown *et al*., 2001; Edgin, 2007; Cierjacks *et al*., 2013) and in a case study where, in total, approximately R9 million was spent attempting to control *R. pseudoacacia* in the eastern Free State using mechanical means (Humphrey, 2016). The costs of control rise exponentially as each control attempt only aggravates the spread. Mechanical control methods result in prolific root suckering (Zimmerman, 1984) and clonal spread (Czarapata, 2005) and no complete or long-term herbicidal solution exists (DeLoach, 1997; Weitzenberg & Zentner, 1997; Sabo, 2000; Edgin, 2007; Cierjacks *et al*., 2013). However, one control option, which has not yet been attempted, is biological control.

Biological control is the most environmentally friendly, cost effective and self-sustaining control method used to suppress IAPs (Zimmermann *et al*., 2004). This method of control has been used as a powerful tool for reducing the costs of management of IAPs worldwide as well as in South Africa (Van Wilgen *et al*., 2004). A variety of biological control agents has been released on a variety of IAPs in South Africa, which have proven to be successful (Olckers & Hill, 1999; Cruttwell McFadyen, 2000; Van Wilgen *et al*., 2004; Hill & Coetzee, 2017). Biological control using seed-attacking insects is the most cost-effective, long-term option for limiting seed production into catchments (Richardson & Kluge, 2008; Van Wilgen *et al*., 2013). For example, Holmes *et al*. (1987) showed that stopping seeding of *Acacia saligna* resulted in an 80 per cent decline in its seed bank after 4–6 years. Additionally, benefit : cost ratios of the seed attacking biological control programmes of *A. longifolia* and *A. pycnantha* have been calculated to be 1465 : 1 and 4433 : 1, respectively (Van Wilgen *et al*., 2004). Potential biological control agents exist for *R. pseudoacacia* (Sheppard *et al*., 2006). The implementation of biological control has the potential to reduce the rate of spread of *R. pseudoacacia* and potentially the density within populations.

In South Africa, 773 IAPs were recorded on the South African plant invader database of which only 77 species have been considered for biological control programmes (Henderson & Wilson 2017). As funding for IAPs management is finite, methods for prioritising IAP to funding agencies are invaluable. Economic studies such as this have the potential to inform the use of scarce funds and resources to be allocated for the effective control of invasive alien plants. Implications for both policy makers and researchers can be drawn from this effort to estimate the economic impacts of *R. pseudoacacia*. Insight and awareness for policy makers has been provided concerning the economic implications of the current and potential situations. Implementing more effective control measures should be an issue of concern to policymakers generally, rather than just to those representing the livestock sector.

Notes

1. The potential distribution of *R. pseudoacacia* was ranked by MaxEnt on a scale from 1 to 7 (Figure 3). Higher probability (values closer to 7) represents areas most suitable for *R. pseudoacacia,* while zero or lower probability indicates areas less suitable for *R. pseudoacacia*.
2. Other economic impacts of invasions, which were not included in this study, are lowering yield and quality of forage, increasing costs of managing and producing livestock, foregone livestock sales and potential decreases in land values (Ditomaso, 2000).
3. For more information on the classification of livestock, see Soji *et al*. (2015).

Acknowledgements

The South African Working for Water (WfW) Programme of the Department of Environmental Affairs: National Resource Management is acknowledged for providing funding. The South African Research Chairs Initiative of the Department of Science and Technology and the National Research Foundation of South Africa also provided funding for this work. Any opinion, finding, conclusion or recommendation expressed in this material is that of the authors and the NRF does not accept any liability in this regard.

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Appendix

Species Distribution Modelling

Species Distribution Models (SDM) are a popular method used to predict the potential geographic distribution of an organism (Robertson *et al*., 2001, 2003; Mau-Crimmins *et al*., 2006; Steiner *et al*., 2008) and to predict the environmental suitability of regions not yet invaded by invasive species (Mgidi *et al*., 2007; De Meyer *et al*., 2008). This is done by quantifying the species–environment relationship, so that the correlation between the occurrence of the species and the environmental parameters within a specific region are determined (Guisan & Thuiller, 2005). A maximum-entropy predictive habitat model (MaxEnt-Version 3.3.0), which is regarded as one of the premier distribution-modelling software packages available (Thompson *et al*., 2011), was used to simulate its potential distribution. Predicting the potential distribution of *R. pseudoacacia* followed a similar method to that of Trethowan *et al*. (2011), who sought to determine the potential distribution of *Campuloclinium macrocephalum* (Less.) DC (Pompom weed) in South Africa. The current distribution data of *R. pseudoacacia*, was obtained from herbaria, GBIF (GBIF, 2015) and SAPIA (SAPIA, 2015) databases, and was used to model the potential distribution of *R. pseudoacacia*. Input layers, which act as environmental variables, are used in the software to generate a probability distribution, starting from the uniform distribution and repeatedly improving the fit to the data (Phillips *et al*., 2006). Suitable bioclimatic predictor variables were selected and downloaded from the WorldClim database (Hijmans *et al*., 2005). The 19 BioClim variables have been widely used in SDM studies (Steiner *et al*., 2008; Trethowan *et al*., 2011; Li *et al*., 2014), as the data can be easily downloaded from the WorldClim database with no further calculations required (Acosta, 2008; Li *et al*., 2014).

The MaxEnt model was calibrated using the obtained records for *R. pseudoacacia* to predict the potential invaded ranges in South Africa. *R. pseudoacacia* have the potential to be distributed across a substantial portion of the country (Figure 3). The distribution results are similar that of Li *et al.* (2014), who sought to determine the global potential geographical distribution of *R. pseudoacacia*.

ARC-MAP 10.2 (ESRI, 2011) was used to overlay different environmental layers onto the model to refine the data. These layers included the MaxEnt layer, the National Land Cover (NLC) 2009 (Bhengu *et al*., 2009), the Mucina and Rutherford (2006) biome layer and the Agricultural Research Council (ARC) (2009) grazing capacity layer.