RHODES UNIVERSITY
Where leaders learn

Perceptions of the role of *Lantana camara* on human well-being and rural livelihoods in Vhembe Biosphere Reserve, South Africa

By

Edward Mhlongo

Thesis submitted in fulfilment of the requirements for the degree of

Master of Science

at

Rhodes University

Department of Environmental Science

Rhodes University

Makhanda

South Africa

January 2021

Abstract

In the past, social aspects on biological invasions were less documented, this hindered the development of sound and effective management of Invasive Alien Species (IAS). However, there has been a shift in trends with more studies on biological invasions integrating local knowledge together with ecological studies to develop effective management interventions. Invasive Alien Species are widespread throughout Southern Africa and are usually prevalent in the rural areas. Limpopo province consists of large rural areas where people depend on natural resources, wild and exotic species for their livelihoods. *Lantana camara* is one of the major invaders that is problematic worldwide having detrimental impacts on biodiversity, ecosystem functions, and economies. This study assessed the perceptions of the role of *L. camara* on the well-being and rural livelihoods of local communities in the Vhembe Biosphere Reserve using household surveys. A total of 300 surveys were administered in six villages. The study further used a two-pronged approach to examine invasion extent and management options. The two-pronged approach included (i) detailed vegetation surveys in 50 household yards within each village, and (ii) focus group to solicit local knowledge of invasion extent and managing *L. camara* by the rural communities. The results of the study showed that almost all the respondents knew *L. camara* and could describe it. Most of the respondents were of the view that *L. camara* had no negative impacts on their livelihoods. Other respondents stated costs associated with *L. camara* were more than benefits and wanted a reduction in *L. camara* densities in the area. Most respondents wanted more government intervention to help in managing *L. camara,* this is because of the perceived future impacts of *L. camara*.

Vegetation survey results showed no significant difference in *L. camara* abundances and plant heights among the six study villages. The average number of *L. camara* counted per household yard in all villages was (2.41 ± 0.20) plants, with average plant basal diameter of (0.94 ± 0.02 cm). There were significant differences in canopy width of *L. camara* among the six study villages. Plant basal diameter was high in Tshakhuma (1.05 ± 0.04 m) and Duthuni (1.00 ± 0.04 m) villages, and low in Ha Mutsha village (0.82 ± 0.03 m). *Lantana camara* canopy width at household level across all villages averaged 1.34 ± 0.03 m. Canopy cover was high in Tshakhuma village (1.70 ± 0.09 m) and low at Ha Mutsha village (1.03 ± 0.03 m). In all six village focus group discussions, it was noted that mechanical clearing of *L. camara* was the most used method, but they reported minimum help from the government particularly Working for Water (WfW).

The study concludes that *L. camara* has no substantial adverse impacts to most of the respondents. The study further noted that *L. camara* is dominant in most household yards and that management is taking place however current control options are not enough on their own. Suggestions for further research are to explore more alternative indigenous species present or easily accessible to the community members which may offer the same benefits as IAS. Furthermore, additional research at local level is required for implementing management techniques best suited for the area.

Keywords: Biological invasions, Invasive alien plants, *Lantana camara* invasion, local knowledge, people perceptions, alien plant management

Declaration

I Edward Mhlongo, herby declare that the work outlined in this thesis was carried out at Rhodes University, Department of Environmental Science under the supervision of Dr. Sheunesu Ruwanza and Dr. Tatenda Dalu. This thesis has not been submitted at this university or any other university, this is my work in design and execution, and all material contained herein has been duly acknowledged.

Signature ______________________ Date 29 January 2021

Acknowledgements

Firstly, I would like to thank the Lord Almighty for his grace and the wisdom bestowed upon me and sustaining me throughout my academic endeavours. Secondly, gratitude to my supervisors Dr. Sheunesu Ruwanza and Dr. Tatenda Dalu for the valuable training throughout this project and whose guidance, support, advice, and in-depth knowledge have been fundamental to this research and pointing it in the right direction. I would like to also thank Dr. Gladman Thondhlana for his valuable contribution to data analysis. My sincerest gratitude to DST/NRF Thuthuka (TTK190117408656) for funding this research.

Many thanks to my family and friends for the support and prayers. My grandparents (Ruston and Audrey Mhlongo) are my source of inspiration and hope, and I thank them for the support and effort they have put into my academic endeavours. I would like to thank my sisters (Felicia, Charmaine, and Wonder Mhlongo) for their unwavering support throughout my studies. I would also like to extend thanks to Unarine Tshishonga, Lily Munzhedzi, and Tshidahisi Nndwayamato for assisting with fieldwork. Lastly, I would like to thank the tribal authorities and communities of all the six villages for partaking in this study.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF BOXES

Chapter 1: General Introduction

1.1 Introduction

Many natural ecosystems have been degraded due to Invasive Alien Species (IAS) (Vilà et al., 2011). The problem is mounting severely in geographic extent as global trade and travel are on the rise (Taylor et al., 2012) and as anthropogenic disturbances increase, making ecosystems more susceptible to invasion (Holmes et al., 2008; Simberloff et al., 2013; Paini et al., 2016). Invasion by alien plants has been reported to compromise ecosystem stability and ecosystem service provision as well as threaten economic productivity and abrading natural capital (Richardson and van Wilgen, 2004). The severity of the problem is illustrated by the incurred economic costs amounting to ZAR65 billion annually in South Africa caused by IAS (Wilson et al., 2017). Studies have shown that the most destructive Invasive Alien Plants (IAPs) transform ecosystems by adding resources, promoting fire, erosion, and litter accumulation (Richardson and van Wilgen, 2004; Vilà et al., 2011; Blackburn et al., 2014). The conflict between IAPs on ecosystems and human aspirations cannot be measured only in monetary terms such as alien plant effects on crop yield, but also in non-monetary terms such as aesthetic losses, loss of important associated organisms or ramifications of the drudgery of hand weeding, which is often assigned to women and children (Ukeje, 2007; Pejchar and Mooney, 2009).

The increase in global trade in the past few years has and will continue to present an opportunity for the transfer of IAPs, with both beneficial and deleterious impacts (Banks et al., 2015). Therefore, the geographic extent of IAPs will increase leading to enormous costs on ecosystems, economy, and society (Pejchar and Mooney, 2009; Witt et al., 2018). Invasive Alien Plants have detrimental costs which may be expressed economically, socially, and ecologically (Pejchar and Mooney, 2009; Semenya et al., 2012). These costs range from changes in livelihoods, ecosystem functions and economic costs incurred eradicating and managing the IAPs (Shackleton et al., 2018). These can include (i) altered habitats for species and change in availability of food resources (Vardien et al., 2012; Jevon and Shackleton, 2015), (ii) the suppression of growth for native vegetation through release of chemicals (Vardien et al., 2012), and (iii) the harbouring of insects such as tsetse fly (*Glossina* spp.) which causes sleeping sickness in local human communities (Day et al., 2003). However, notwithstanding the adverse effects' studies have revealed that IAPs do not only have detrimental effects but offer positive contributions as well (Shackleton et al., 2007; Semenya et al., 2012; dos Santos et al., 2014). This has led to some IAPs receiving increased recognition and acceptance due to their ability to contribute positively to rural livelihoods (Kannan et al., 2016).

1.2 The use of Invasive Alien Species (IAS)

The introduction of IAS into an area may be deliberate or accidental (Groves et al., 2005). Reasons for introduction of IAS may be for economic gain, aesthetic value and importing for a specific function (McNeely, 2001). Many of the IAS when left unchecked spread out of control and invade the area they were introduced to (Perrings et al., 2002, 2009). Rural communities depend on natural resources as assets, and these assets have shaped the livelihoods of many communities (Kent and Dorward, 2014). Natural assets are defined as the resources derived from nature upon which individuals and households make a living from (Scoones, 1998; Kent and Dorward, 2014). The misuse of these natural resources and lack of knowledge on IAS and their contributions to the environment is what exacerbates invasion by alien species (Itholeng, 2008).

The impacts of IAS are often evaluated differently by rural people depending on how it influences their economic needs (Shackleton et al., 2007; Rai et al., 2012; dos Santos et al., 2014). Invasive species have different characteristics altogether this results in some being beneficial to one community and detrimental to another (Rai et al., 2012). The costs and benefits with time become deeply incorporated into their livelihoods and are recognised as being of cultural significance (Shackleton et al., 2007). For example, the invasive Australian *Acacia* spp. have a lot of livelihood uses (e.g., fuelwood, construction material, poles, tool handles) to rural communities around the world (Kull et al., 2011, Kannan et al., 2014). Traditional healers of the Thulamela Local Municipality (TLM) in South Africa use the leaves of *Ricinus communis* to treat bites and stings from insects (Semenya et al., 2012). Further uses are derived from *Ageratina adenophora* which produces green manure that is used to increase nutrient supply on agricultural lands in Nepal and thus increasing yields of rice (Baral et al., 2017).

1.3 Integrating Traditional Ecological Knowledge (TEK) into ecological studies

Historically studies on biological invasions mainly focused on ecological aspects often overlooking the social aspects (Drake et al., 2016). The precautionary principle highlights the importance of public participation in decision making (World Commission on the Ethics of Scientific Knowledge and Technology, 2005). Traditional people possess an immense knowledge of the natural resources available to them for use (Huntington, 2011). Integration of Traditional Ecological Knowledge (TEK) into scientific research paves way for adaptive management (Pfeiffer and Voeks, 2008). There are many definitions of TEK and in the context of this study TEK refers to the types of knowledge about the environment derived from the experience, observation and traditions of a particular group of people accumulated over time which is often passed on to generations (Usher, 2000).

Many authors (e.g., Shackleton et al., 2007, 2020; Shackleton and Gambiza, 2008) have argued that integration of TEK offers crucial information on management of biological invasions. This has been demonstrated in studies by Sundaram et al. (2012) who used TEK to get a better understanding of *L. camara* invasion dynamics from community of Soliga in South India. Shackleton et al. (2015) made use of local knowledge to get a better understanding of local perceptions and management of *Prosopis* invasion in South Africa. Invasive alien species play pivotal roles to livelihoods of rural poor, and in some instances the roles played often surpass those of native species (dos Santos et al., 2014). The role played by these species often make it difficult for management as there is conflict which arises amongst users and non-users (Zengeya et al., 2017). Removal of IAS without consulting relevant stakeholders may have deleterious impacts on their livelihoods (Shackleton and Gambiza, 2008). And thus, consultations should be made with local communities when policies for management purposes are being initiated (Shackleton and Shackleton, 2016).

1.4 Motivation of the study

The integration of TEK into scientific studies has seen an increase over the years, this stems from the need to balance economic, environmental and social aspects which are significant knowledge areas for dynamic management (Sundaram et al., 2012). Understanding of communities' perceptions of IAS is crucial in planning management strategies, this is because some IAS are integrated in the livelihoods of the communities (Shackleton and Gambiza, 2008; dos Santos et al., 2014). Depending on the context some IAS play more crucial roles than their native counterparts (dos Santos et al., 2014), while some are detrimental to the surrounding environment (Drake et al., 2016). This presents a challenge for management as species are perceived as conflict-generating species (Zengeya et al., 2017). Similar studies have been done on other IAS in South Africa (Jevon and Shackleton, 2015; Ngorima and Shackleton, 2019), however, recent studies have focused on the benefits/uses only and overlooked negative impacts to humans (Semenya et al., 2012; Simba et al., 2013; Drake et al., 2016). This study is therefore motivated by the need to bring together scientific knowledge and TEK to examine perceptions and uses of *L. camara* and their influence on livelihoods within the Vhembe Biosphere Reserve (VBR). It is perceived that, gathering people's perceptions of IAS will help in developing holistic management plans that value the needs of communities affected by the IAP. *Lantana camara* was chosen as a case study species due to its dominance in South Africa and in the study area.

1.5 Study area

This study was conducted in VBR, Limpopo Province of South Africa. The total area of the biosphere is 30 700 km^2, and it has an estimated population of 1.5 million people (Stats SA, 2011). The VBR is generally subjected to variable rainfall ranging from 400 mm in the low lying areas to 1800 mm in the mountainous areas (Mpandeli, 2014) which falls in summer (October to March) being hot in summer with temperatures of 18-40°C and mild in winter (May to August) 12-25°C (South African Weather Service, 2020). The VBR is rich in biodiversity, this can be attributed to the climatic conditions, geomorphological diversity, and location (Dombo et al., 2006). The biosphere reserve is home to several nature reserves such as Nzhelele, Venetia Limpopo, Hangclip, and Nwanedi. Private game farming and conservation activities take place within the region which attract tourists to the biosphere (Jivanji, 2013). Six villages were identified in the reserve (Figure 1.1), and selection of the villages was because they had been observed to have *L. camara* in most of their household yards. The six villages selected were Ha Mutsha, Tshakhuma, Murunwa, Duthuni, Matshavhawe, and Ha Maelula (Table 1.1).

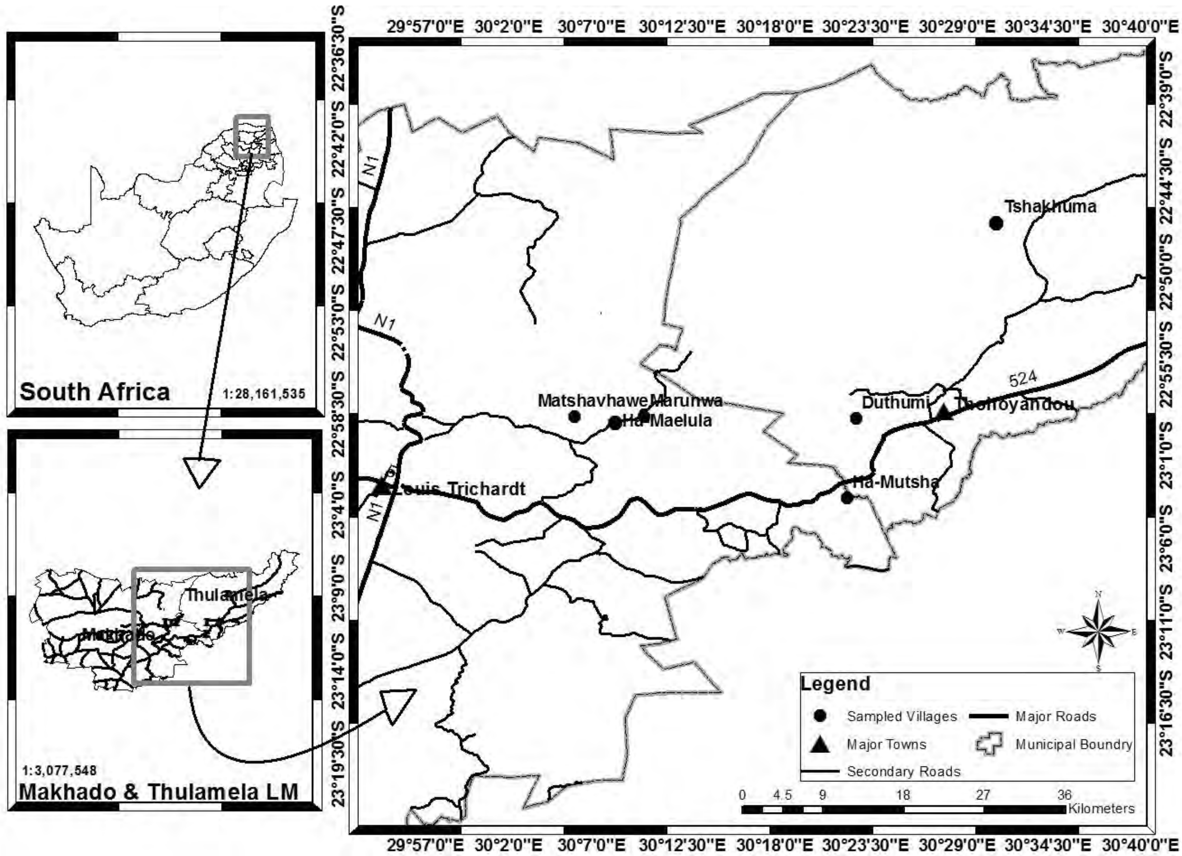

Figure 1.1 Map showing all the six study villages in the Vhembe Biosphere Reserve

Tshakhuma (23.0441°S, 30.3001°E), Murunwa (22.9816°S, 30.1633°E), Duthuni (22.9722°S, 30.3810°E), Matshavhawe (22.9755°S, 30.1026°E), Ha Mutsha (23.0512°S, 30.3599°E) and Ha Maelula (22.9831°S, 30.1402°E) villages are located 48 km, 34 km, 70 km, 28 km, 53 km, and 31 km, respectively from Makhado. All six villages are found within the Soutpansberg Mountain Bushveld vegetation type. The vegetation in the study area comprises of dense tree layers with poorly developed grassy layers. Common tree species include *Acacia karoo, Catha edulis, Berchemia zeyheri*, and *Bridelia molis*, and small shrubs of *Rhus magalismontana* and *Helichrysum kraussii* (Mucina and Rutherford, 2006). The bioregion has a mean annual precipitation of 800 mm and experiences summer rainfall and dry winters. The bioregion is characterised by rocky areas with acidic dystrophic and mesotrophic sandy, loamy soil (Mucina and Rutherford, 2006).

Table 1.1 Demographic information of the 6 villages

Villages	Municipality	Questionnaires	Population	Households
Ha Mutsha	Makhado	50	207	97
Matshavhawe	Makhado	50	1 735	420
Tshakhuma	Makhado	50	17 371	4 273
Murunwa	Makhado	50	2 697	608
Ha Maelula	Makhado	50	1 598	394
Duthuni	Thulamela	50	6 345	1 655

Source: population and household data are from Stats SA, community profile census (2011)

1.6 Research objectives and conceptual framework

The study aims to examine the effects of *L. camara* invasion on local communities in Vhembe Biosphere Reserve and to investigate *L. camara* invasion extent at household level.

Specific objectives

1. To determine the effects of *L. camara* on human well-being and rural livelihoods in Vhembe Biosphere Reserve communities.
2. To assess the local knowledge and perceptions to *L. camara* by Vhembe Biosphere Reserve communities.
3. To examine *L. camara* invasion extent at household level within the Vhembe Biosphere Reserve.
4. To examine *L. camara* management options used in Vhembe Biosphere Reserve.

The number of IAPs is increasing and so are the impacts these plant species cause to the environment, society, and economies (Pimentel et al., 2001). Nevertheless, resources for management are limited, which makes prioritisation unavoidable. Since the ecosystem services approach is becoming central in biological invasion, understanding the social, economic, and ecological effects of an IAP in this case *L. camara* on the livelihoods of rural communities becomes important for management purposes. In trying to understand the role of *L. camara* in rural livelihoods of communities within VBR, the conceptual framework (Figure 1.2 and 1.3) proposed by Shackleton et al. (2007) which aims to interpret the impacts of IAS on rural livelihoods and the Sustainable Livelihood Framework (SLF) (Figure 1.4) are adopted for this study.

1.6.1 A conceptual framework for interpreting the impacts of IAS on rural livelihoods

The framework (Figure 1.2) proposed by Shackleton et al. (2007) presents four variables since the time of invasion by IAS whether they are deliberately or not deliberately introduced into an area. The first curve represents the increase in abundance of IAS with time, being time dependent it exhibits a sigmoid shape. The second one shows benefits of IAS (if any) on local livelihoods. An increase in abundance of IAS is followed by an increase in the benefits of the IAS up to a certain threshold. The third one represents costs incurred from IAS. It encompasses all costs economic, social, and ecological. The fourth one represents the livelihood vulnerabilities linked to IAS. As the introduction of IAS produces livelihood opportunities vulnerability is reduced and the costs are minimal. The increase in costs associated with IAS leads to an increase in vulnerability as the benefits are outweighed by the costs (Shackleton et al*.,* 2007).

In Figure 1.2 below phase 1 represents the stage when invasion is in its early state and abundance of IAS is low with little to no observable costs, management is not required at this state as abundance is low. In the second phase abundance of IAS has increased and is continuing to increase, the benefits (if any) are on the rise as well and individuals are aware of the benefits associated with the IAS and this will lead to changes in local livelihoods of community members. Consequently, towards the end of stage two costs are increasing, and management options need to be considered. Management options may be simple and can be arranged by members of the community themselves. In the final stage the benefits have been exceeded by the costs associated with IAS, two things could occur which will include mitigating the impacts or leaving impacts as they are which will exacerbate local livelihood vulnerability (Shackleton et al*.,* 2007).

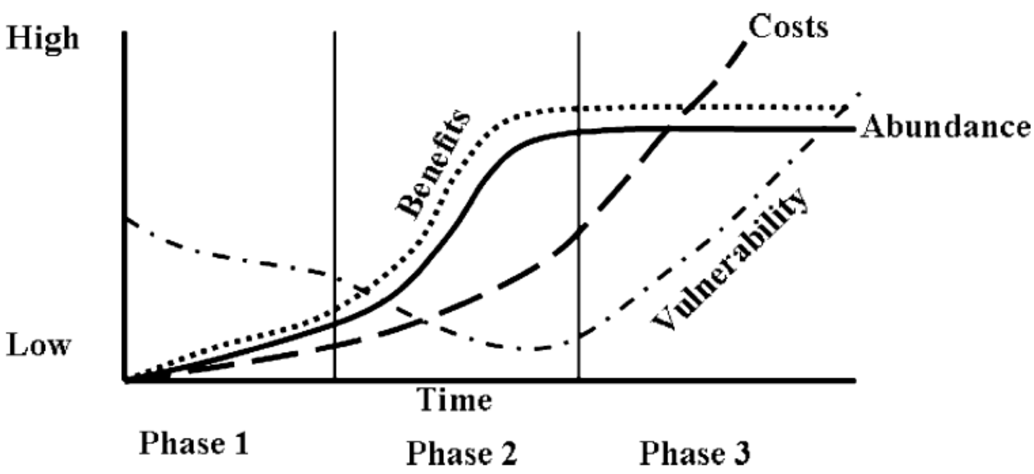

Figure 1.2 Conceptual framework that interprets the impacts of IAS on rural livelihood. Adopted from Shackleton et al (2007).

The shape of the curves will be influenced by the characteristics of the species and local context which will in turn produce four categories of species based on ability of IAS to compete (strong or weak) and its usefulness (high or low) (Figure 1.3). These four categories will include useful highly competitive species, undesirable highly competitive species, undesirable weakly competitive and useful weakly competitive species (Shackleton et al., 2007).

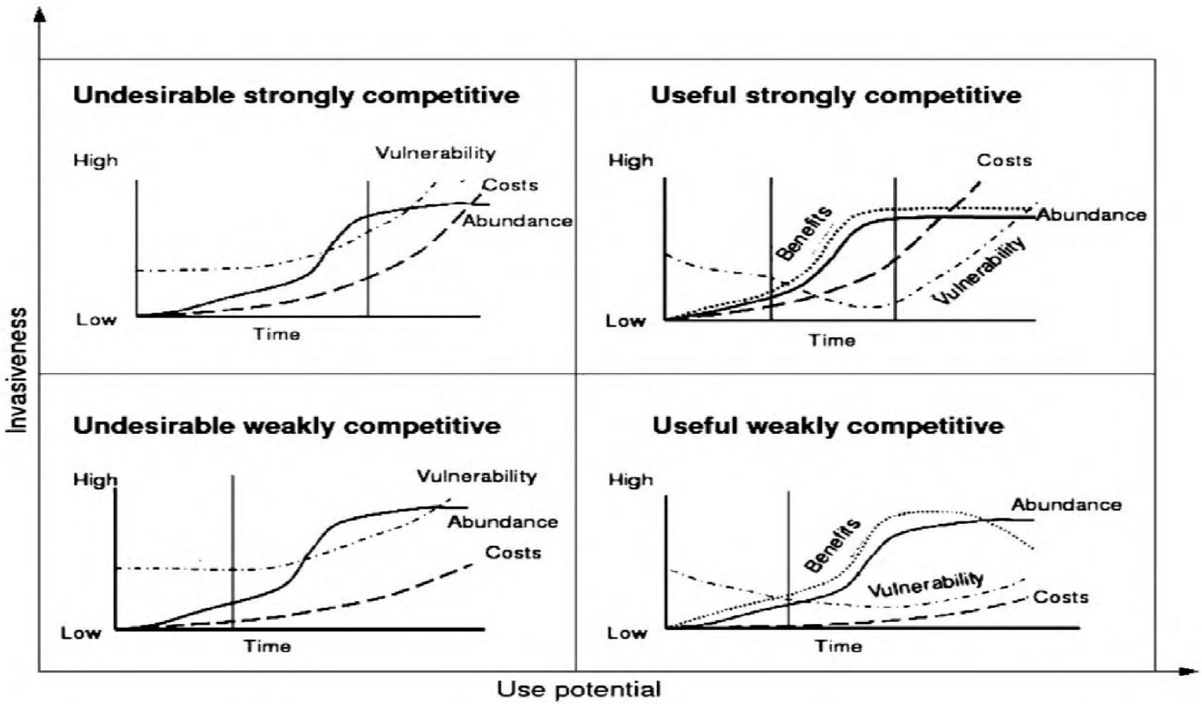

Figure 1.3 Conceptual framework for the variety of IAS (Note x axis for weakly competitive species is longer as it takes longer for effects to occur) Adopted from Shackleton et al (2007).

1.6.2 Sustainable Livelihood Framework (SLF).

The SLF is a rural appraisal tool used in decision making and policy designs which is geared at poverty alleviation (Hadju, 2006). It is a framework that provides insights to assets which are available to households and complex systems that underpin livelihoods (Chambers and Conway, 1992). It bridges the gap between people and the surrounding environment which impacts livelihood strategies by either enhancing or impeding them (Serrat, 2008). Livelihoods are diverse and complex, the SLF has become an important tool for showing the diversity and complexity of livelihoods (Chambers and Conway, 1992). The SLF consists of five main components (Figure 1.4) namely, livelihood resources, livelihood strategies, sustainable livelihood outcomes, vulnerability context and policies and institutions (Serrat, 2008).

Livelihoods are composed of assets (human, physical, social, financial, and natural capital) and activities required (Figure 1.4) as means of living (Chambers and Conway, 1992; Scoones, 1998), which the poor often have to make choices from (Serrat, 2008). These assets are;

(a) Human capital; this includes health and nutrition, skills and knowledge, and the capacity to work or adapt.
(b) Social capital; this includes common rules and sanctions, shared beliefs and values, and social connections
(c) Physical capital; includes tools and technology for production, and infrastructure such as roads, transport and buildings.
(d) Natural capital; these are the natural resources available to people and these include biodiversity, land and ecosystem services.
(e) Financial capital; includes money in the form of savings, wages, credit, and debt.

The strength of the SLF lies in that it, (i) seeks to comprehend livelihoods in a dynamic and historical context, (ii) encourages the investigation of relationships between different activities that contribute to livelihoods, and (iii) stresses the importance of linkages between sectors (Serrat, 2008). The shortcomings of the SLF are that it, (i) downplays that enhancing livelihoods of an individual or a group may undermine those of others, (ii) disregards the power dynamics (inequalities), and (iii) assumes assets can be expanded in incremental fashion (Serrat, 2008). Rural communities make use of diverse resources such as natural products, capital, and knowledge to earn income for their households (Hebinck and Lent, 2007). Subsequently this study makes use of the SLF to assess the role of *Lantana camara* on rural livelihoods in communities within the VBR. It is important to note that this thesis deals with a partial list of livelihood assets, namely natural and human capital with financial capital to a certain extent.

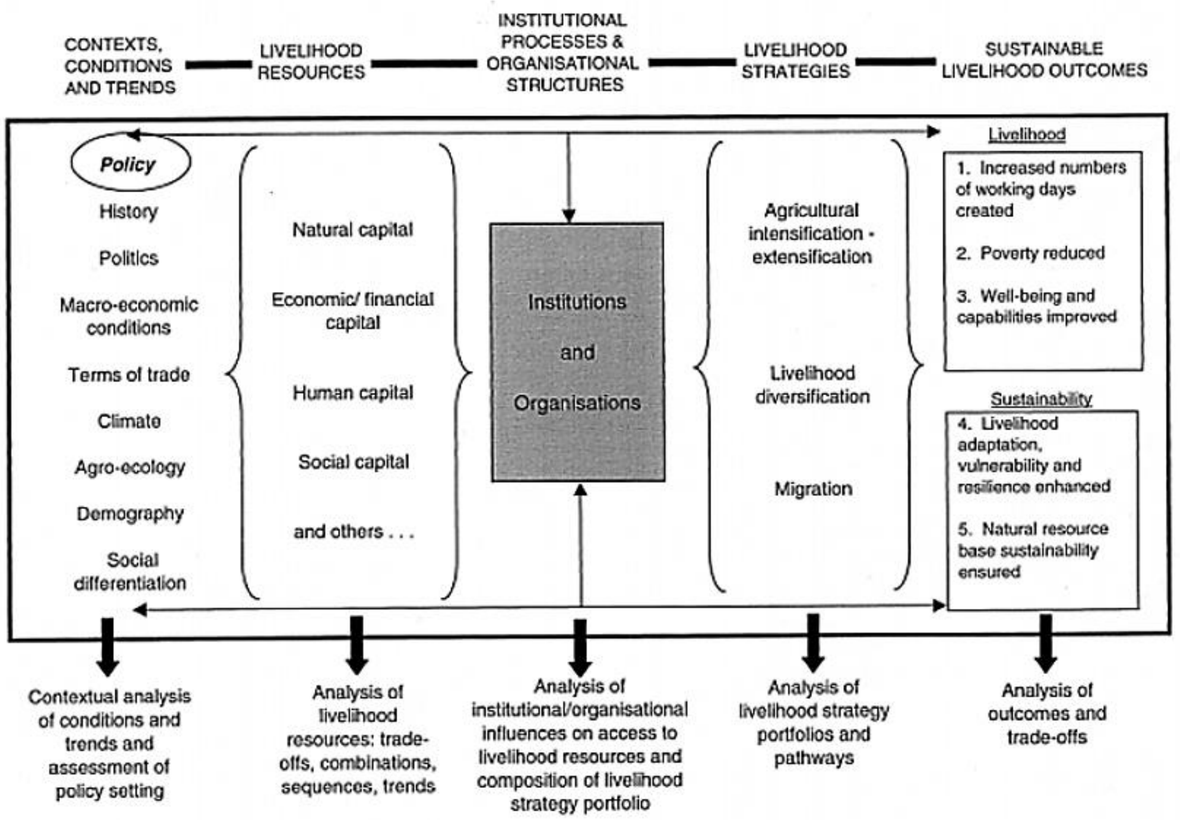

Figure 1.4 Sustainable livelihood framework (Scoones, 1998)

1.7 Thesis outline

This thesis comprises of five chapters. Chapter 1 provides introduction and highlights what the thesis is about. It gives a description of the study area, detailing the aims/objectives of the study and discusses the conceptual frameworks used. Chapter 2 is the extensive review of literature. Chapter 3 and 4 are presented in a paper format, each chapter has its own detailed background/introduction, methodology, methods, results, discussion, and conclusion. Chapter 5 presents the overall conclusions and recommendations for the thesis.

Chapter 1: This chapter is a general introduction and gives a brief overview of the thesis covering aims, objectives and conceptual frameworks used in this thesis.

Chapter 2: Provides a detailed overview of the literature review.

Chapter 3: Perceptions on the role of Lantana camara on human well-being and rural livelihoods in Vhembe Biosphere Reserve, South Africa. This chapter explores the local knowledge and perceptions of *L. camara* across six villages. Responses from the respondents are presented here.

Chapter 4: Lantana camara invasion extent and management approaches by local communities in Vhembe Biosphere Reserve, South Africa. This chapter investigates the invasion extent of *L. camara* at household level and management options employed in the area. Investigating invasion extent was done to gauge the density of *L. camara* populations.

References

Baral, S., Adhikari, A., Khanal, R., Malla, Y., Kunwar, R., Basnyat, B., Gauli, K., Acharya, R., 2017. Invasion of alien plant species and their impact on different ecosystems of Panchase Area, Nepal. Banko Janakari 27, 31-42.

Chambers, R., Conway, G., 1992. Sustainable rural livelihoods: Practical concepts for the 21st century, IDS Discussion paper 296, Institute of Development Studies, University of Sussex, Brighton, UK.

Dombo, L., Crafford, J., Fouche, P., Gaigher, I., Hahn, N., Linden, J., Rosmarin, J., 2006. The proposed Vhembe Biosphere Reserve application to UNESCO. Limpopo Province Department of Economic Development. Republic of South Africa: Environment and Tourism.

dos Santos, L.L., do Nascimento, A.L.B., Vieira, F.J., da Silva, V.A., Voeks, R., Albuquerque, U.P., 2014. The cultural value of invasive species: A case study from semi–arid Northeastern Brazil. Economic Botany 68, 283-300.

Drake, K.K., Bowen, L., Nussear, K.E., Esque, T.C., Berger, A.J., Custer, N.A., Waters, S.C., Johnson, J.D., Miles, A.K., Lewison, R.L., 2016. Negative impacts of invasive plants on conservation of sensitive desert wildlife. Ecosphere 7, e01531.

Groves, R.H., Boden, R., Lonsdale, W.M., 2005. Jumping the garden fence: Invasive garden plants in Australia and their environmental and agricultural impacts. CSIRO, WWF-Australia, Sydney.

Hebinck, P., Lent, P., (Eds). 2007. Livelihoods and Landscapes: The People of Guquka and Koloni and their resources. Brill, Leiden/Boston.

Holmes, T.P., Prestemon, J.P., Abt, K.L., (Eds). 2008. The economics of forest disturbances: Wildfires, storms, and invasive species. Springer Science and Business Media.

Huntington, H.P., 2011. The local perspective. Nature 478, 182-183.

Jevon, T., Shackleton, C.M., 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.

Jivanji, Y., 2013. Game ranching and land reform: Claims for the land exclaim tension: a case study of the Mapungubwe region. (PhD Thesis). University of Cape Town, South Africa.

McNeely, J.A., (Eds). 2001. An introduction to human dimensions of invasive alien species. The great reshuffling: Human dimensions of invasive alien species. Gland, Switz/Cambridge, UK: IUCN.

Mpandeli, S., 2014. Managing climate risks using seasonal climate forecast information in Vhembe District in Limpopo Province, South Africa. Journal of Sustainable Development 7, 68-81.

Mucina, L., Rutherford, M.C., 2006. The vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19. (South African National Biodiversity Institute: Pretoria, South Africa). Memoirs of the Botanical Survey of South Africa.

Ngorima, A., Shackleton, C.M., 2019. Livelihood benefits and costs from an invasive alien tree (*Acacia dealbata*) to rural communities in the Eastern Cape, South Africa. Journal of Environmental Management 229, 158-165.

Paini, D.R., Sheppard, A.W., Cook, D.C., De Barro, P.J., Worner, S.P., Thomas, M.B., 2016. Global threat to agriculture from invasive species. Proceedings of the National Academy of Sciences 113, 7575-7579.

Perrings, C., Fenichel, E., Kinzig., A., (Eds). 2010. Externalities of globalization: Bioinvasions and trade. Globalization and Bioinvasions: Ecology, Economics, Management and Policy, Perrings C, Mooney H, Williamson M pp 42-55. Oxford University Press, Oxford.

Perrings, C., Williamson, M., Barbier, E.B., Delfino, D., Dalmazzone, S., Shogren, J., Simmons, P., Watkinson, A., 2002. Biological invasion risks and the public good: An economic perspective. Conservation Ecology 6.

Pfeiffer, J.M., Voeks, R.A., 2008. Biological invasions and biocultural diversity: Linking ecological and cultural systems. Environmental Conservation, 281-293.

Rai, R.K., Scarborough, H., Subedi, N., Lamichhane, B., 2012. Invasive plants – Do they devastate or diversify rural livelihoods? Rural farmers' perception of three invasive plants in Nepal. Journal for Nature Conservation 20, 170-176.

Scoones, I., 1998. Sustainable rural livelihoods. A framework for analysis. IDS Working Paper 72. Institute of Development Studies, University of Sussex, Brighton.

Semenya, S.S., Tshisikhawe, M.P., Potgieter, M.T., 2012. Invasive alien plant species: A case study of their use in the Thulamela Local Municipality, Limpopo Province, South Africa. Scientific Research and Essays 7, 2363-2369.

Serrat, O., 2008. The sustainable livelihoods approach (p. 5). Washington DC: Asia Development Bank.

Shackleton, C.M., Gambiza, J., 2008. Social and ecological trade-offs in combating land degradation: The case of invasion by a woody shrub (*Euryops Floribundus*) at Macubeni, South Africa. Land Degradation and Development 19, 454-464.

Shackleton, C.M., McGarry, D., Fourie, S., Gambiza, J., Shackleton, S.E., Fabricius, C., 2007. Assessing the effects of invasive alien species on rural livelihoods: Case Examples and a Framework from South Africa. Human Ecology 35, 113-127.

Shackleton, R.T., Le Maitre, D.C., Richardson, D.M., 2015. Stakeholder perceptions and practices regarding *Prosopis* (mesquite) invasions and management in South Africa. Ambio 44, 569-581.

Shackleton, R.T., Novoa, A., Shackleton, C.M., Kull, C.A., 2020. The social dimensions of biological invasions in South Africa. In Biological Invasions in South Africa pp. 701-729. Springer, Cham.

Simba Y.R., Kamweya A.M., Mwangi P.N., Ochora J.M., 2013. Impact of the invasive shrub, *Lantana camara L.* on soil properties in Nairobi National Park, Kenya. International Journal of Biodiversity and Conservation 5, 803–809

Simberloff, D., Martin, J.L., Genovesi, P., Maris, V., Wardle, D.A., Aronson, J., Courchamp, F., Galil, B., García-Berthou, E., Pascal, M., 2013. Impacts of biological invasions: what's what and the way forward. Trends in Ecology and Evolution 28, 58-66.

South African Weather Service. 2020. Annual state of the Climate of South Africa 2019. Pretoria. South Africa

Stats SA (Statistics South Africa). 2011. Census 2011 Statistical release-P0301.4. Available from: http://www.statssa.gov.za.

Sundaram, B., Krishnan, S., Hiremath, A.J., Joseph, G., 2012. Ecology and impacts of the invasive species, *Lantana camara*, in a social-ecological system in South India: Perspectives from local knowledge. Human Ecology 40, 931-942.

Usher, P.J., 2000. Traditional ecological knowledge in environmental assessment and management. Arctic 183-193.

Wilson, J.R., Gaertner, M., Richardson, D. M., Van Wilgen, B. W., 2017. Contributions to the national status report on biological invasions in South Africa. Bothalia-African Biodiversity and Conservation, 47, 1-8.

Unesco/Commission Mondiale de l'Ethique des Connaissances Scientifiques et des Technologies. 2005. The precautionary principle: World Commission on the Ethics of Scientific Knowledge and Technology (COMEST*)*. Unesco.

Zengeya, T., Ivey, P., Woodford, D.J., Weyl, O., Novoa, A., Shackleton, R., Richardson, D., van Wilgen, B., 2017. Managing conflict-generating invasive species in South Africa: Challenges and trade-offs. Bothalia-African Biodiversity and Conservation 47, 1-11.

Chapter 2 Literature Review

2.1 Invasive species in South Africa

Invasive Alien Species (IAS) are species which exist outside their native range, whose presence in the new area may potentially cause economic and environmental harm as well as pose detrimental impacts to animal, human, and plant health (Beck et al., 2008; Pejchar and Mooney, 2009). There are over 1400 IAS in South Africa which threaten biodiversity and cost the nation ZAR15 billion (U$1 billion) annually (van Wilgen et al., 2020). The group with the most species recorded is terrestrial plants with 759 species (Richardson et al., 2020). Certain alien species are vital for food, clothing and medicine and thus were deliberately or accidentally introduced into South Africa by a diverse group of individuals from various places (van Wilgen et al., 2020).

Invasive alien species have invaded South Africa in large numbers (Richardson et al., 2020). These species have a large distribution range and often alter the invaded ecosystem and pose detrimental impacts on human livelihoods, ecosystem functions and services, and biodiversity (Le Maitre et al., 2020; O'Connor and van Wilgen 2020). In the Northern Cape, Orange River catchment *Prosopis* invasions reduce the mean annual rainfall (MAR) by 9 million m^3 per year (Dzikiti et al., 2013). Furthermore, Invasive Alien Plants (IAPs) have reduced the grazing capacity of rangelands in South Africa by replacing palatable grasses with unpalatable ones, for example *Nasella trichotoma* in the mountain grassland biome of the Eastern Cape and *Pennisetum setaceum* in the Nama-Karoo (O'Connor and van Wilgen, 2020).

Urban areas in South Africa are also not spared from biological invasions (Potgieter et al., 2020). This is because of several reasons such as (i) the intricate network of pathways available in towns and cities which propagate IAS, (ii) recurring introductions of alien species used for various reasons (ornaments, pets, horticulture, and aquaculture), and (iii) human aided disturbances and resource availability which provide opportunities for establishment and reproduction of IAS (Dehnen-Schmutz et al., 2007; Kowarik et al., 2013; McLean et al. 2017; Potgieter et al., 2020). The biomass from IAPs poses a serious threat to biomes dependent on fire by altering fire regimes (van Wilgen, 2009), furthermore proximity to infrastructure poses a serious risk often endangering humans and property (van Wilgen et al., 2012).

There is a need to manage IAS due to their increased hazardous impacts on ecosystems, biodiversity, and human well-being (Shackleton et al., 2016). Management often involves preventing spread of IAS, eradicating existing local invaders, and protection and monitoring of areas where IAS have been removed (Gaertner et al., 2016) or in other instances improving benefits IAS pose (Shackleton et al., 2016). Management of IAS may often be refuted due to conflict of interest arising from different stakeholders (Gaertner et al., 2016; Zengeya et al., 2017). Therefore, there is a need to consider views of all stakeholders when considering management options.

2.2 Use of Invasive Alien Species in South Africa

Invasive alien plants are often put on the spotlight for their negative impacts on biodiversity, ecosystems and their services, health and well-being of humans (Simberloff et al., 2013). It has been argued that rural South Africans are most affected by IAPs (Shackleton et al., 2011; Reynolds et al., 2020). Despite these impacts IAPs have positive contributions to the environment and humans (Ricciardi et al., 2017). Invasive alien species were primarily inaugurated to serve a specific function (commercial, aesthetics, ornamentation, food, and raw material) however, some were accidently introduced (van Wilgen et al., 2001; Richardson and van Wilgen, 2004; Richardson et al., 2011). Consequently, many of these species were widely disseminated across the country, which were incorporated into livelihoods of rural communities due to their societal value (Zengeya et al., 2017).

Shackleton et al. (2011) reported on the value Prickly pear (*Opuntia ficus-indica*) has to livelihoods of communities in Makana Municipality, an average of ZAR1469 was earned in a season per trader from trading prickly pear. Similarly, Ngorima and Shackleton, (2019) found the value of silver wattle (*Acacia dealbata*) from fencing to be ZAR525 per annum across three villages in the Eastern Cape Province. In the northern parts of South Africa in the Limpopo Province, *Psidium guajava* is used by the VhaVenda to treat diarrhoea (Ramalivhana et al., 2010). The BaPedi use roots of *L. camara* which are boiled and taken orally for hypertension (Semenya et al., 2012b). The dried bark of *Eucalyptus camaldulensis* is used to treat asthma, sinusitis, fever and sore throat (Semenya and Maroyi, 2018). The powdered leaves of *Urtica urens* are applied to burn wounds by individuals from the Graaff-Reinet and Murraysburg regions (Van Wyk et al., 2008). Taking into account the history and the immense extent of biological invasions in South Africa (van Wilgen et al., 2020), it is clear IAS are widespread and are being used across the country contributing to livelihoods of rural poor in various ways.

2.3 Conflict-generating Invasive Alien Species

The benefits and negative effects of IAS differ amongst various places depending on the socio-economic context, nature of the invaded area, the species and its invasive potential (Kull et al., 2011; van Wilgen and Richardson, 2014). Some species have both benefits and negative impacts, these are termed conflict-generating species (Zengeya et al., 2017). The conflict arises from the different views held by stakeholders on the benefits and damages they have on ecosystems they are found in (Zengeya et al., 2017). How people regard IAS whether beneficial, negative or no impact depends on several factors that influence their perceptions (Kueffer, 2013). According to Schermerhorn et al. (2006) perceptions are defined as processes where individuals organise, select, retrieve, interpret, and respond to information from the world, which will advertently shape their actions and behaviours.

The conflict of interest across various areas and between stakeholders in controlling IAS and deriving benefits is often inevitable (Ngorima and Shackleton, 2019). For example, in South Africa silver wattle (*Acacia dealbata*) has significant negative impacts on biodiversity and water resources, whilst providing huge benefits such as building material and firewood (De Wit et al., 2001). Ngorima and Shackleton, (2019) found that households in Matatiele had derived value of ZAR2300 (US$143) per year from firewood collected from silver wattle. Subsequently, they also found silver wattle to be a threat to food security.

2.4 Traditional Ecological Knowledge (TEK)

Traditional Ecological Knowledge (TEK) is defined as a collection of beliefs, practices, understandings, and values that individuals accumulate over time through shared relationships, experiences and observations which is shared between people and their environment (Berkes et al., 2000; Zent, 2001; Von Glasenapp and Thornton, 2011). Traditional ecological knowledge has been of value to mainstream conservation (Warren, 1996). This is because the primary bearers of TEK are old local individuals who possess immense wealth of TEK (Gómez-Baggethun and Reyes-García, 2013). Traditional ecological knowledge is not only of importance to locals but also for policy makers and managers (Shackleton and Gambiza, 2008). This is because TEK acts as a guiding tool for policy design, project development and allows for participation from local stakeholders (Rodríguez-Martínez, 2008). Ferreira-Rodríguez et al. (2020) made use of TEK to identify pathways and dispersal vectors for the invasive Asian clam (*Corbicula*) which in turn was used for raising awareness amongst stakeholders for management purposes.

However, despite possessing this knowledge there has been a decline in TEK, for example there has been a 40% decline in agricultural knowledge between old and new generation in the villages surrounding the Doñana National Park in Spain (Gómez-Baggethun et al., 2010). In other parts of the world, TEK is making a comeback. For example, people living in the basin of lake Titicaca in Peru use traditional agroecological methods to conserve soil and water resources (Saylor et al., 2017). Traditional ecological knowledge has been of paramount importance to modern ecological studies (Crall et al., 2010).

2.5 Factors influencing perceptions towards IAS

Social perceptions of IAS are influenced by several factors such as stakeholders' knowledge of IAS (including TEK), economic impacts accrued of IAS, various cultural values and beliefs and socio-demographic variables (Kapitza et al., 2019; Shackleton et al., 2011, 2019). Perceptions are context specific and vary through time and space (Shackleton et al., 2007). Perceptions towards IAS may also change as more knowledge is gained about IAS (van Wilgen et al., 2012). Perceptions towards IAS may be positive when people are deriving benefits from an IAS and may also become negative when people are negatively impacted (Pfeiffer and Voeks, 2008). For example, the kudzu (*Pueraria montana*) plant which was introduced to USA in the 1930s for soil erosion control quickly became problematic and by 1950s it had covered 1.2 million ha of land and was responsible for killing native trees, collapsing buildings, and damaging utility poles (Gulizia and Downs, 2019).

Shackleton et al. (2019) proposed a conceptual framework (Figure 2.1) of the primary factors that influence peoples' perceptions of IAS. There are 6 primary factors namely, individuals, effects, species, landscape context, socio-cultural context and institutional, governance and policy context. Due to these several interacting factors perceptions may become extremely complex.

Individuals: Psychological approaches are key to understanding how people perceive their surrounding environment. A person's beliefs, values and knowledge influence perceptions. This is based on a person's personal experiences and observation of the effects of IAS. Beliefs and values will differ amongst people. For example, scientists' beliefs may vary from laypeople (Shackleton et al., 2019).

Species: Perceptions are also influenced by the characteristics of the IAS. Some IAS have traits that make them favourable and thus they are perceived as being positive, while those that possess less favourable traits are perceived in a negative light (Kueffer and Kull, 2017). People will feel good about colourful plants such as the invasive jacaranda tree (*Jacaranda mimosifolia*) in South Africa, while having negative perceptions of thorny the giant sensitive plant (*Mimosa diplotricha*) in south eastern Ethiopia (Wakjira, 2011). The resident time of a species is also important as it influences perceptions in several ways. The longer the species' resident time the more readily it is perceived as a native species (Shackleton et al., 2007; Kull et al., 2014). Consequently, with longer resident time and as the species increases in abundance and its effects increase over time it may be perceived in a negative light (Shackleton et al., 2019).

Effects: Effects can be positive or negative depending on the economic, ecological and social context (Jeschke et al., 2014). The effects may vary between stakeholder groups resulting in conflict of interest (Zengeya et al., 2017; Shackleton et al., 2019). For example, the benefits of *Prosopis* on local livelihoods in South African rural communities which provides fuelwood and charcoal, compared to their counterparts practicing agriculture who experience negative effects such as the cost of clearing fields and livestock health (Shackleton et al., 2015). In such instances, perceptions of IAS will vary based on the benefits and costs accrued. Some species have benefits and little to no negative effects whilst others have inconsequential benefits with substantial negative effects, this goes on to support views that the effects of IAS are not uniform and will not be perceived the same through space and time (Shackleton et al., 2007).

Landscape context: The types of ecosystem, land use and land cover are some of the factors that influence perceptions in the landscape context. Perceptions of IAS in urban landscapes which are highly modified will vary significantly from rural lands and conservation areas which remain unchanged (Shackleton et al., 2015). Rural community members such as farmers perceived *Prosopis* in a negative light due to the negative impacts on livestock and crops, while urban informal settlers perceived it in a positive way due to benefits such as aesthetic value and acting as windbreaks (Shackleton et al., 2015). Similarly, a feral pig (*Sus scrof*) in Florida, USA, has negative aesthetic implications across various areas such as three state parks, forest and wetlands (Engeman et al., 2003).

Socio-cultural context: This refers to the interaction of people through various social systems such as beliefs, rules, traditions, practices and ideas which advertently shape perceptions (Kull et al., 2011). Perceptions may also be influenced directly or indirectly through shared conversations and practices as well as media and educational structures (Shackleton et al., 2019). The manner in which people react to IAS may also be influenced by land ownership (i.e. government, private or communal) and access to use, this is because even on private land (i.e. in South Africa) the control of IAS is still regarded as dilemma for the government (Urgenson et al., 2013). Failed attempts at management and previous disputes may also influence people's perceptions (Middleton, 2012).

Institutional, governance and policy context: This represents a formalised structure of socio-cultural structures (Shackleton et al., 2019). Historical efforts to control IAS through governance and policies has taken place at local, regional and national levels and had previously focused on agriculture (Kueffer and Kull, 2017). Therefore, the emphasis on boundaries and differences between local, regional areas and countries influences how people perceive IAS (Kueffer, 2013; Kueffer and Kull, 2017). Legislation in the early days called for people to manage IAS, and with time government and institutional organisations took over role of management (Shackleton et al., 2019). This was due to the need for more research and the lack of capacity by individuals which potentially influenced perceptions on responsibility for control (Urgenson et al., 2013). Recent policies now include wider scopes of biodiversity, ecosystem services, human well-being and livelihoods (Foxcroft et al., 2017).

The increase in global trade and travel has also seen increase in the spread of IAS (Seebens et al., 2017). This has prompted international organisations to be widely involved in the management of IAS through policies and treaties to try and stop invasions, and some of these include the Convention on International Trade in Endangered Species (CITES), International Plant Protection Convention (IPPC) and United Nations Convention on Biological Diversity (CBD) (Fisher, 2005; Campbell et al., 2009; Keller and Lodge, 2010). There may be differences in the local, regional, and national policies which can influence perceptions. For example, protection of native vegetation in India resulted in individuals resorting to use of IAS as an alternative source because these are not protected by law (Nesper et al., 2017; Shackleton et al., 2019).

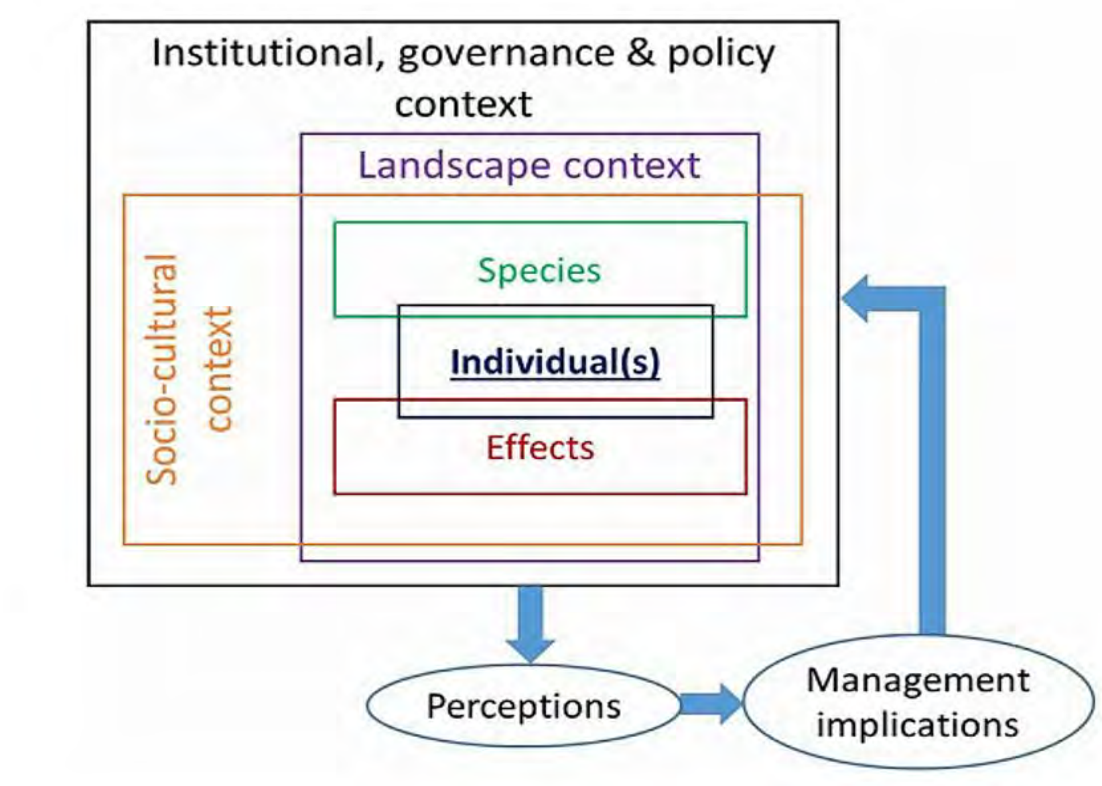

Figure 2.1 A conceptual framework of the primary factors that influence peoples' perceptions of invasive alien species.

2.6 Study species

2.6.1 *Lantana camara* characteristics

Lantana camara originates from tropical regions of Central and South America (Ghisalberti, 2000). It belongs to the Verbenaceae family and there are over 600 varieties of *L. camara* worldwide (Priyanka and Joshi, 2013). It is an evergreen, multi stemmed thorny shrub with an average height of 2 m, in some instances potentially growing beyond 4 m (Sharma et al., 1981; Swarbrick, 1998). The mature leaves of *L. camara* are rough and give off an appalling odour (Sharma et al., 1981; Sharma, 2007). The leaves can grow between 5-9 cm long and take many shapes from ovate, oblong to rounded and not rounded (Sharma et al., 1981). The fleshy fruits are 0.5 cm in diameter and are green which turn dark purple to black when ripe (Sharma et al., 1981, 1988, 2005).

Flowers of *L. camara* occur in clusters and take on a variety of colours (Priyanka and Joshi, 2013). *Lantana camara* flowers all year round when light and moisture are present, and only flowers in wetter and hotter months in drier regions (Swarbrick, 1998). The natural propagation of *L. camara* is mainly from seeds dispersed from fruit eating bird via droppings (Sharma et al., 1988; Priyanka and Joshi, 2013). *Lantana camara* also reproduces vegetatively through layering, which is a process where the stems and cuttings of *L. camara* begin to establish after coming into contact with soil moisture (Walton, 2006; Priyanka and Joshi, 2013). Seed germination is facilitated by anthropogenic disturbances (fire, construction, slashing), and seeds are viable for up to 2-5 years (Priyanka and Joshi, 2013).

2.6.2 Benefits and costs of *L. camara*

Lantana camara has a wide variety of uses (Pejchar and Mooney, 2009). The plant is widely used as an ornament (Cilliers, 1983; Day et al., 2003; Vardien et al., 2012) due to its variety of colourful flowers (Semenya et al., 2012a). The alkaloids contained in the plant have the following properties; antibacterial, anti-inflammatory, anti-microbial and anti-tumour (Patel, 2011; Bhagwat et al., 2012), which have the potential to be utilized in the field of medicine. Other medicinal uses include use as lotion for leprous ulcers (Ghisalberti, 2000), oil from *L. camara* is used as an antiseptic on wounds (Dabur et al., 2007; Kurade et al., 2010), the boiled water decoction is used to treat drug related poisonings of the liver and kidneys (Nayak et al., 2008). Sathish et al. (2011) reported the leaves of *L. camara* to be potentially antioxidant. *Lantana camara* has been used as a nematicide against nematodes such as the *Meloidogyne javanica* (Ali et al., 2001). In India the plant has been used as raw material for craftwork (Kannan et al., 2014) such as making baskets and furniture (Patel, 2011; Kannan et al., 2014). Community members of Garhwal Himalaya use *L. camara* for fuelwood (Kumar and Sharma, 2009). Furthermore, it enriches soil with nitrogen thus improving the soil quality

(Patel, 2011). *Lantana camara* biomass is also used as a substrate in the production of biogas and bioethanol (Pathak et al., 2005; Patel, 2011).

The impacts of *L.camara* alter ecosystems and their ability to function through processes such as the addition and removal of resources, such as the increase in soil pH (Ruwanza and Shackleton, 2016). In different regions around the globe including South Africa, *L. camara* has reduced the diversity of ground dwelling invertebrates, suppressed regeneration of native vegetation via allelopathy, and the poisoning of livestock (van Wilgen et al., 2001; Vardien et al., 2012). The dense thickets of *L. camara* obstruct access and utilisation to certain parts of land and also outcompetes native vegetation (Day et al., 2003; Sundaram et al., 2012; Vardien et al., 2012) and in some instances displacing human beings (Shackleton et al., 2017). *Lantana camara* has been reported to reduce the economic viability of crops through its allelopathic properties which reduce vigour of crops and other native plants (Day et al., 2003; Sharma et al., 2005). Exposure of the plant on human skin causes skin irritation and itching (Day et al., 2003), and it gives off a bad odour when touched (Sharma, 2007).

2.6.3 *Lantana camara* in South Africa

Lantana camara, a notorious global invasive shrub originating from tropical and subtropical South and Central America, has invaded approximately two million hectares of land in South Africa (Urban et al., 2011). *Lantana camara* was first recorded in South Africa in the 1850s (Baars and Neser, 1999) and the plant is widespread throughout the country having invaded all South African provinces and is found within 7 of the 9 South African biomes (Vardien et al., 2012). It is genetically diverse and has a tolerance for a wide range of environmental conditions (Cilliers, 1983; Day et al., 2003). More than 50 varieties of *L. camara* occur in South Africa alone (Spies and Stirton, 1982a, 1982b).

It is listed as a category 1b species which makes it prohibited from trade and planting (NEMBA Act 10 of 2004). It is most prominent in warmer moist areas than the drier areas of the country (Baars and Neser, 1999; Bhagwat et al., 2012; Vardien et al., 2012). Its occurrence in the drier areas is restricted to riparian areas and compact gardens (Vardien et al., 2012). Future projection on distribution shows northern parts of Limpopo, Mpumalanga and coastal areas such as Western Cape province to have suitable climate for *L. camara* expansion (Subhashni and Lalit, 2014).

2.6.4 Management of *L. camara* in South Africa

Efforts to control *L. camara* through mechanical, chemical and biological control have been established in South Africa (Vardien et al., 2012). Much of the alien plant control is done by the Working for Water (WfW) programme which was established in 1995 with the objectives of reducing water loss through the reduction of terrestrial IAS nationwide and poverty alleviation through employment of community members (Beater et al., 2008). Control of *L. camara* by WfW is mostly though integrated means i.e., mechanical cutting the plants as close to the stem base as possible and adding an herbicide to prevent re-sprouting.

Biological control of *L. camara* dates back to 1902, where insect species from Mexico were introduced to Hawaii in the year 1902 (Perkins et al., 1924), soon after countries such as Australia followed suit in 1914 (Day et al., 2003b) with South Africa later on in 1961 (Baars et al., 2003). Biological control of *L. camara* has had success from other regions in the world, for example, the unintended release of insects in Mauritius that stopped its emergence as a major weed (Fowler et al., 1999). Despite success stories there has been some failures of biological control in South Africa and other regions on the globe (Mukwevho et al., 2018). The inconsistency in performance of biological control is due to a number of factors such as the different varieties of the weed (Cilliers and Neser, 1991), high levels of parasitism on control agents, and distribution of control agents due to climate (Day and Neser, 2000). An example of climate as a factor was reported by Day et al. (2003) where inland regions of Queensland and central Queensland had low numbers of the biological control agent (leaf-feeding Lepidoptera) due to low rainfall (700 mm).

The mismatch between the agents and plant varieties may be attributed to the different genetic varieties of the plant. There are over 50 varieties of the plant recognised in South Africa (Spies, 1984). Some biocontrol agents prefer some varieties over others, for example *T. scrupulosa* was found not to be as efficient on the pink variety as compared to other varieties (Cilliers and Neser, 1991; Katembo et al., 2020). Predation and parasitism encountered by the agents in the field, for example *O. scabripennis* being attacked by birds, spiders and other predatory insects (Heystek and Olckers, 2003). Climatic conditions are also significant factors that affect the distribution patterns of the biocontrol agents (Urban et al., 2011), for example *T. scrupulosa* was found to cause more damage to the plant during the dry season as compared to the wet season (Thakur et al., 1992). Thus, the current biological control options are not adequate enough to eradicate the plant and to prevent its spread (Urban et al., 2011). In South Africa biological control only acts as a supplement to mechanical and chemical control as it neither stops nor kills the plant but only reduces its rate of reproduction and growth (Urban et al., 2011).

Biological control has been widely established in many countries and has proven least effective in places affected by *L. camara*, the weed is not killed, or its spread suppressed (Katembo et al., 2020). Biological control plays a supporting role, it helps minimise the combined costs of chemical and mechanical control (Urban, 2010; Urban et al., 2011). In the 1960s the following *L. camara* biocontrol agents, leaf chewing moth *Neogalea sunia*, leaf chewing moth *Salbia haemorrhoidalis*, leaf sucking bug *Teleonemia scrupulosa*, leaf chewing moth *Hypena laceratalis*, and fruit mining fly *Ophiomyia lantanae* were introduced into South Africa (Baars and Neser, 1999). However, *H. laceratalis* and *O. lantanae* were already present in the country (Cilliers, 1983; Cilliers and Neser, 1991).

Since then, new biological agents have been developed and released e.g., *Acedia lantanae* a flower galling mite, *Coelocephalapion camarae* a petiole galling beetle, *Falconia intermedia* a leaf sucking bug, *Longitarsus bethae* a root chewing beetle, *Ophiomyia camarae* a leaf mining fly and *Passalora lantanae var. lantanae* a fungus (Urban et al., 2011). *Teleonemia scrupulosa* became established throughout South Africa, while *H. laceratalis* and *N. sunia* failed to establish (Cilliers, 1983). *Neogalea sunia* laboratory cultures became wiped out by an unknown disease (Cilliers, 1983), whilst *T. scrupulosa* and *Octotoma scabripennis* were reported to have caused significant damage to the plant through defoliation, however not to the degree where the plant was brought under control (Urban et al., 2011). Predictions were done to measure the outcome of the introductions. Two of the newly developed agents, *O. camarae* and *A. lantanae* exceeded the predicted outcomes, while the remaining agents failed to live up to predictions, implying the outcomes were overestimated (Urban et al., 2011). Recent studies (e.g., Urban et al., 2011; Katembo et al., 2020) suggest that the biocontrol agents only managed to reduce the plants' vigour.

Several herbicides are available for use against *L. camara* as a form of chemical control. *Lantana camara* regrows vigorously after herbicide treatment and regrowth should be sprayed again, this makes chemical control expensive (Cilliers, 1983; Urban et al., 2011; Vardien et al., 2012). Mechanical control of *L. camara* involves uprooting small plants and seedlings by hand, making use of tractors for larger thick stemmed plants that are above one metre in height (Cilliers, 1983; Vardien et al., 2012), and all the plants cut down should be heaped up allowed to dry then burned. While the combination of mechanical and chemical control is the most widely used and effective method in reducing *L. camara* populations in South Africa, the method is costly and labour intensive (Vardien et al., 2012).These methods only offer a temporal solution to the problem (Urban et al., 2011). Thus, the management and control of the plant through its utilisation is an avenue which should be explored more (Patel, 2011).

References

Ali, N.I., Siddiqui, A., Zaki, M.J., Shaukat, S.S., 2001. Nematicidal potential of *Lantana camara* against *Meloidogyne javanica* in Mungbean [*Vigna radiata (L.*) Wilczek]. Nematologia Mediterranea (Italy).

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

Baars, J.R., Urban, A.J., Hill, M.P., 2003. Biology, host range, and risk assessment supporting release in Africa of *Falconia intermedia* (Heteroptera: Miridae), a new biocontrol agent for *Lantana camara*. Biological Control 28, 282-292.

Beater, M., Garner, R., Witkowski, E., 2008. Impacts of clearing invasive alien plants from 1995 to 2005 on vegetation structure, invasion intensity and ground cover in a temperate to subtropical riparian ecosystem. South African Journal of Botany 74, 495-507.

Beck, K.G., Zimmerman, K., Schardt, J.D., Stone, J., Lukens, R.R., Reichard, S., Randall, J., Cangelosi, A.A., Cooper, D., Thompson, J.P., 2008. Invasive species defined in a policy context: Recommendations from the Federal Invasive Species Advisory Committee. Invasive Plant Science and Management 1, 414-421.

Berkes, F., Colding, J., Folke, C., 2000. Rediscovery of traditional ecological knowledge as adaptive management. Ecological Applications 10, 1251-1262.

Bhagwat, S.A., Breman, E., Thekaekara, T., Thornton, T.F., Willis, K.J., 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.

Campbell, M.L., Grage, A., Mabin, C., Hewitt, C.L., 2009. Conflict between international treaties: Failing to mitigate the effects of introduced marine species. Dialogue 28, 46-56.

Cilliers, C.J., 1983. The weed, *Lantana camara L*., and the insect natural enemies imported for its biological control into South Africa. Journal of the Entomological Society of Southern Africa 46, 131-138.

Cilliers, C.J., Neser, S., 1991. Biological control of *Lantana camara* (Verbenaceae) in South Africa. Agriculture, ecosystems and environment 37, 57-75.

Crall, A.W., Newman, G.J., Jarnevich, C.S., Stohlgren, T.J., Waller, D.M., Graham, J., 2010. Improving and integrating data on invasive species collected by citizen scientists. Biological Invasions 12, 3419-3428.

Dabur, R., Gupta, A., Mandal, T.K., Singh, D.D., Bajpai, V., Gurav, A.M., Lavekar, G.S., 2007. Antimicrobial activity of some Indian medicinal plants. African Journal of Traditional, Complementary and Alternative Medicines 4, 313-318.

Day, M.D., Broughton, S., Hannan-Jones, M.A., 2003. Current distribution and status of *Lantana camara* and its biological control agents in Australia, with recommendations for further biocontrol introductions into other countries. Biocontrol News and Information 24, 63-76.

Day, M.D., Neser, S., 2000. Factors influencing the biological control of *Lantana camara* in Australia and South Africa, in: Proceedings of the X Symposium on Biological Control of Weeds. pp. 897-908.

Dehnen-Schmutz, K., Touza, J., Perrings, C., Williamson, M., 2007. A century of the ornamental plant trade and its impact on invasion success. Diversity and Distributions 13, 527-534.

De Wit, M.P., Crookes, D.J., van Wilgen, B.W., 2001. Conflicts of interest in environmental management: Estimating the costs and benefits of a tree invasion. Biological Invasions 3, 167-178.

Dzikiti, S., Schachtschneider, K., Naiken, V., Gush, M., Moses, G., Le Maitre, D.C., 2013. Water relations and the effects of clearing invasive *Prosopis* trees on groundwater in an arid environment in the Northern Cape, South Africa. Journal of Arid Environments 90, 103-113.

Engeman, R.M., Smith, H.T., Shwiff, S.A., Constantin, B., Woolard, J., Nelson, M., Griffin, D., 2003. Prevalence and economic value of feral swine damage to native habitat in three Florida state parks. Environmental Conservation 30, 319-324.

Ferreira-Rodríguez, N., Pavel, A.B., Cogălniceanu, D., 2020. Integrating expert opinion and traditional ecological knowledge in invasive alien species management: *Corbicula* in Eastern Europe as a model. Biological Invasions, 1-13.

Fisher, J.P., 2005. An overview of international initiatives, treaties, agreements, and management actions addressing alien invasive species. The way forward: Building capacity to combat impacts of aquatic invasive alien species and associated trans-boundary pathogens.

Fowler, S.V., Ganeshan, S., Mauremootoo, J., Mungroo, Y., 1999. Biological control of weeds in Mauritius: past successes revisited and present challenges, in: Proceedings of the X International Symposium on Biological Control of Weeds. Citeseer, pp. 4-14.

Foxcroft, L.C., Pyšek, P., Richardson, D.M., Genovesi, P., MacFadyen, S., 2017. Plant invasion science in protected areas: Progress and priorities. Biological Invasions 19, 1353-1378.

Gaertner, M., Larson, B.M., Irlich, U.M., Holmes, P.M., Stafford, L., van Wilgen, B.W., Richardson, D.M., 2016. Managing invasive species in cities: A framework from Cape Town, South Africa. Landscape and Urban Planning 151, 1-9.

Ghisalberti, E.L., 2000. *Lantana camara L.* (Verbenaceae). Fitoterapia 71, 467-486.

Gómez-Baggethun, E., Mingorria, S., Reyes-García, V., Calvet, L., Montes, C., 2010. Traditional ecological knowledge trends in the transition to a market economy: Empirical study in the Doñana natural areas. Conservation Biology 24, 721-729.

Gómez-Baggethun, E., Reyes-García, V., 2013. Reinterpreting change in traditional ecological knowledge. Human Ecology 41, 643-647.

Gulizia, J.P., Downs, K.M., 2019. A review of Kudzu's use and characteristics as potential feedstock. Agriculture 9, 220.

Heystek, F., Olckers, T., 2003. Impact of the *Lantana* mirid in South Africa. Presented at the Proceedings of the eleventh International Symposium on Biological Control of Weeds, p. 606.

Jeschke, J.M., Bacher, S., Blackburn, T.M., Dick, J.T., Essl, F., Evans, T., Gaertner, M., Hulme, P.E., Kühn, I., Mrugala, A., 2014. Defining the impact of non-native species. Conservation Biology 28, 1188-1194.

Kannan, R., Shackleton, C.M., Shaanker, R.U., 2014. Invasive alien species as drivers in socio-ecological systems: Local adaptations towards use of *Lantana* in Southern India. Environment Development and Sustainability 16, 649-669.

Kapitza, K., Zimmermann, H., Martín-López, B., von Wehrden, H., 2019. Research on the social perception of invasive species: A systematic literature review. NeoBiota 43, 47.

Katembo, N., Witkowski, E.T., Simelane, D.O., Urban, A.J., Byrne, M.J., 2020. Impact of biocontrol agents on *Lantana camara* in an inland area of South Africa. BioControl 1–12.

Keller, R.P., Lodge, D.M., 2010. Prevention: Designing and implementing national policy and management programs to reduce the risks from invasive species. Bioinvasions and globalization: Ecology, Economics, Management, and Policy 220.

Kowarik, I., Lippe, M., Cierjacks, A., 2013. Prevalence of alien versus native species of woody plants in Berlin differs between habitats and at different scales. Preslia, 85, 113-132.

Kueffer, C., 2013. Integrating natural and social sciences for understanding and managing plant invasions. Biodiversity and Society in the Pacific Islands 71-96.

Kueffer, C., Kull, C.A., (Eds). 2017. Non-native species and the aesthetics of nature, in: Vilà, M., Hulme, P.E. Impact of biological invasions on ecosystem services. Springer International Publishing, Cham, pp. 311-324.

Kull, C.A., Shackleton, C.M., Cunningham, P.J., Ducatillon, C., Dufour-Dror, J.M., Esler, K.J., Friday, J.B., Gouveia, A.C., Griffin, A.R., Marchante, E., Midgley, S.J., Pauchard, A., Rangan, H., Richardson, D.M., Rinaudo, T., Tassin, J., Urgenson, L.S., von Maltitz, G.P., Zenni, R.D., Zylstra, M.J., 2011. Adoption, use and perception of Australian acacias around the world: Adoption, use, and perception of Australian acacias. Diversity and Distributions 17, 822-836.

Kull, C.A., Tassin, J., Carrière, S.M., 2014. Approaching invasive species in Madagascar. Madagascar Conservation and Development 9, 60-70.

Kumar, M., Sharma, C.M., 2009. Fuelwood consumption pattern at different altitudes in rural areas of Garhwal Himalaya. Biomass and Bioenergy 33, 1413-1418.

Kurade, N.P., Jaitak, V., Kaul, V.K., Sharma, O.P., 2010. Chemical composition and antibacterial activity of essential oils of *Lantana camara*, *Ageratum houstonianum* and *Eupatorium adenophorum.* Pharmaceutical Biology 48, 539-544.

Le Maitre, D.C., Blignaut, J.N., Clulow, A., Dzikiti, S., Everson, C.S., Görgens, A.H. and Gush, M.B., 2020. Impacts of plant invasions on terrestrial water flows in South Africa. In Biological Invasions in South Africa pp. 431-457. Springer, Cham.

McLean, P., Gallien, L., Wilson, J.R., Gaertner, M., Richardson, D.M., 2017. Small urban centres as launching sites for plant invasions in natural areas: Insights from South Africa. Biological Invasions 19, 3541-3555.

Middleton, K., 2012. Renarrating a biological invasion: Historical memory, local communities and ecologists. Environment and History 61–95.

Mukwevho, L., Olckers, T., Simelane, D.O., 2018. Occurrence of different *Lantana camara* varieties across four South African provinces and their susceptibility to a biotype of the gall-forming mite *Aceria lantanae*. Biocontrol Science and Technology 28, 377-387.

Nayak, B.S., Raju, S.S., Ramsubhag, A., 2008. Investigation of wound healing activity of *Lantana camara L*. in Sprague dawley rats using a burn wound model. International Journal of Applied Research in Natural Products 1, 15-19.

Nesper, M., Kueffer, C., Krishnan, S., Kushalappa, C.G., Ghazoul, J., 2017. Shade tree diversity enhances coffee production and quality in agroforestry systems in the Western Ghats. Agriculture, Ecosystems and Environment 247, 172-181.

Ngorima, A., Shackleton, C.M., 2019. Livelihood benefits and costs from an invasive alien tree (*Acacia dealbata*) to rural communities in the Eastern Cape, South Africa. Journal of Environmental Management 229, 158-165.

O'Connor, T.G., van Wilgen, B.W., 2020. The impact of invasive alien plants on rangelands in South Africa. In Biological Invasions in South Africa pp. 459-487. Springer, Cham.

Patel, S., 2011. A weed with multiple utility: *Lantana camara.* Reviews in Environmental Science and Bio/Technology 10, 341-351.

Pathak, P., Singh, A., Pandey, P., Rupainwar, D., 2005. Investigations on production of biogas using *Lantana* leaves and cow dung mixtures. Indian Journal of Environmental Protection 25, 1033.

Pejchar, L., Mooney, H.A., 2009. Invasive species, ecosystem services and human well-being. Trends in Ecology and Evolution 24, 497-504.

Perkins, R.C.L., Swezey, O.H., 1924. The introduction into Hawaii of insects that attack *Lantana*. Bulletin of the Experiment Station of the Hawaiian Sugar Planters' Association 16, 1-83.

Pfeiffer, J.M., Voeks, R.A., 2008. Biological invasions and biocultural diversity: Linking ecological and cultural systems. Environmental Conservation 281-293.

Potgieter, L.J., Douwes, E., Gaertner, M., Measey, J., Paap, T., Richardson, D.M., 2020. Biological invasions in South Africa's urban ecosystems: Patterns, processes, impacts, and management. In Biological Invasions in South Africa pp. 275-309. Springer, Cham.

Priyanka, N., Joshi, P.K., 2013. A review of *Lantana camara* studies in India. International Journal of Scientific and Research Publications 3, 1-11.

Ramalivhana, J.N., Moyo, S.R., Obi, C.L., 2010. The possible role of medicinal plants in tackling resistant microbial pathogens in Limpopo Province, South Africa. Journal of Medicinal Plants Research 4, 999-1002.

Reynolds, C., Venter, N., Cowie, B.W., Marlin, D., Mayonde, S., Tocco, C., Byrne, M.J., 2020. Mapping the socio-ecological impacts of invasive plants in South Africa: Are poorer households with high ecosystem service use most at risk? Ecosystem Services 42, 101075.

Ricciardi, A., Blackburn, T.M., Carlton, J.T., Dick, J.T., Hulme, P.E., Iacarella, J.C., Jeschke, J.M., Liebhold, A.M., Lockwood, J.L., MacIsaac, H.J., 2017. Invasion science: A horizon scan of emerging challenges and opportunities. Trends in Ecology and Evolution 32, 464-474.

Richardson, D.M., Foxcroft, L.C., Latombe, G., Le Maitre, D.C., Rouget, M., Wilson, J.R., 2020. The biogeography of South African terrestrial plant invasions. In Biological Invasions in South Africa pp. 67-96. Springer, Cham.

Richardson, D.M., Wilson, J.R., Weyl, O.L.F., Griffiths, C.L., (Eds). 2011. South Africa: Invasions, in D. Simberloff, M. Rejmánek. Encyclopedia of biological invasions, pp. 643–651, University of California Press, Berkeley, CA.

Richardson, D.M., van Wilgen, B.W., 2004. Invasive alien plants in South Africa: How well do we understand the ecological impacts? South African Journal of Science 100. 45-52.

Rodríguez-Martínez, R.E., 2008. Community involvement in marine protected areas: The case of Puerto Morelos reef, México. Journal of Environmental Management 88, 1151-1160.

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

Saylor, C.R., Alsharif, K.A., Torres, H., 2017. The importance of traditional ecological knowledge in agroecological systems in Peru. International Journal of Biodiversity Science, Ecosystem Services and Management 13, 150-161.

Schermerhorn, J., Hunt, J., Obson, R., 2000. Organizational Behavior. McGraw – Hill, New York

Seebens, H., Blackburn, T.M., Dyer, E.E., Genovesi, P., Hulme, P.E., Jeschke, J.M., Pagad, S., Pyšek, P., Winter, M., Arianoutsou, M., 2017. No saturation in the accumulation of alien species worldwide. Nature communications 8, 1-9.

Semenya, S., Potgieter, M., Tshisikhawe, M., Shava, S., Maroyi, A., 2012a. Medicinal utilization of exotic plants by Bapedi traditional healers to treat human ailments in Limpopo province, South Africa. Journal of Ethnopharmacology 144, 646-655.

Semenya, S., Tshisikhawe, M.P., Potgieter, M.T., 2012b. Invasive alien plant species: A case study of their use in the Thulamela Local Municipality, Limpopo Province, South Africa. Scientific Research and Essays 7, 2363-2369.

Semenya, S., Maroyi, A., 2018. Exotic plants used therapeutically by Bapedi traditional healers for respiratory infections and related symptoms in the Limpopo province, South Africa. Indian Journal of Traditional Knowledge 17, 663-671.

Shackleton, C.M., Gambiza, J., 2008. Social and ecological trade-offs in combating land degradation: The case of invasion by a woody shrub (*Euryops Floribundus*) at Macubeni, South Africa. Land Degradation and Development. 19, 454-464.

Shackleton, C.M., McGarry, D., Fourie, S., Gambiza, J., Shackleton, S.E., Fabricius, C., 2007. Assessing the effects of invasive alien species on rural livelihoods: Case examples and a framework from South Africa. Human Ecology 35, 113-127.

Shackleton, R.T., Le Maitre, D.C., Richardson, D.M., 2015. Stakeholder perceptions and practices regarding *Prosopis* (mesquite) invasions and management in South Africa. Ambio 44, 569-581.

Shackleton, R.T., Le Maitre, D.C., van Wilgen, B.W., Richardson, D.M., 2016. Identifying barriers to effective management of widespread invasive alien trees: *Prosopis* species (mesquite) in South Africa as a case study. Global Environmental Change 38, 183-194.

Shackleton, R.T., Richardson, D.M., Shackleton, C.M., Bennett, B., Crowley, S.L., Dehnen-Schmutz, K., Estévez, R.A., Fischer, A., Kueffer, C., Kull, C.A., Marchante, E., Novoa, A., Potgieter, L.J., Vaas, J., Vaz, A.S., Larson, B.M.H., 2019. Explaining people's perceptions of invasive alien species: A conceptual framework. Journal of Environmental Management 229, 10-26.

Shackleton, R.T., Witt, A.B., Aool, W., Pratt, C.F., 2017. Distribution of the invasive alien weed, *Lantana camara*, and its ecological and livelihood impacts in eastern Africa. African Journal of Range and Forage Science 34, 1-11.

Shackleton, S., Kirby, D., Gambiza, J., 2011. Invasive plants–friends or foes? Contribution of prickly pear (*Opuntia ficus-indica*) to livelihoods in Makana Municipality, Eastern Cape, South Africa. Development Southern Africa 28, 177-193.

Sharma, G.P., 2007. Effect of *Lantana Camara L.* cover on local depletion of tree population in The Vindhyan Tropical Dry Deciduous Forest of India. Applied Ecology and Environmental Research 5, 109-121.

Sharma, G.P., Raghubanshi, A.S., Singh, J.S., 2005. *Lantana* invasion: An overview. Weed Biology and Management 5, 157-165.

Sharma, O.P., Makkar, H.P.S., Dawra, R.K., 1988. A review of the noxious plant *Lantana camara*. Toxicon 26, 975-987.

Sharma, O.P., Makkar, H.P.S., Dawra, R.K., Negi, S.S., 1981. A review of the toxicity of *Lantana camara* (*Linn*) in animals. Clinical Toxicology 18, 1077-1094.

Simberloff, D., Martin, J.L., Genovesi, P., Maris, V., Wardle, D.A., Aronson, J., Courchamp, F., Galil, B., García-Berthou, E., Pascal, M., 2013. Impacts of biological invasions: What's what and the way forward. Trends in Ecology and Evolution 28, 58-66.

Spies, J.J., 1984. A cytotaxonomic study of *Lantana camara* (Verbenaceae) from South Africa. South African Journal of Botany 3, 231-250.

Spies, J.J., Stirton, C.H., 1982a. Embryo sac development in some South African cultivars of *Lantana camara*. Bothalia 14, 113-117.

Spies, J.J., Stirton, C.H., 1982b. Meiotic studies of some South African cultivars of *Lantana camara* (Verbenaceae). Bothalia 14, 101-111.

Subhashni, T., Lalit, K., 2014. Impacts of climate change on invasive *Lantana camara L*. distribution in South Africa. African Journal of Environmental Science and Technology 8, 391-400.

Sundaram, B., Krishnan, S., Hiremath, A.J., Joseph, G., 2012. Ecology and impacts of the invasive species, *Lantana camara*, in a social-ecological system in South India: Perspectives from local knowledge. Human Ecology 40, 931-942.

Swarbrick, J.T., Willson, B.W., Hannan-Jones. M.A., 1998. *Lantana camara L*. In: Panetta FD, Groves RH, Sheperd RCH, editors. The biology of Australian weeds. Meredith, Victoria: RG and FJ Richardson, 119-140.

Thakur, M., Mukhtar, A., Thakur, R.K., 1992. *Lantana* weed (*Lantana camara var. aculeata Linn*.) and its possible management through natural insect pests in India. Indian Forester 118, 466-488.

Urban, A., 2010. *Lantana* control recommendations. SAPIA News 16, 2.

Urban, A.J., Simelane, D.O., Retief, E., Heystek, F., Williams, H.E., Madire, L.G., 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.

Urgenson, L.S., Prozesky, H.E., Esler, K.J., 2013. Stakeholder perceptions of an ecosystem services approach to clearing invasive alien plants on private land. Ecology and Society 18, 26.

van Wilgen, B.W., 2009. The evolution of fire and invasive alien plant management practices in fynbos. South African Journal of Science 105, 335-342.

van Wilgen, B.W., Forsyth, G.G., Le Maitre, D.C., Wannenburgh, A., Kotzé, J.D., 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.

van Wilgen, B.W., Measey, J., Richardson, D.M., Wilson, J.R., Zengeya, T.A., 2020. Biological invasions in South Africa: An overview. In Biological Invasions in South Africa pp. 3-31. Springer, Cham.

van Wilgen, B.W., Richardson, D.M., 2014. Challenges and trade-offs in the management of invasive alien trees. Biological Invasions 16, 721-734.

van Wilgen, B.W., Richardson, D.M., Le Maitre, D.C., Marais, C., Magadlela, D., 2001. The economic consequences of alien plant invasions: Examples of impacts and approaches to sustainable management in South Africa. Environment, Development and Sustainability 3, 145-168.

Van Wyk, B.E., De Wet, H., Van Heerden, F.R., 2008. An ethnobotanical survey of medicinal plants in the southeastern Karoo, South Africa. South African Journal of Botany 74, 696-704.

Vardien, W., Richardson, D.M., Foxcroft, L.C., Thompson, G.D., Wilson, J.R., Le Roux, J.J., 2012. Invasion dynamics of *Lantana camara L.* (sensu lato) in South Africa. South African Journal of Botany 81, 81-94.

Von Glasenapp, M., Thornton, T.F., 2011. Traditional ecological knowledge of Swiss alpine farmers and their resilience to socioecological change. Human Ecology 39, 769-781.

Wakjira, M., 2011. An invasive alien weed giant sensitive plant (*Mimosa diplotricha Sauvalle*) invading Southwestern Ethiopia. African Journal of Agricultural Research 6, 127-131.

Walton, C., 2006. Global invasive species database: *Lantana camara*. Department of Natural Resources, Queensland, Australia and IUCN/SSC Invasive Species Specialist Group.

Warren, D.M., 1996. Indigenous knowledge, biodiversity conservation and development. Sustainable development in third world countries. Applied and Theoretical Perspectives 81–88.

Zengeya, T., Ivey, P., Woodford, D.J., Weyl, O., Novoa, A., Shackleton, R., Richardson, D., van Wilgen, B., 2017. Managing conflict-generating invasive species in South Africa: Challenges and trade-offs. Bothalia-African Biodiversity and Conservation 47, 1-11.

Zent, S., 2001. Acculturation and ethnobotanical knowledge loss among the Piaroa of Venezuela: Demonstration of a quantitative method for the empirical study of TEK change. On biocultural diversity. Linking language, Knowledge, and the Environment 190-211.

Chapter 3: Perceptions of the Role of *L. camara* on Human Well-being and Rural Livelihoods in Vhembe Biosphere Reserve, South Africa

3.1 Introduction

Invasive alien species (IAS) are one of the major significant drivers of global change that have detrimental impacts on the environment and humans (Pimentel et al., 2001, 2005). Their success in invaded areas is dependent on factors such as the absence of predators and competitors, increase in global trade, and changing climatic conditions (Hobbs and Mooney, 2000; Hulme, 2009; Zerebecki and Sorte, 2011). Invasive alien plants (IAPs) like many other IAS alter the invaded community in many ways that include changes in native species diversity, changing major ecosystem functions and impacting human well-being (Ehrenfeld, 2003; Pejchar and Mooney, 2009; Simberloff et al., 2013). Research into biological invasions has been an instrumental tool in guiding management decisions that are aimed at reducing costs associated with IAS and in other instances to improve the benefits provided by such species (Shackleton et al., 2015a). However, most research on the impacts of IAS is traditionally from an ecological perspective and does not take into account the social dimension of biological invasions (Egoh et al., 2008; Sundaram et al., 2012; Shackleton et al., 2017b). Studies that assess the perceptions, knowledge and practices regarding IAS often highlight the needs, wants, drivers, negative impacts, and attitudes towards IAS (Shackleton et al., 2007; Rai et al., 2012). These studies can provide important insights into whether IAS possesses both harmful and beneficial traits which may cause conflicts (Shackleton et al., 2015a, 2017b). For example, *Prosopis* (mesquite) provides fodder and fuelwood, but also has adverse impacts for farmers in South Africa (Shackleton et al., 2015a, 2015b, 2015c).

Southern Africa is one of the regions in the world which is severely affected by IAS, and most IAS are widespread in rural areas (Macdonald et al., 2003). According to Jevon and Shackleton (2015) approximately 20 million people in South Africa are living in rural areas, and are dependent on collection of wild resources, arable land and livestock agriculture for their households (Shackleton et al., 2007). South Africa is amongst the most biologically diverse nations in the world which is at the helm of investigating biological invasions and their control (Jevon and Shackleton, 2015; van Wilgen et al., 2020). A flagship control programme, Working for Water (WfW) established in 1995 is geared at the eradication of IAS and poverty alleviation through employment of people from disadvantaged backgrounds to clear IAS (Euston-Brown et al., 2007; van Wilgen et al., 2012). Despite achieving success in some areas, the programme has faced many challenges (van Wilgen and Wannenburgh, 2016). Some of the challenges included the conflict of interests for both beneficial and harmful species, focusing scarce resources to certain projects due to limited budget, lack of monitoring programmes which are often expensive to implement due to a plethora of factors such as differences in spatial and time scales, and collection of data on regular basis (van Wilgen and Wannenburgh, 2016). One of the most widespread IAS targeted by WfW is *L. camara* (Jevon and Shackleton, 2015).

Lantana camara is one of the worst weeds globally and it is ranked among the top 100 highest impacting species in the world (Batianoff and Butler, 2003). Similar to other IAS, it has adverse impacts on biodiversity, human well-being and ecosystem functions (Day and Neser, 2000). *Lantana camara* is an evergreen, thorny and multi-stemmed shrub consisting of many horticultural hybrids (Vardien et al., 2012; Priyanka and Joshi, 2013) which flowers all year round (Sharma et al., 2005) and reaches heights between 1-4 m and heights of about 8-15 m when supported by other vegetation (Swarbrick et al., 1998). Over 50 varieties of *L. camara* have been identified in South Africa (Spies and Stirton, 1982). It thrives in warm tropical, subtropical and temperate regions in open and unshaded areas (Sharma et al., 2005). Its distribution across many regions was due to human introduction as a popular ornamental plant, which later escaped into the wild and invaded natural habitat (Stirton, 1977; Sharma et al., 2005). In South Africa, the species is listed as a category 1b species. Category 1b species are prohibited from any form of trade or planting and are to be managed and where possible be removed or destroyed (NEMBA Act 10 of 2004).

Lantana camara has a number of adverse impacts including the disruption of ecological succession and decrease in biodiversity (Ghisalberti, 2000; Day et al., 2003a), reducing the economic viability of crops (Sharma et al., 2005; Vardien et al., 2012), outcompeting native vegetation which in turn affects agriculture (Sharma et al., 2005), altering species habitats (Jevon and Shackleton, 2015). Furthermore, *L. camara* harbours unwanted pests such as tsetse fly *(*Glossina spp.) which causes sleeping sickness (Day et al., 2003a). In Kenya, *L. camara* has been reported to reduce native natural resources such as medicinal plants (Shackleton et al., 2017a). The dense impenetrable thickets formed by *L. camara* impedes access to certain parts of land for humans and livestock (Sundaram et al., 2012; Vardien et al., 2012; Shackleton et al., 2017a). In India *L. camara* has invaded 13.2 million ha of land, and the cost of clearing the land is $70 per ha which is equivalent to ZAR1082 (Negi et al., 2019). Similarly, in Uganda Shackleton et al. (2017a) reported that rural communities incur costs between $400-500 (ZAR6182-7728) per annum of clearing *L. camara*. Despite the negative impacts, *L. camara* has some benefits for people and the environment (Day et al., 2003a; Semenya et al., 2012a; Sundaram et al., 2012; dos Santos et al., 2014; Kannan et al., 2014) some of which include use as medicine (Day et al., 2003a; Semenya et al., 2012a), making baskets and furniture (Kannan et al., 2014), use as a hedge (Ghisalberti, 2000; Day et al., 2003a).

Generalisations of IAS at global scale may differ from that of local scale because the responses to IAS by locals may range from being negative, positive and unnoticed depending on the local context (Shackleton et al., 2007). Invasive alien species are widespread in the Limpopo province of South Africa (Semenya et al., 2012a) and have many uses despite their detrimental impacts. Traditional healers in the Waterberg District of Limpopo province use the leaves of *Opuntia stricta* and *Schinus molle* while they are fresh to treat toothaches and chest pains (Maema et al., 2016). Species such as *Ricinus communis* are used to treat sores (Semenya et al., 2012b), *Argemone ochroleuca* is used to treat ailments such as Asthma (Maema et al., 2016). It is clear IAS play an important role in the livelihoods of communities in the Limpopo province (Semenya et al., 2012a, 2012b; Maema et al., 2016; Semenya and Maroyi, 2020). In light of this context, the aim the study was to 1) assess the local knowledge and perceptions of *L. camara* by Vhembe Biosphere Reserve communities and 2) to determine the effects of *L. camara* on human well-being and rural livelihoods in Vhembe Biosphere Reserve communities.

3.2 Methods

Research was conducted in line with Rhodes University and Ethical Standards guidelines and only commenced after it was approved by the relevant ethics committee (Rhodes University Ethics Number 2019-0795-799). Prior to commencement the research and its objectives were introduced to the local traditional leaders and ward councillors to provide a detailed insight to the purpose of the study. After getting permission from the relevant authorities, individuals were approached for their participation. This study used a qualitative approach to gain a better insight into the perceptions on the role of *L. camara*. The study collected primary data in the form of semi-structured questionnaire surveys.

3.2.1 Questionnaire survey

To assess the effects of *L. camara* invasion on human well-being and rural livelihoods as well as on local knowledge and perceptions data was collected using household questionnaire interviews. Purposive sampling method was used in this study. Following a reconnaissance survey in the study area six villages namely, Duthuni, Matshavhawe, Tshakhuma, Murunwa, Ha Maelula, and Ha Mutsha (Figure 3.1) were selected based on *L. camara* being present in the homesteads. A total of 300 households (50 per village) were purposely selected for interviews based on prior knowledge of the presence of *L. camara* in the homesteads. One adult member per household was targeted for interviews. Questions were designed to (a) assess the local knowledge and perceptions of *L. camara* invasion (b) find out the effects of *L. camara* invasion on human well-being and rural livelihoods to local communities (Appendix 1). An image of mature *L. camara* was used to help participants familiarise and identify the plant at their household.

The questionnaire consists of three main sections: (1) questions on the demographics of the respondents, (2) questions relating to knowledge and perceptions regarding *L. camara*, (3) questions relating to the effects of *L. camara.* To assess community perceptions, questions were assessed on a three-point scale ranging from score 1 - *yes*, score 2 – *no* and 3 – *don't know.* Similarly, respondents were asked to indicate their perceived impacts of *L. Camara*, from a range of score *(1) harmful* - *(*2) *beneficial* – *(*3) *no impact* – and (4) *both beneficial and harmful*. For example, perceptions on invasions risks by *L. camara* will range from score (1) *harmful* – (2) *beneficial* – (3) *no impact* – (4) *both beneficial and harmful,* following Shackleton (2015).

3.3 Data analysis

The data from household questionnaire surveys was recorded on paper which was later transferred into Microsoft Excel where it was arranged before being exported to be analysed using Stasoft Statistica version 10. Chi-Square tests (χ^2) were used to assess differences in responses to local knowledge and perceptions regarding *L. camara* in the different villages. Open ended questions were analysed using Chi-Square test. The primary reason was that many of the open-ended responses were cross-classified by other categorical variables. A descriptive summary is provided for the responses from the interviews. Significant aspects were attentive to the knowledge and perceptions of local people on *L. camara* presence and impacts on their livelihoods, including benefits (uses and costs).

3.4 Results

3.4.1. Demographics of the sample population

Female respondents made up 70% of the sample population (Table 3.1). Education level was generally low. Only 5% of the respondents had university level education and 18% completed matric level education. Just over one-third (36%) of respondents had primary level education while 14% had attended high school and over one fourth (27%) had no formal education. The main source of income for respondents in the study was government grants (47%), followed by self-employment (34%), employment (11%), and pensions (2%). Those who were self-employed run small businesses such as spaza shops or selling fresh produce at local markets. The average number of people in households was significantly different (p < 0.001) between the villages and the household size was highest at Matshavhawe 9.0 ± 0.5 and lowest at Tshakhuma 5.7 ± 0.4.

Table 3.1 Demographic data and character sample

	Duthuni	Tshakhuma	Murunwa	Matshavhawe	Ha Mutsha	Ha Maelula	Mean
No of households	50	50	50	50	50	50	50
No of people per hh	6.4 ± 0.3	5.7 ± 0.4	7.0 ± 0.3	9.0 ± 0.5	8.0 ± 0.4	7.4 ± 0.3	7.2 ± 0.4
Proportion of adult females (%)	52	68	78	88	62	72	70
Proportion of those with University Education (%)	6	12	6	4	4	-	5.3
Proportion of those with matric (%)	22	22	14	8	28	14	17.5
Proportion of those with high school (%)	10	18	18	16	10	14	14.3
Proportion of those with primary education (%)	44	8	40	52	32	38	35.6
Proportion of those with no formal education (%)	18	40	22	20	26	34	26.6

3.4.1 Knowledge and perceptions of *L. camara*

Most of the respondents (>96%) across all villages were aware of *L. camara* and acknowledged its presence on their property (Table 3.2). There was a significant difference in the responses of participants on the density of *L. camara* across all 6 villages (X^2 = 44.3, df = 20, p < 0.001). A few respondents (8%) (Figure 3.1) in Ha Maelula, 4% in Tshakhuma and 2% in Duthuni categorised *L. camara* as being common on their properties, while about one-third (31%) in Ha Mutsha, one-fourth (24%) Ha Maelula and less than one-fourth (20%) Duthuni and Matshavhawe, Murunwa (18%) and Tshakhuma (10%) had moderate invasions on their properties. Less than one-third (28%) of the respondents in Duthuni, half (52%) in Tshakhuma, less than half in (42%) Ha Maelula, about two-thirds (63%) in Murunwa, over half (54%) in Matshavhawe, and less than half (44%) in Ha Mutsha reported scarce invasion of *L. camara*. About 50% of the respondents in Duthuni, 30% in Tshakhuma, 26% Ha Maelula, 18% in Murunwa, 26% Matshavhawe and 25% Ha Mutsha categorized *L. camara* invasions as very scarce in their households. Very few (4%) of the respondents in Tshakhuma reported *L. camara* populations being very common in their households. Respondents were asked if they planted *L. camara* and only 2 of the respondents in Ha Maelula stated they planted it. Most respondents (>82%) across all villages said that *L.*

camara germinated naturally, while the rest of the respondents stated they found it present when they moved to the property. Most respondents (>80%) in Duthuni and Tshakhuma, and approximately three-quarters (76%) in Ha Maelula and (71%) Ha Mutsha and over half (65%) in Murunwa and (56%) Matshavhawe said that *L. camara* is not spreading on their yard. Very few (<5%) of the respondents in Matshavhawe, Tshakhuma and Murunwa stated that they did not know it is spreading.

Table 3.2 Respondents' responses to questions relating to knowledge and perceptions of *L. camara* across six the villages

Questions	Ha Mutsha	Tshakhuma	Ha Maelula	Duthuni	Matshavhawe	Murunwa	X^2, df, *p* value
Do you know *L. camara?* (*% Yes*)	96	100	100	100	100	98	7.1, 5, 0.2
Do you have it on your property? (% *Yes*)	96	100	100	100	100	98	7.1, 5, 0.2
Did you plant *L. camara* on your property? (% *Yes*)	4	0	2	0	0	2	23.1, 10, 0.1
Is it spreading on your property? (% *Yes*)	29	18	24	12	42	30	20.0, 10, 0.3
Is it spreading in the area? (% *Yes*)	30	64	54	42	56	30	47.4, 10, 0.001*
Are you aware it is an Invasive Spp? (% *Yes*)	29	40	20	64	20	36	29.7, 5, 0.001*
Does it displace spp important to your livelihoods? (% *Yes*)	6	30	8	22	6	7	21.9, 5, 0.001*

* denotes significant differences between villages

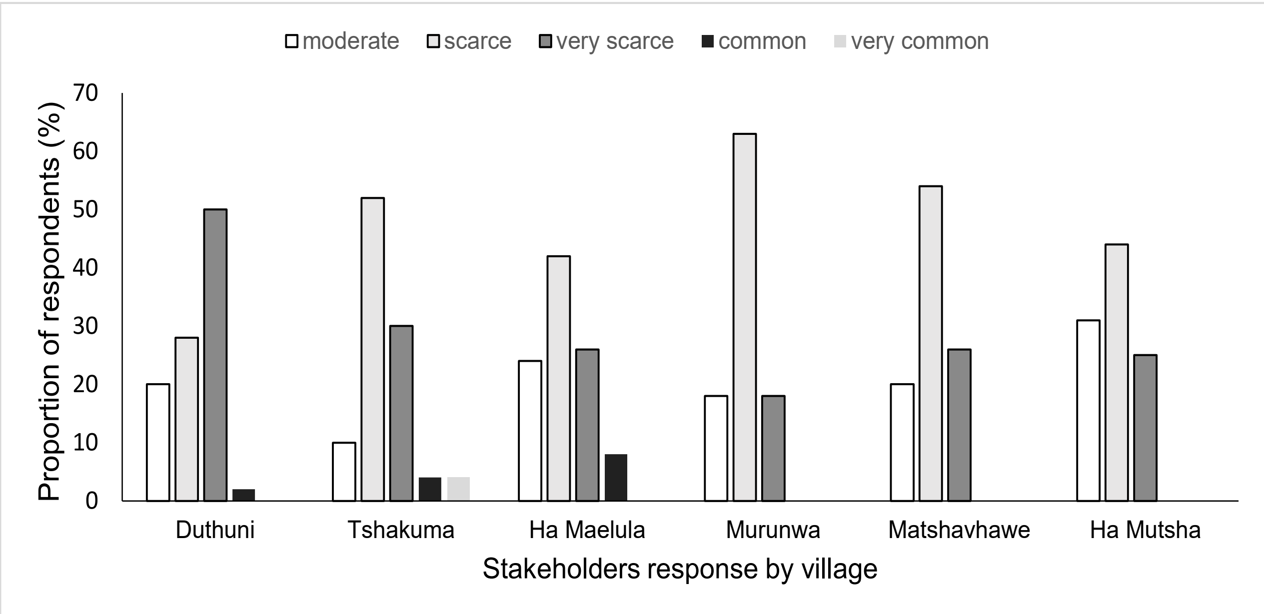

Figure 3.1 Respondents' views on the density of *L. camara* per household

Over a quarter of the respondents (30%) in Ha Mutsha and Murunwa, and more than half in Ha Maelula (54%) and Matshavhawe (56%) with a sizeable proportion in Tshakhuma (64%) and less than half (42%) in Duthuni said *L. camara* is spreading in the area. A sizeable proportion (64%) of the respondents from Duthuni were aware of *L. camara* being an IAS while remaining villages were less aware of this with respondents in Ha Maelula and Matshavhawe being the least (20%) aware (Table 3.2). When asked about their perceptions on the density of *L. camara* over the last five to ten years, a pattern is observed in the responses by respondents who noted an increase and decrease in the density of *L. camara* across all six villages (Figure 3.2), there was a significant difference in their responses (X^2 =77.8; df = 15; $p < 0.001$).

Perceived increases in density were reported by more respondents at Ha Maelula (70%) than Matshavhawe (54%), followed by Murunwa (27%) and Tshakhuma (18%). A high proportion of respondents from Tshakhuma (72%) reported noticing a decrease in density of *L. camara*. Some of the respondents in Duthuni (26%), Tshakhuma (10%), Ha Maelula (8%), Murunwa (16%), Matshavhawe (38%), and Ha Mutsha (21%) said they didn't know if the density had increased or decreased within the specified period. Very few of the respondents in Duthuni (4%) perceived that *L. camara* had stayed the same.

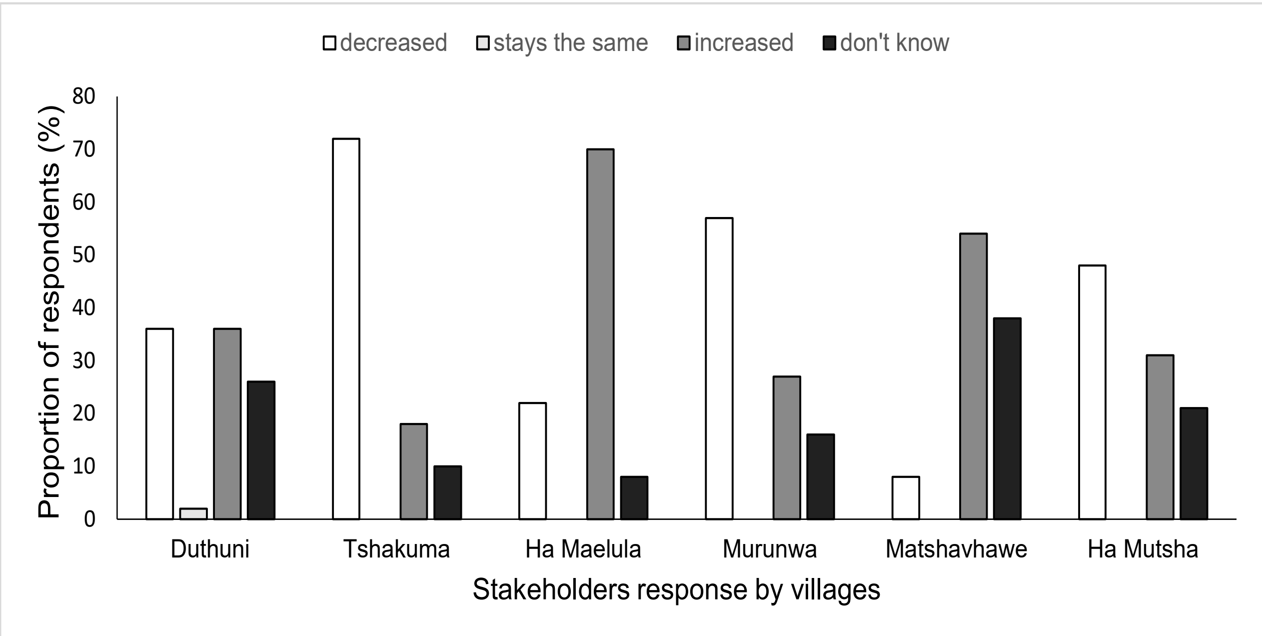

Figure 3.2 Respondents' views on the density of *L. camara* in the area over last 5-10 years

3.4.2 Costs and benefits of *L. camara*

A substantial proportion of the respondents in all of the villages; Duthuni (60%), Tshakhuma (58%), Ha Maelula (64%), Murunwa (69%), Matshavhawe (60%), and Ha Mutsha (71%) were of the view that *L. camara* had no impact on their livelihoods. A moderate number of the respondents perceived *L. camara* to be harmful (Figure 3.5). Few of the respondents (Table 3.3) recognized the benefits *L. camara* provided. A small proportion of the respondents in Duthuni (2%), Tshakhuma (8%), and Ha Mutsha (2%) reported that *L. camara* was both beneficial and harmful. A total of six types of categories for benefits were reported by the respondents (Table 3.3).

Table 3.3 Respondent's views of the benefits and uses (%) of *L. camara*

Category	Ha Mutsha	Tshak huma	Ha Maelula	Duthuni	Matsha vhawe	Murunwa	Mean
Medicine	2	8	0	6	8	4	5.6
Fruit consumption	0	6	0	8	12	8	8.5
Fence/Hedge	4	2	2	4	0	0	3
Ornament	0	0	2	0	0	0	2
Mosquito repellent	2	0	0	0	2	0	2
Preservative	2	0	0	0	0	0	2

There was no significant difference in the responses of the perceived benefits of *L. camara*. (X^2 = 8.5, df = 5, p > 0.001). Fruit consumption and medicine were categories with a fair percentage of users across the six villages. Very few of the respondents reported on other direct and indirect uses of *L. camara* (see Box 1, Figure 3.3). Very few respondents in Ha Maelula (2%) liked *L. camara* and said they kept it because of its bright colourful flowers and hence it was used as an ornament. Some of the uses of *L. camara* for medicinal purposes included treating sore eyes and teeth, using it to treat colds and fevers by boiling the leaves to use as medicine.

Box 1 Quotes of the benefits and uses of *Lantana camara* from respondents in all 6 villages

1. *"The black fruits when crushed are used as ink/dye for decorating mats and writing"*
2. "*It is used for toothaches; you boil the roots in water and use water to swish aching tooth"*

3. *"You break the branches with leaves which have an odour and burn it placing it anywhere you do not want mosquitoes"*
4. *"Washing water bottles by breaking the stems while they are green into smaller parts and putting them in water bottles with soap to scrub out any dirt"*
5. *"Used as a preservative when storing seeds, branches with leaves are placed into a container and sealed in together with the seeds"*
6. *"Used as part of a fence to help stop livestock from eating my crops"*

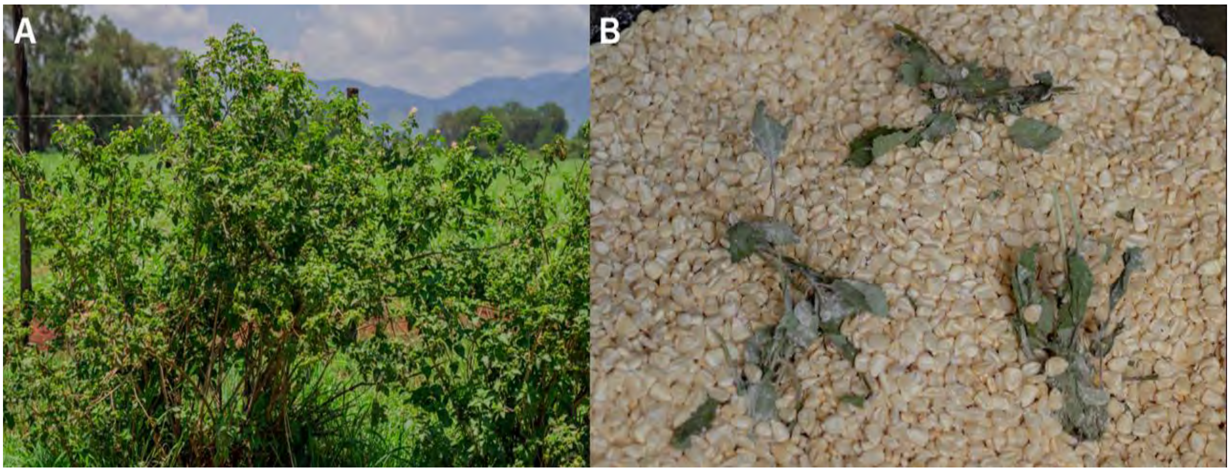

Figure 3.3 Photos showing (A) use of *L. camara* to supplement security against livestock, and (B) use of *L. camara* as a preservative in storing of seeds.

A total of 8 major costs of *L. camara* were listed by the respondents (Table 3.4). There was no significant difference in the responses of the perceived major costs of *L. camara* (X^2 = 7.4, df = 5, $p > 0.001$) The most cited costs of *L. camara* were negative impacts of the plant in outcompeting native vegetation, being toxic to livestock and thorny pricking humans which often causes itchiness to the skin (see Box 2, Figure 3.4). Other adverse impacts of *L. camara* reported include harbouring of snakes and other unwanted animals, bad odour caused by coming into contact with *L. camara*, dense weed that grows everywhere and causing sickness in children from overeating its fruits. A few of the respondents in Tshakhuma and Duthuni mentioned that *L. camara* extracts a lot of water. There was no significant difference (X^2 = 24.7, df = 15, $p > 0.001$) in the responses of perceived costs associated with *L. camara* across the six villages (Figure 3.5).

Table 3.4 views of negative impacts of *L. camara* across the six villages

Negative impacts (Costs/Harm)	Ha Mutsha	Tshakhuma	Ha Maelula	Duthuni	Matshavhawe	Murunwa	Mean
Thorny	12	8	22	6	6	14	11.3
Causes itchy skin	0	0	14	0	4	4	7.3
Toxic to livestock	8	0	12	4	20	8	11
Bad odour	4	0	4	0	0	2	3.3
Dense weed grows everywhere	2	2	8	2	0	2	3.2
Water extraction	0	10	0	4	0	0	7
Harbours snakes	2	8	2	4	0	0	4
Outcompetes native vegetation	4	12	6	20	0	0	10.5

Box 2 Quotes of the costs of *Lantana camara* from all 6 villages

1. *"it grows almost everywhere", and another respondent stated, "children's playing fields have shrunk in size because of the presence of the plant."*
2. *"it adds no value to my livelihood, I want it removed because it is taking space for useful plants."*
3. *"Half of the youth don't know this plant today, to them it is just another plant which they hardly notice, it has become useless and has no value."*
4. *"It is now modern times, and nobody uses it as a fence anymore, most people opt for fences made from steel and walls it only consumes space everywhere now."*
5. *"It grows on fences getting intertwined with fence, destroying it and sometimes causing an unpleasant look."*
6. *"It is a thorn in my sight, there is nowhere you can go where you cannot find it, there is limited access to land we used to have access to i.e., rivers, land we plough on."*
7. *"Managing the plant is a challenge because when you cut, uproot and burn it another will pop up again. It is like a sickness that has no cure."*

Figure 3.4 Photos showing *L. camara* (A) obstructing access to rivers, (B) obstructing access to a water tank at a school, and (C) growing and becoming intertwined with fence, creating an unpleasant look

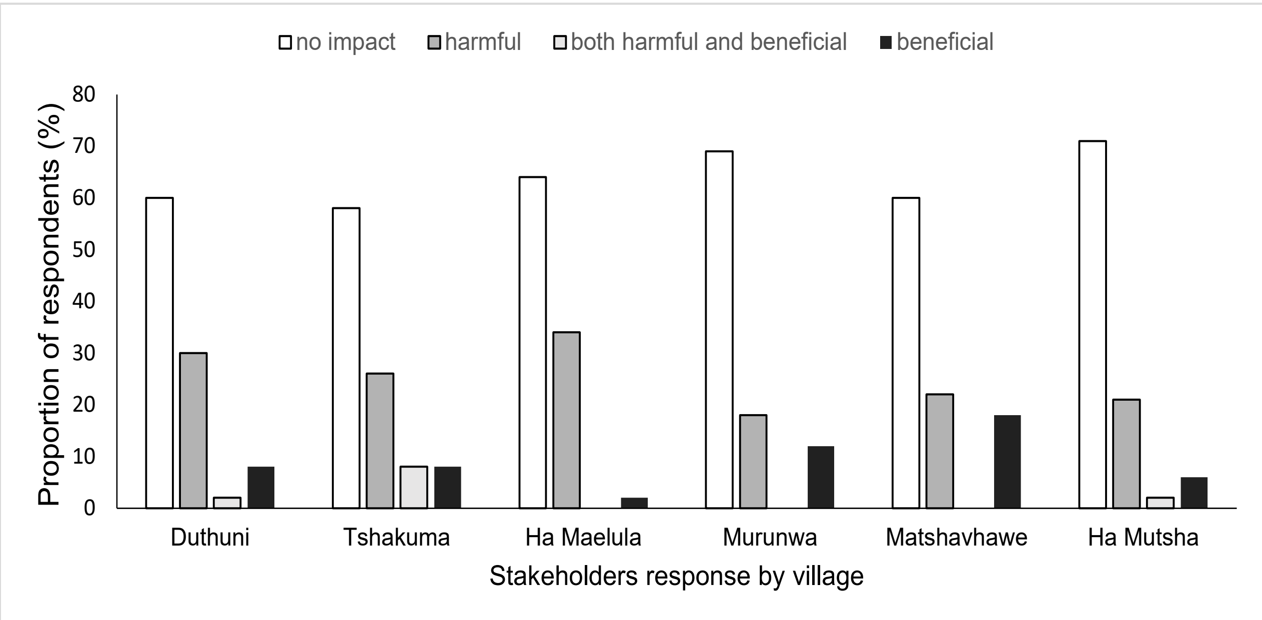

Figure 3.5 Respondents' views of impacts of *L. camara* across six villages

3.5 Discussion

3.5.1 Knowledge and perceptions of *L. camara*

Most of the respondents were familiar with *L. camara* and were able to describe it. The respondents believed *L. camara* to be spreading in the area, and similarly a pattern was observed amongst a small number of respondents with responses of *L. camara* decreasing in the area. The views that *L. camara* is spreading are also shared in other communities from South Africa (Jevon and Shackleton, 2015) and other parts of the world (Sundaram et al., 2012; Shackleton et al., 2017a). Bioclimatic modelling by Vardien et al. (2012) using arrays of climatic variables found *L. camara* to be suitable to expand in Limpopo province. This is supported further by Subhashni and Lalit, (2014) who deduced that current and future climate of Limpopo province provides suitable conditions for spread of *L. camara*. The distribution range of *L. camara* is largely in the tropics or subtropic climate (Day et al., 2003; Taylor and Kumar, 2013) of which Southern Africa is located in (Crétat et al., 2012).

Factors that favours *L. camara* expansion include anthropological disturbances from agriculture, construction along road sides, railways and abandoned fields (Munir, 1996; Day et al., 2003a; Shackleton et al., 2013; Taylor and Kumar, 2013; Subhashni and Lalit, 2014) which are some of the activities taking place in these villages. Many of the respondents were not aware that *L. camara* is an IAP, and those that were aware were informed by WfW personnel. Rural communities do not differentiate indigenous species from invasive ones, because they categorize species based on their cultural significance and ability to contribute towards their livelihoods (dos Santos et al., 2014).

Results from household surveys showed high knowledge levels and uses of *L. camara*, however, use of the plant to warrant utilisation as a management option is low. Invasive alien plants have either positive, negative or both implications on livelihoods of community members (Shackleton et al., 2019), and in the current study *L. camara* did not seem to have severe livelihood impacts as a few of respondents found the plant to be beneficial and a majority found it not harmful.

When it was disclosed that *L. camara* is an invasive some expressed disbelief, similar to reports in Shackleton (2007) for *Prickly pear.* Thus, most community members were not aware of the invasion status of the plant though they are aware of the existence of such plants within their communities. However, community members that have worked with WfW seem to have knowledge of its invasive status. Local traditional communities possess immense wealth of Traditional Ecological Knowledge (TEK) linked to nature (Molnár et al., 2017). Traditional ecological knowledge has played a significant role in managing of natural resources and dealing with disturbances (Gómez-Baggethun et al., 2010). For example, the primary bearers of TEK in the communities are the elderly and transmission of this knowledge towards new generation is becoming increasingly limited (Gómez-Baggethun et al., 2010) and thus the lack of TEK may have detrimental impacts on the environment and livelihoods of communities. For example, Falayi (2017) highlighted impacts on the loss of ecological knowledge in Fairburn village, South Africa where the youth have no knowledge on which wild food is safe to consume. Furthermore, the lack of knowledge may hinder effective implementation of management practices and policies due to insufficient understanding of the overall cost and benefits of IAS (Shackleton and Shackleton, 2016). The individuals who had knowledge of *L. camara* within the communities were able to make use it. This is supported Semenya et al. (2012) where *L. camara* was often used by traditional healers.

3.5.2 Costs and benefits of *L. camara*

For this study there were uses of *L. camara* in the Vhembe Biosphere Reserve, which concur with reports from Semenya et al. (2012) and from other parts of the world namely India (Kannan et al., 2014; Sundaram et al., 2012, 2015). However, there were less benefits provided by the plant which is supported by findings from Shackleton et al. (2017a) from communities in Uganda. The benefits listed by the respondents as mentioned in other studies (Jevon and Shackleton, 2015; Shackleton et al., 2017a) were not substantial. These benefits were for medicinal and ornamental purposes (Day et al., 2003a; Semenya et al., 2012a; Mbambala et al., 2017). However, some of the benefits listed by respondents such as use as a preservative and mosquito repellent are not commonly cited in the literature. This entails that uses of IAPs might be community dependent, thus not uniform across the world.

Most community members deemed *L. camara* to be useless, they stated that it had no cultural or monetary value nor is it impacting their livelihoods, the findings which are similar to a study by Jevon and Shackleton (2015). This is perhaps because most of them reported scarce populations of *L. camara* at their households and thus immediate costs are not felt, as argued by Shackleton et al. (2007) that with low densities of IAS, costs and benefits may be very low. As reported by Shackleton et al. (2007) perceptions towards IAS vary with time between different individuals, groups, and areas. This would explain one the reasons for only a small number of users of *L. camara* in the VBR villages. Other reasons for a small number of users could be as a result of the loss of ecological knowledge which is not transferred to the youth and adapting to new ways of living by the different stakeholders. The changes in livelihoods with introduction of technology have led to simplified modern lives and in turn loss of ecological knowledge. The decrease in plant use is not necessarily attributed to *L. camara* being scarce, but rather different preferences by the community members.

Results from this study are different from that of other communities in South Africa (e.g. Jevon and Shackleton, 2015) and other parts of the world (Shackleton et al., 2017a) where individuals have reported negative impacts to their livelihoods caused by *L. camara.* For example, *L. camara* growing on pathways hinders collection of fuel-wood for the Soliga community in India (Sundaram et al., 2012), negative impacts on crop production in Uganda which reduces crop yield (Shackleton et al., 2017a) and destroying important native trees for community of Mazeppa Bay in South Africa (Jevon and Shackleton, 2015). However, some of the few negative impacts listed by the respondents were similar to literature in other parts of the world (Ghisalberti, 2000; Day et al., 2003a, 2003b; Sundaram et al., 2012; Vardien et al., 2012; Shackleton et al., 2017a). These include toxicity to livestock, negative impacts on native vegetation, forming dense impenetrable thickets which restrict access to land.

3.6 Conclusions

Exploitation of IAS to enhance livelihoods is widespread across the globe, and this is also the case for *L. camara*. However, despite the abundance of *L. camara* most of the respondents were not negatively impacted substantially and were aware of the impacts it possesses. Those who were making use of it were able to do so due to extensive knowledge of the plant. Many were not aware it is an IAP, and this reiterates the notion that rural communities categorise species based on their significance and ability to provide products and services to their livelihoods. The study corroborates the existing body of knowledge on the impacts (both beneficial and harmful) of *L. camara* felt globally by communities. The study recommends that active involvement of stakeholders with new developments pertaining to *L. camara* be considered as they are the primary bearers of knowledge on *L. camara* in the area and are the ones directly impacted by *L. camara*. Raising awareness and education is also of paramount importance for all stakeholders involved, this ensures all parties benefiting or experiencing impacts understand the plight others have to endure. This could in turn potentially lead to improved use of *L. camara* without degrading livelihoods of others.

References

Batianoff, G.N., Butler, D.W., 2003. Impact assessment and analysis of sixty-six priority invasive weeds in south-east Queensland. Plant Protection Quarterly 18, 11-15.

Crétat, J., Pohl, B., Richard, Y., Drobinski, P., 2012. Uncertainties in simulating regional climate of Southern Africa: Sensitivity to physical parameterizations using WRF. Climate Dynamics 38, 613-634.

Day, M.D., Neser, S., 2000. Factors influencing the biological control of *Lantana camara* in Australia and South Africa, in: Proceedings of the X Symposium on Biological Control of Weeds. pp. 897-908.

Day, M. D., Broughton, S., Hannan-Jones, M.A., 2003a. Current distribution and status of *Lantana camara* and its biological control agents in Australia, with recommendations for further biocontrol introductions into other countries. Biocontrol News and Information 24, 63-76.

Day M., Wiley C.J., Playford J., Zalucki, M.P., 2003b. *Lantana*: Current Management Status and Future Prospects. ACIAR, Canberra, ACT, Australia

dos Santos, L.L., do Nascimento, A.L., Vieira, F.J., da Silva, V.A., Voeks, R., Albuquerque, U.P., 2014. The cultural value of invasive species: A case study from semi–arid Northeastern Brazil. Economic Botany 68, 283-300.

Dweba, T.P., Mearns, M.A., 2011. Conserving indigenous knowledge as the key to the current and future use of traditional vegetables. International Journal of Information Management 31, 564-571.

Egoh, B., Reyers, B., Rouget, M., Richardson, D.M., Le Maitre, D.C., van Jaarsveld, A.S., 2008. Mapping ecosystem services for planning and management. Agriculture, Ecosystems and Environment 127, 135-140.

Ehrenfeld, J.G., 2003. Effects of exotic plant invasions on soil nutrient cycling processes. Ecosystems 6, 503-523.

Euston-Brown, D., Rathogwa, N., Richardson, D.M., 2007. Development of a clearing protocol based on ecological criteria for mesic savannas and sweet grassveld for the Working for Water Programme. Unpublished report. The Working for Water Programme, Department of Water Affairs and Forestry Cape Town.

Falayi, M., 2017. Understanding social-ecological changes in Fairbairn village, Eastern Cape. (MSc Thesis). Rhodes University.

Ghisalberti, E.L., 2000. *Lantana camara L.* (Verbenaceae). Fitoterapia 71, 467-486.

Gómez-Baggethun, E., Mingorria, S., Reyes-García, V., Calvet, L., Montes, C., 2010. Traditional ecological knowledge trends in the transition to a market economy: Empirical study in the Doñana natural areas. Conservation Biology 24, 721-729.

Hobbs, R.J., Mooney, H.A., 2005. Invasive species in a changing world: The interactions between global change and invasives. Scope-Scientific Committee on Problems of the Environment International Council of Scientific Unions 63, 310.

Hulme, P.E., 2009. Trade, transport and trouble: Managing invasive species pathways in an era of globalization. Journal of Applied Ecology 46, 10-18.

Jevon, T., Shackleton, C.M., 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, C.M., Shaanker, R.U., 2014. Invasive alien species as drivers in socio-ecological systems: Local adaptations towards use of *Lantana* in Southern India. Environment Development and Sustainability 16, 649-669.

Macdonald, I.A.W., Reaser, J.K., Bright, C., Neville, L.E., Howard, G.W., Murphy, S.J., Preston, G., (Eds). 2003. Invasive alien species in Southern Africa: National reports and directory of resources. Global Invasive Species Programme, Cape Town, South Africa

Maema, L.P., Potgieter, M., Mahlo, S.M., 2016. Invasive alien plant species used for the treatment of various diseases in Limpopo Province, South Africa. African Journal of Traditional, Complementary and Alternative Medicines 13, 223-231.

Mbambala, S.G., Tshisikhawe, M.P., Masevhe, N.A., 2017. Invasive alien plants used in the treatment of HIV/AIDS-related symptoms by traditional healers of Vhembe municipality, Limpopo Province, South Africa. African Journal of Traditional, Complementary and Alternative Medicines 14, 80-88.

Molnár, V.A., Süveges, K., Molnár, Z., Löki, V., 2017. Using traditional ecological knowledge in discovery of rare plants: A case study from Turkey. Acta Societatis Botanicorum Poloniae 86, 1-10.

Mpandeli, S., 2014. Managing climate risks using seasonal climate forecast information in Vhembe District in Limpopo Province, South Africa. Journal of Sustainable Development 7, 68-81.

Mucina, L., Rutherford, M.C., 2006. The vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19. (South African National Biodiversity Institute: Pretoria, South Africa). Memoirs of the Botanical Survey of South Africa.

Munir, A.A., 1996. A taxonomic review of *Lantana camara L.* and *L. montevidensis* (Spreng.) Briq. (Verbenaceae) in Australia. Journal of the Adelaide Botanic Garden, 1-27.

Negi, G.C., Sharma, S., Vishvakarma, S.C., Samant, S.S., Maikhuri, R.K., Prasad, R.C., Palni, L.M., 2019. Ecology and use of *Lantana camara* in India. The Botanical Review 85, 109-130.

Pejchar, L., Mooney, H.A., 2009. Invasive species, ecosystem services and human well-being. Trends in Ecology and Evolution 24, 497-504.

Pimentel, D., McNair, S., Janecka, J., Wightman, J., Simmonds, C., O'connell, C., Tsomondo, T., 2001. Economic and environmental threats of alien plant, animal, and microbe invasions. Agriculture, Ecosystems and Environment 84, 1-20.

Pimentel, D., Zuniga, R., Morrison, D., 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. Ecological Economics 52, 273-288.

Priyanka, N., Joshi, P.K., 2013. A review of *Lantana camara* studies in India. International Journal of Scientific and Research Publications 3, 1-11.

Rai, R.K., Scarborough, H., Subedi, N., Lamichhane, B., 2012. Invasive plants – Do they devastate or diversify rural livelihoods? Rural farmers' perception of three invasive plants in Nepal. Journal for Nature Conservation 20, 170-176.

Republic of South Africa, 2004. National Environmental Management: Biodiversity Act 10 of 2004. Proc. R47/Government Gazette.

Ross, K.B., 2017. Traditional terrain: Land, gender, and cultural biodiversity preservation in Venda, South Africa. (PhD Thesis). Michigan State University.

Semenya, S., Maroyi, A., 2020. Assessment of useful alien plant species cultivated and managed in rural home gardens of Limpopo Province, South Africa. Scientifica, 2020.

Semenya, S., Potgieter, M., Tshisikhawe, M.P., Shava, S., Maroyi, A., 2012a. Medicinal utilization of exotic plants by Bapedi traditional healers to treat human ailments in Limpopo province, South Africa. Journal of Ethnopharmacology 144, 646-655.

Semenya, S., Tshisikhawe, M.P., Potgieter, M.T., 2012b. Invasive alien plant species: A case study of their use in the Thulamela Local Municipality, Limpopo Province, South Africa. Scientific Research and Essays 7, 2363-2369.

Shackleton, C.M., McGarry, D., Fourie, S., Gambiza, J., Shackleton, S.E., Fabricius, C., 2007. Assessing the effects of invasive alien species on rural livelihoods: Case examples and a framework from South Africa. Human Ecology 35, 113-127.

Shackleton, C.M., Shackleton, R.T., 2016. Knowledge, perceptions and willingness to control designated invasive tree species in urban household gardens in South Africa. Biological Invasions 18, 1599-1609.

Shackleton, R., Shackleton, C., Shackleton, S., Gambiza, J., 2013. Deagrarianisation and forest revegetation in a biodiversity hotspot on the Wild Coast, South Africa. PloS one 8, e76939.

Shackleton, Ross T., Le Maitre, D.C., Richardson, D.M., 2015a. Stakeholder perceptions and practices regarding *Prosopis* (mesquite) invasions and management in South Africa. Ambio 44, 569-581.

Shackleton, Ross T, Le Maitre, D.C., van Wilgen, B.W., Richardson, D.M., 2015b. Use of non-timber forest products from invasive alien *Prosopis* species (mesquite) and native trees in South Africa: Implications for management. Forest Ecosystems. 2, 16.

Shackleton, Ross T., Le Maitre, D.C., van Wilgen, B.W., Richardson, D.M., 2015c. The impact of invasive alien *Prosopis* species (mesquite) on native plants in different environments in South Africa. South African Journal of Botany 97, 25-31.

Shackleton, R.T., Richardson, D.M., Shackleton, C.M., Bennett, B., Crowley, S.L., Dehnen-Schmutz, K., Estévez, R.A., Fischer, A., Kueffer, C., Kull, C.A., Marchante, E., Novoa, A., Potgieter, L.J., Vaas, J., Vaz, A.S., Larson, B.M.H., 2019. Explaining people's perceptions of invasive alien species: A conceptual framework. Journal of Environmental Management 229, 10-26.

Shackleton, R.T., Witt, A.B., Aool, W., Pratt, C.F., 2017a. Distribution of the invasive alien weed, *Lantana camara*, and its ecological and livelihood impacts in eastern Africa. African Journal of Range and Forage Science 34, 1-11.

Shackleton, R.T., Witt, A.B., Nunda, W., Richardson, D.M., 2017b. *Chromolaena odorata* (Siam weed) in eastern Africa: Distribution and socio-ecological impacts. Biological Invasions 19, 1285-1298.

Sharma, G.P., Raghubanshi, A.S., Singh, J.S., 2005. *Lantana* invasion: An overview. Weed Biology and Management 5, 157-165.

Simberloff, D., Martin, J.L., Genovesi, P., Maris, V., Wardle, D.A., Aronson, J., Courchamp, F., Galil, B., García-Berthou, E., Pascal, M., 2013. Impacts of biological invasions: What's what and the way forward. Trends in Ecology and Evolution 28, 58-66.

Spies, J.J., Stirton, C.H., 1982. Meiotic studies of some South African cultivars of *Lantana camara* (Verbenaceae). Bothalia 14, 101-111.

Stirton, C.H., 1977. Some thoughts on the polyploid complex *Lantana camara L*. (Verbenaceae)., in: Proceedings of the Second National Weeds Conference of South Africa. pp. 321-340.

Subhashni, T., Lalit, K., 2014. Impacts of climate change on invasive *Lantana camara L*. distribution in South Africa. African Journal Environmental Science and Technology 8, 391-400.

Sundaram, B., Ankila Hiremath, J., Krishnaswamy, J., 2015. Factors influencing the local scale colonisation and change in density of a widespread invasive plant species, *Lantana camara*, in South India. NeoBiota 25, 27-46.

Sundaram, B., Krishnan, S., Hiremath, A.J., Joseph, G., 2012. Ecology and impacts of the invasive species, *Lantana camara*, in a social-ecological system in South India: Perspectives from local knowledge. Human Ecology 40, 931-942.

Taylor, S., Kumar, L., 2013. Potential distribution of an invasive species under climate change scenarios using CLIMEX and soil drainage: A case study of *Lantana camara L*. in Queensland, Australia. Journal of environmental management 114, 414-422.

Tshiguvho, T., 2008. Sacred traditions and biodiversity conservation in the Forest Montane region of Venda, South Africa. Clark University.

van Wilgen, B.W., Forsyth, G.G., Le Maitre, D.C., Wannenburgh, A., Kotzé, J.D.F., 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.

van Wilgen, B. W., Measey, J., Richardson, D. M., Wilson, J. R., Zengeya, T. A., 2020. Biological invasions in South Africa: An overview. In Biological Invasions in South Africa pp. 3-31. Springer, Cham.

van Wilgen, B.W., Wannenburgh, A., 2016. Co-facilitating invasive species control, water conservation and poverty relief: Achievements and challenges in South Africa's Working for Water programme. Current Opinion in Environmental Sustainability 19, 7-17.

Vardien, W., Richardson, D.M., Foxcroft, L.C., Thompson, G.D., Wilson, J.R., Le Roux, J.J., 2012. Invasion dynamics of *Lantana camara L.* (sensu lato) in South Africa. South African Journal of Botany 81, 81-94.

Zerebecki, R.A., Sorte, C.J., 2011. Temperature tolerance and stress proteins as mechanisms of invasive species success. PLOS one 6, e14806.

Chapter 4: *Lantana camara* Invasion Extent and Management Approaches by Local Communities in Vhembe Biosphere Reserve

4.1 Introduction

Invasive Alien Species (IAS) are one of the major threats globally accounting for the decrease in biodiversity (Shah and Makhambera, 2019). Invasive alien species are defined as species introduced into an area deliberately or not deliberately whose presence in the area has the potential to cause harm to the economy, environment and human health (Beck et al., 2008). Invasive alien species are capable of surviving a wide range of environmental conditions (Vila and Weiner, 2004), their biological characteristics such as the rapid reproduction and growth rates, lack of predators and competition enable them to thrive in environments they invade (Vila and Weiner, 2004). Invasive alien species cost nations enormous amounts of money, with the United States of America losing an estimated US$120 billion to IAS yearly (Pimentel et al., 2005). In Kenya and Ethiopia, *Prosopis* has had detrimental impacts on the rural livelihoods by restricting access to grazing land for livestock and causing loss of native species (Shackleton et al., 2015). In Uganda, households lose an average of US$400-500 per annum due to *Lantana camara* invasions (Shackleton et al., 2017a). Although IAS are known to have detrimental costs on ecosystems and livelihoods, some IAS provide benefits. For example, an invasive tree *Melaleuca quinquenervia* in Florida USA is generating US$15 million annually on honey production (Pejchar and Mooney, 2009). Furthermore, the use of *L. camara* as a substitute for the overharvested bamboo trees in Southwest India (Kannan et al., 2014). In Africa, the southernmost part of the continent is the most adversely affected by IAS (Macdonald et al., 2003).

South Africa is a country rich in biodiversity with a history of biological invasions and their management (van Wilgen et al., 2020). The history of IAS introductions in South Africa was centered around a socio-political environment (van Wilgen et al., 2020). South Africa spends ZAR1.5 billion per year (US$86 million) to control Invasive Alien Plants (IAPs) (Wilson et al., 2017). The country's rangelands suffer losses of ZAR340 million yearly (US$19 million) in livestock production due to IAPs (O'Connor and van Wilgen, 2020). Furthermore, it has been estimated that IAPs are responsible for the loss of 3000 m^3 of water yearly (Le Maitre et al., 2000; Wilson et al., 2017). Invasive alien plants are responsible for the reduction of mean annual runoff (MAR) by 1.44 billion m^3 yearly (Le Maitre et al., 2020). In the Northern Cape Province, some farmers reported that the cost of clearing *Prosopis* per hectare is three times more than the price they had purchased the land for (Shackleton et al., 2015). Despite these detrimental impacts IAPs provide a plethora of beneficial uses such as being sources of food, fuel wood, fodder, shade, aesthetics and medicinal (O'Connor and van Wilgen, 2020). For example, the wood from *Pinus patula* is highly sought after for use in making of furniture (Semenya et al., 2012). *Melia azedarach* was grown mainly for aesthetics by members of the Mier Municipality in the Northern Cape, South Africa (Shackleton and Shackleton, 2018). Although IAPs are beneficial to a certain extent, their benefits are outweighed by their negative impacts (O'Connor and van Wilgen, 2020). The enormous costs of combating IAS has had many species spread unchecked due to the exorbitant costs associated with their management (Kannan et al., 2014).

Lantana camara is one example of such IAPs that are problematic worldwide (Foxcroft and Richardson, 2003; Vardien et al., 2012). In South Africa, *L. camara* is one of the major invaders alongside *Acacia mearnsii* and *Opuntia ficus-indica* (Henderson and Wilson, 2017; Richardson et al., 2020). *Lantana camara* originates from central South America (Day et al., 2003; Vardien et al., 2012; Taylor and Kumar, 2013) and was introduced in South Africa pre-1990 (Bhagwat et al., 2012). It is dominant in the warm moist parts of South Africa (Vardien et al., 2012). Some of the negative impacts of *L. camara* include release of allelopathic chemicals (Vardien *et al.,* 2012) that suppress native vegetation (McWilliam, 2000). Furthermore, negative impacts include toxicity to livestock which leads mortality (Vardien *et al.,* 2012), excessive addition and removal of soil nutrient resources and also causing an increase in soil pH, exacerbating the rate of erosion (Ruwanza and Shackleton, 2016), dense thickets restrict access to water sources (Shackleton et al., 2017a), reduced grazing potential of land (Vardien et al., 2012), labour intensive to clear and displacement of human individuals (Shackleton et al., 2017a).

Despite it having detrimental impacts on livelihoods of the rural poor communities (Semenya et al., 2012; Shackleton et al., 2017a), it also presents some benefits where it is used as a hedge in Uganda (Shackleton et al., 2017a). In India, it is used to make furniture (Kannan et al., 2014), and in South Africa it is used as an ornament and also medicine (Semenya et al., 2012). The negative and positive effects shows that the plant is a conflict-generating IAS that might be difficult to manage, thus the need for both ecological and social studies on the species (Zengeya et al., 2017). According to Zengeya et al. (2017) conflict-generating species are defined as species that have both negative and beneficial effects towards stakeholders, and their management is controversial due to stakeholder interest. In South Africa, *L. camara* is listed as a category 1b species, which is prohibited from being traded nor planted and should be destroyed (NEMBA Act 10 of 2004).

The integration of local human knowledge into ecological studies focusing on biological invasions paves way for a better understanding of IAS and their sustainable management

(Sundaram et al., 2012). This is because IAS are already embedded into the local livelihoods of rural poor communities either as exploited resources or as managed species (Shackleton et al., 2007). Local communities are best suited to provide an understanding of crucial information on biological invasions such as time since invasion and responses towards invasion (Shackleton et al., 2020). For example, Sundaram et al. (2012) used local knowledge from the Soliga community in South India to get a better understanding of the invasion process of *L. camara*. Rist et al. (2010) reported on use of local ecological knowledge in forest management in Indian forest communities and in South Africa. Shackleton et al. (2015) made use of local knowledge to get a better understanding of local perceptions and management of *Prosopis* invasion.

Previous studies (e.g. Simba et al., 2013a, 2013b; Drake et al., 2016) had focused mainly on reporting the negative impacts of IAS without taking into account the diverse roles played by IAS in the rural livelihoods of the poor (Egoh et al., 2008). This tilted the scale for both social and ecological impacts in terms of management with the former often getting overlooked (dos Santos et al., 2014). Some IAS have become naturalized, making them culturally important and have become equal or more important in their use than native species in areas where they have invaded (Shackleton et al., 2007; dos Santos et al., 2014), and thus their negative impacts may not be noticed by the users. For example *Opuntia ficus-indica* is of importance to communities in the Eastern Cape, South Africa where it provides income to the locals from the sale of its fruit (Shackleton et al., 2011). Shackleton et al. (2015) reported on the various uses of *Prosopis* in the Northern Cape which include use as fuelwood and pods for food. Therefore, the removal of IAS without taking into consideration the social impacts on the livelihoods of rural poor may have detrimental impacts (dos Santos et al., 2014). Thus, this study used a two-pronged approach to: (i) examine the invasion extent of *L. camara* at household yards, and (ii) assess local management approaches towards *L. camara* invasion in Vhembe Biosphere Reserve, in Limpopo province of South Africa.

4.2 Methods

This study used a mixed approach (both qualitative and quantitative methods). The quantitative method was used for collecting data on ecological surveys and, qualitative method was used to solicit information from questionnaire surveys and focus group discussions. Primary data was collected in all instances for this study. Sampling methods included purposive sampling for ecological surveys and questionnaires, and convenience sampling for focus group discussions. Convenience sampling is a type of sampling method that selects members of a target population based on a practical criterion such as easy accessibility, availability, and geographical proximity (Etikan et al., 2016). The rationale behind choosing this method was because of the ease of access to participants and its inexpensive nature due to the limited budget constraints.

4.2.1 Household yard *L. camara* surveys

Ecological surveys were conducted in 50 households per village where *L. camara* was present. A count of all the *L. camara* trees present in the household yard was conducted. For each counted *L. camara*, plant height, canopy width, and plant basal diameter at base were recorded. Height and canopy width of *L. camara* plants were measured (in meters) using a tape measure. For canopy width, the plant was viewed from all sides to determine the widest side to measure. Plant basal diameter measurements (diameter at base) were measured (in centimetres) using a Vernier callipers. For multi-stemmed plants, diameter of all stems at base were recorded and averaged to represent the plants diameter.

4.2.2 Village participation: focus group discussions and questionnaire surveys

Focus group discussions (FGDs) were conducted in all six villages with the aid of a TshiVenda translator to gather additional information on *L. camara* invasion on human well-being and community perceptions about the plant, impacts and control options. The six villages were Ha Mutsha, Tshakhuma, Murunwa, Duthuni, Matshavhawe, and Ha Maelula (see Table 1.1 in Chapter 1 for village description). The FGDs were made up of 8 to 10 individuals. The participants were selected using convenience sampling method, so as to have a good representation of the diverse village members. Prior to the discussion, a transect walk was conducted in all villages. The transect walk aimed to verify the presence of *L. camara* in the village and to confirm if the villagers know about the plant. The duration of each focus group discussion was between 60-90 minutes. In each FGD meeting, the facilitator (the researcher and translator) began the meeting by presenting a summary of the *L. camara* in South Africa. The floor was opened for participants to discuss (i) its invasion presents and extent in the area, (ii) knowledge of the plant by participants, (iii) uses of *L. camara*, (iv) effects of the plant on villagers, and (v) management approaches being used in villages. During each discussion, time was allocated to discuss each point and clarify relevant issues raised by the participants. The researcher and translator recorded the notes during the discussions. The captured notes were compared at the end of the meeting to ensure that discussion results were captured accurately.

4.3 Data analysis

The data from household yard surveys was recorded on paper which was later transferred into Microsoft Excel where it was arranged before being exported to be analysed using Stasoft Statistica version 10. A summary of descriptive statistics was conducted. Proof of normality and homogeneity of variances were tested using the Kolmogorov-Smirnov tests and Levene's test respectively, and data was normally distributed. One-way analysis of variance (ANOVA) was used to compare vegetation measurement across the six villages. A Tukey-HSD homogenous post-hoc test was used where significant differences were observed. Focus group discussions results were presented as a summary of the discussions at the meetings based on notes taken during the meetings. Results of management approaches gathered from the FGD were combined with those gathered from the questionnaire survey and these were analyses using Chi-Square tests (χ^2). Open ended responses from questions in the questionnaires were analysed using Chi-Square test. The primary reason was that many of the open-ended responses were cross-classified by other categorical variables.

4.4 Results

4.4.1 *Lantana camara* surveys

The diameter of *L. camara* measured at household level among all villages averaged 0.94 ± 0.02 cm. Analysis of Variance analysis showed a significant (F = 4.956, $p < 0.001$) difference among the six villages for plant basal diameter (Figure 4.1a). Plant basal diameter was high in Tshakhuma (1.05 ± 0.04 cm) and Duthuni (1.00 ± 0.04 cm) villages and was low in Ha Mutsha village (0.82 ± 0.03 cm). The *L. camara* canopy width at household level among all villages averaged 1.34 ± 0.03 m. The ANOVA results showed a significant (F = 14.045, $p < 0.001$) difference among the six villages for canopy width (Figure 4.1b). Canopy width was high in Tshakhuma village (1.70 ± 0.09 m) and was low in Ha Mutsha village (1.03 ± 0.03 m).

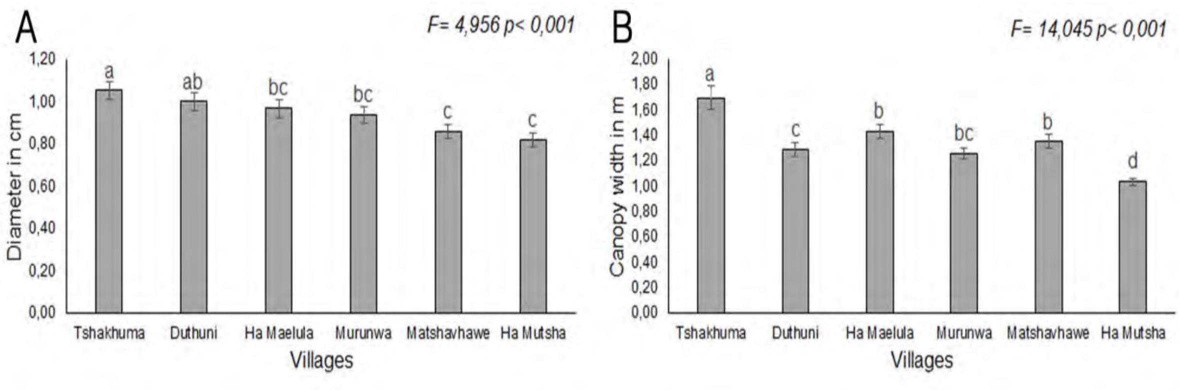

Figure 4.1 *Lantana camara* Diameter (A) and Canopy width (B) among 6 villages in the Vhembe Biosphere Reserve, South Africa (A letter on the bar graph represents level of significance, Bars with same letters are not statistically significant)

The average number of *L. camara* counted per household yard in all villages was 2.41 ± 0.20 plants, and their height averaged 1.31 ± 0.02 m (Figure 4.2a, b). However, there were no significant difference in *L. camara* abundances (F = 0.737, p = 0.596) and plant height (F = 1.114, p = 0.351) of *L. camara* among the six villages.

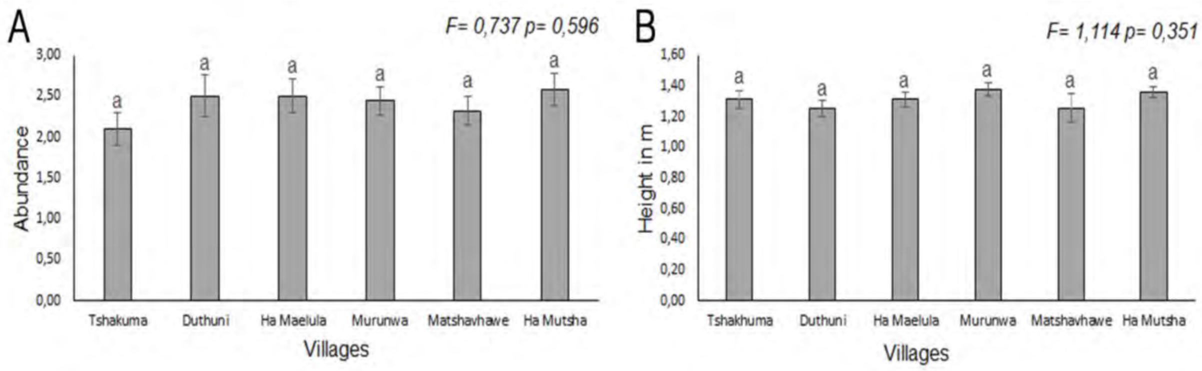

Figure 4.2 *Lantana camara* Abundance (A) and Height (B) among 6 villages in the Vhembe Biosphere Reserve, South Africa (A letter on the bar graph represents level of significance, Bars with same letters are not statistically significant)

4.4.2 Focus group discussion responses

Members of the focus group discussion from all villages stated that they knew *L. camara,* but almost all from Duthuni, Murunwa, Ha Maelula and Ha Mutsha stated they do not know that it is an IAP. In the different villages they referred to it using local *Venda* names which are Tshidzimbampotole, Tshidzimbambule and Tshidzimbavhalisa (Tshidzimba). Focus group discussion participants stated that they knew of both *L. camara* (Tshidzimbampotole or Tshidzimbambule*)* and *Lantana rugosa* (Tshidzimbavhalisa). They acknowledged that the new variety of *L. camara* was the problematic one and that *L. rugosa* (Tshidzimba) wasn't. They stated the key differences between *L. camara* and *L. rugosa* were the size and colour of the flowers which were small and pink for *L. rugosa* compared to a variety of colours on the hybrids of *L. camara.* Other key differences indicated by FGDs participants were the size of *L. rugosa* which is smaller compared to *L. camara* and that *L. rugosa* has no odour when its leaves are crushed. Most of the respondents in all villages were born in the area and do not remember the exact time they first noticed *L. camara* but did state it was when they were younger. However, one respondent stated he first noticed it in 1970 when he was working on a farm near Tzaneen.

Nearly all the respondents indicated that they would like to see density of *L. camara* reduced, with only a few that stating they would love to a see a decrease but not to remove it completely for future generations to see. Most of the respondents noticed an increase in the density of *L. camara* in their area over the last decade. Members of the focus group discussions attributed the increase in density of *L. camara* to birds which feed on the fleshy fruits and spread the seeds. Group members also reported that *L. camara* is more prevalent along bodies of water, especially rivers. Some respondents reported on the growth of *L. camara* over last decade saying:

> **Respondent A** *"It has grown rapidly and has covered the land I used to farm on, nothing is left"*.

> **Respondent B** *"You can find a lot of this plant at the river, even along bridges"*.

another respondent further stated:

> **Respondent C** *"It is now modern times and nobody uses it as a fence anymore, most people opt for fences made from steel and walls".*

4.4.3 Management of *L. camara*

Almost all the respondents in the six villages said they controlled *L. camara,* and there was a significant difference ($p < 0.001$) in the responses from respondents when asked if they managed *L. camara* (Table 4.1). The most common method of managing *L. camara* populations was cutting and burning. Although less than 2% of the respondents knew of chemical control options for *L. camara*, they stated it was costly to get a hold of the chemicals. Some of the respondents in Tshakhuma (18%), Ha Maelula (2%) and 4% in Ha Mutsha, Duthuni and Murunwa stated that they received some information on IAS and their uses. This information was acquired at tribal gatherings, through word of mouth from other individuals. A majority of the respondents at all the villages wanted to see a decrease in the abundance of *L. camara* in their area, although more respondents in Ha Mutsha, Ha Maelula, Murunwa and Duthuni than in Tshakhuma and Matshavhawe reported so (Table 4.1). A handful of the respondents in Ha Maelula and Murunwa (6%), Ha Mutsha (2%), and Tshakhuma (10%) mentioned they had received assistance from government in managing *L. camara*. While the remaining respondents reported no assistance from government. As reported by one respondent:

> **Respondent D** *"the only places we have seen cleared is along the rivers".*

Working for Water (WfW) was cited as the main organisation responsible for assisting in management of *L. camara*. Most of the respondents across all six villages wanted assistance from the government in managing *L. camara*. Respondents stated that assistance from the government could be in the form of providing tools and chemicals to clear *L. camara*, contract people providing jobs that target *L. camara* densities and making awareness campaigns that aim to inform stakeholders within communities of *L. camara* and other IAS. As expressed by a respondent:

Respondent E *"our children are not working, there are no jobs bringing back the contracts would help manage the plant and also create jobs for our youth".*

Another respondent further stated:

Respondent F "the government can assist us by providing us with tools and chemicals, because these are expensive to get ourselves"

Table 3.5 Respondents' perceptions, views and practices related to management of *L. camara* across the six villages

Questions	Ha Mutsha	Tshakhuma	Ha Maelula	Duthuni	Matshavhawe	Murunwa	X^2, df, *p* value
Would you be happy if *L. camara* decreased in your area? *Yes* (%)	81	68	84	76	62	86	18.5, 10, 0.1
Do you manage the plant? *Yes* (%)	65	96	80	92	70	67	25.8, 5, 0.001*
Do you receive any information regarding use of IAS? *Yes* (%)	4	18	2	4	0	4	20.1, 5, 0.001*
Do you receive assistance from government in managing the plant? *Yes* (%)	2	10	6	0	0	6	10.3, 5, 0.1
Would you like the government to assist you in managing *L. camara*? *Yes* (%)	65	64	72	72	70	61	7.3, 10, 0.7

*denotes significant difference

4.5 Discussion

4.5.1 *Lantana camara* invasion extent at household level

Vegetation surveys at household yards revealed that *L. camara* is widespread within the VBR communities. *Lantana camara* is best suited to grow in the subtropical, tropical and warm temperate regions (Day et al., 2003; Taylor and Kumar, 2013). In South Africa it is also prevalent in the warm, moist subtropical parts of the country (Vardien et al., 2012; Shackleton et al., 2017a), and it is capable of surviving under harsh conditions that receive less rainfall (Urban et al., 2011). This explains its distribution across a few villages which are semi-arid subtropical. *Lantana camara* thrives in disturbed areas as with many other IAS that exploit disturbances (Gelbard and Belnap, 2003). For example roadsides, bridges, riparian areas, cleared forests and anywhere anthropological activities persist (Munir, 1996; Vardien et al., 2012; Taylor and Kumar, 2013). In most of the households surveyed there were many forms of disturbances such as clearing the land for home gardens and construction, and thus these activities could have facilitated the spread of *L. camara*. *Lantana camara* tolerates a variety of soil types, however it has a preference for well drained soils that are not hydromorphic (Day et al., 2003; Taylor and Kumar, 2013). This is one of the reasons that explains the presence of *L. camara* in all the villages which consist of acidic dystrophic and mesotrophic sandy, loamy soils that are well drained (Mucina and Rutherford, 2006).

Lantana camara has a variety of bright beautiful and colourful flowers, thus its desired use as an ornamental plant (Semenya et al., 2012; Vardien et al., 2012), and this was the main reason for its introduction in South Africa (Morton, 1994). In other parts of the world (Oosthuizen, 1964; Morton, 1994; Ghisalberti, 2000; Simelane, 2002; Patel, 2011; Bhagwat et al., 2012; Vardien et al., 2012) and South Africa (Jevon and Shackleton, 2015), *L. camara* is used as a popular hedge. Similarly, this was the case for a few of the households in the six villages where *L. camara* was used as a protective hedge against animals and thieves. Although its widely distributed in South Africa as a popular ornamental plant (Vardien et al., 2012; Jevon and Shackleton, 2015), the primary dispersal route is mostly through birds (Day et al., 2003; Bhagwat et al., 2012; Vardien et al., 2012; Shackleton et al., 2017a). This is reinforced by results from the focus group discussion where respondents stated although they manage *L. camara*, birds feeding on fruits keep on spreading the seeds. The community members who participated in the focus group discussion noted that there is an abundance of *L. camara* in household yards and next to water bodies (i.e., rivers). This confirms the results of the vegetation surveys at household level, and this is consistent with studies by Le Maitre et al. (2000); Shackleton et al. (2007); Vardien et al. (2012) that invasion by IAPs are largely confined to riparian areas.

4.5.2 Management of *L. camara*

Despite all efforts by the government and local people to eradicate *L. camara*, it remains a major concern in the area. Almost all the respondents were making efforts to control *L. camara,* similar to efforts by community members in Uganda (Shackleton et al., 2017a). Common methods of managing *L. camara* included cutting and burning, which are popular methods cited in other parts of the world (Sharma, 1988; Sharma et al., 1988, 2005; Sundaram et al., 2012). However, the respondents stated that constant intervention for management of *L. camara* is required as the plant grows back again after applied management strategies, which is also true for other IAPs such as *Chromolaena odorata* (Shackleton et al., 2017b). Respondents said they needed government intervention to help manage *L. camara* densities and most of them wanted tools to help manage *L. camara* and employing of more individuals under the WfW programme to clear *L. camara* and other IAS. This presents a challenge as mechanical control of IAS is both costly and labour intensive and not effective on its own and thus needs to be supplemented with other methods

(Vardien et al., 2012). This has been documented in studies about other IAS. For example, the case of *Prosopis* in the Northern Cape, South Africa where the costs of clearing it are at ZAR29 million ($1.8 million) yearly (Wise et al., 2012). In South Africa, various management options exist for the management of IAPs, these include chemical, mechanical and biological control. It is estimated that *L. camara* populations were reduced by 50% between 1995 and 2008, using a combination of all three control methods, however this came with exorbitant costs amounting up to ZAR300 million (U$17.9 million) (van Wilgen et al., 2012).

The use of chemicals is beyond the means of the respondents, this is because of the expensive costs associated with chemical control (Sharma et al., 2005) and the source of income for half of the respondents which is grants. This is a consistent trend for rural poor communities which is highlighted by Shackleton et al. (2018). In South Africa, the most widely used and successful method of clearing *L. camara* is the integrated approach which is a combination of both mechanical and chemical methods (Vardien et al*.,* 2012). The respondents who once worked for WfW, often cleared the native species *Lippia javanica* mistaking it for *L. camara* as admitted by some of the respondents during focus group discussions. During the FGDs it was discovered that the priority for clearing *L. camara* was often given to riparian areas, communal land and not on individual households within the local communities.

South Africa has taken an integrated approach to managing IAPs under the WfW programme, which combines a plethora of methods for control however with most common being both mechanical and chemical control (Vardien et al., 2012). Mechanical control involves the use of slashing, and in areas where there are small seedlings pulling by hand is employed (Cilliers, 1983; Euston-Brown et al., 2007). This is often supplemented with chemical control which is the application of a chemical to the leaves or to the stump of the trees after cutting (Vardien et al., 2012). Chemical control as a standalone method is not always effective because *L. camara* regrows after the treatment and so follow up operations are required which highlight how costly and labour intensive it is to implement (Cilliers, 1983; Vardien et al., 2012). Results of this study seem to suggest the need for utilisation of IAPs by communities to be incorporated in management intervention, though it might be a double-edged sword which may increase the spread of *L. camara* due to utilization as it is transported from one place to another and may also yield limited results. Common problems in managing IAS include the lack of information, awareness, and communication which were highlighted by Githae and Magana (2017). This hinders decision making that could come up with effective and consistent management strategies from the different stakeholders involved. Invasive alien species are perceived as being both negative and positive by different individuals based on personal experience and observations with an IAS (Shackleton et al., 2019).

4.6 Conclusions

The presence of *L. camara* in all villages is attributed to disturbances due to anthropologic activities since the plant is an opportunistic invader. Although *L. camara* was introduced as an ornamental pant, the primary dispersal route is through frugivorous birds which consume the fruits and disperse the seeds. *Lantana camara* is further propagated by anthropogenic disturbances, which enable favourable conditions and pave way for its invasion. At household level, the management of *L. camara* was done manually by the local people which often involved cutting (slashing), uprooting and burning. Organisations such as WfW were doing little to support local people. This could be because WfW seems to prioritise rivers, plantations, and communal land rather than household yards. The current methods are not eradicating the plant or stopping its propagation. There is a need to investigate new management methods while strengthening and improving current ones.

References

Beck, K.G., Zimmerman, K., Schardt, J.D., Stone, J., Lukens, R.R., Reichard, S., Randall, J., Cangelosi, A.A., Cooper, D., Thompson, J.P., 2008. Invasive species defined in a policy context: Recommendations from the Federal Invasive Species Advisory Committee. Invasive Plant Science and Management 1, 414-421.

Bhagwat, S.A., Breman, E., Thekaekara, T., Thornton, T.F., Willis, K.J., 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.

Cilliers, C.J., 1983. The weed, *Lantana camara L*., and the insect natural enemies imported for its biological control into South Africa. Journal of the Entomological Society of Southern Africa 46, 131-138.

Day M., Wiley C.J., Playford J., Zalucki, M.P., 2003. *Lantana*: Current Management Status and Future Prospects. ACIAR, Canberra, ACT, Australia

dos Santos, L.L., do Nascimento, A.L.B., Vieira, F.J., da Silva, V.A., Voeks, R., Albuquerque, U.P., 2014. The cultural value of invasive species: A case study from semi–arid Northeastern Brazil. Economic Botany 68, 283-300.

Drake, K.K., Bowen, L., Nussear, K.E., Esque, T.C., Berger, A.J., Custer, N.A., Waters, S.C., Johnson, J.D., Miles, A.K., Lewison, R.L., 2016. Negative impacts of invasive plants on conservation of sensitive desert wildlife. Ecosphere 7, e01531.

Egoh, B., Reyers, B., Rouget, M., Richardson, D.M., Le Maitre, D.C., van Jaarsveld, A.S., 2008. Mapping ecosystem services for planning and management. Agriculture, Ecosystems and Environment 127, 135-140.

Etikan, I., Musa, S.A., Alkassim, R.S., 2016. Comparison of convenience sampling and purposive sampling. American Journal of Theoretical and Applied Statistics 5, 1-4.

Euston-Brown, D., Rathogwa, N., Richardson, D.M., 2007. Development of a clearing protocol based on ecological criteria for mesic savannas and sweet grassveld for the Working for Water Programme. Unpublished report. The Working for Water Programme, Department of Water Affairs and Forestry Cape Town.

Foxcroft, L.C., Richardson, D.M., 2003. Managing alien plant invasions in the Kruger National Park, South Africa. Plant Invasions: Ecological Threats and Management Solutions 385–403.

Gelbard, J.L., Belnap, J., 2003. Roads as conduits for exotic plant invasions in a semiarid landscape. Conservation Biology 17, 420-432.

Ghisalberti, E.L., 2000. *Lantana camara L*. (Verbenaceae). Fitoterapia 71, 467-486.

Henderson, L., Wilson, J.R., 2017. Changes in the composition and distribution of alien plants in South Africa: An update from the Southern African Plant Invaders Atlas. Bothalia-African Biodiversity and Conservation 47, 1-26.

Jevon, T., Shackleton, C.M., 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.

Jivanji, Y., 2013. Game ranching and land reform: Claims for the land exclaim tension: A case study of the Mapungubwe region. (PhD Thesis). University of Cape Town.

Kannan, R., Shackleton, C.M., Shaanker, R.U., 2014. Invasive alien species as drivers in socio-ecological systems: Local adaptations towards use of *Lantana* in Southern India. Environment Development and Sustainability 16, 649-669.

Le Maitre, D.C., Blignaut, J.N., Clulow, A., Dzikiti, S., Everson, C.S., Görgens, A.H.M., Gush, M.B., (Eds). 2020. Impacts of plant invasions on terrestrial water flows in South Africa, in: van Wilgen, B.W., Measey, J., Richardson, D.M., Wilson, J.R., Zengeya, T.A. Biological Invasions in South Africa pp. 431-457. Springer, Cham.

Le Maitre D.C., Versfeld D.B., Chapman, R.A., 2000. The impact of invading alien plants on surface water resources in South Africa: A preliminary assessment. Water SA 26, 397-40.

Macdonald, I.A.W., Reaser, J.K., Bright, C., Neville, L.E., Howard, G.W., Murphy, S.J., Preston, G., (Eds). 2003. Invasive alien species in Southern Africa: National reports and directory of resources. Global Invasive Species Programme, Cape Town, South Africa

McWilliam, A., 2000. A plague on your house? Some impacts of *Chromolaena odorata* on Timorese livelihoods. Human Ecology 28, 451-469.

Morton, J.F., 1994. Lantana, or red sage (*Lantana camara L*., [Verbenaceae]), notorious weed and popular garden flower; some cases of poisoning in Florida. Economic Botany 48, 259.

Mpandeli, S., 2014. Managing climate risks using seasonal climate forecast information in Vhembe District in Limpopo Province, South Africa. Journal of Sustainable Development 7, 68-81.

Mucina, L., Rutherford, M.C., 2006. The vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19. (South African National Biodiversity Institute: Pretoria, South Africa). Memoirs of the Botanical Survey of South Africa.

Munir, A.A., 1996. A taxonomic review of *Lantana camara L*. and *L. montevidensis* (Spreng.) Briq. (Verbenaceae) in Australia. Journal of the Adelaide Botanic Garden 17, 1–27.

O'Connor, T.G., van Wilgen, B.W., (Eds). 2020. The impact of invasive alien plants on rangelands in South Africa, in: van Wilgen, B.W., Measey, J., Richardson, D.M., Wilson, J.R., Zengeya, T.A. Biological invasions in South Africa, Invading Nature - Springer Series in Invasion Ecology pp. 459-487. Springer, Cham.

Oosthuizen, M.J., 1964. The biological control of *Lantana camara L*. in Natal. Journal of the Entomological Society of Southern Africa 27, 03-16.

Patel, S., 2011. A weed with multiple utility: *Lantana camara*. Reviews in Environmental Science and Biotechnology 10, 341-351.

Pejchar, L., Mooney, H.A., 2009. Invasive species, ecosystem services and human well-being. Trends in Ecology and Evolution 24, 497-504.

Pimentel, D., Zuniga, R., Morrison, D., 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. Ecological Economics 52, 273-288.

Republic of South Africa, 2004. National Environmental Management: Biodiversity Act 10 of 2004. Proc. R47/Government Gazette.

Richardson, D.M., Foxcroft, L.C., Latombe, G., Le Maitre, D.C., Rouget, M., Wilson, J.R., (Eds). 2020. The biogeography of South African terrestrial plant invasions, in: van Wilgen, B.W., Measey, J., Richardson, D.M., Wilson, J.R., Zengeya, T.A. Biological Invasions in South Africa pp. 67–96. Springer, Cham.

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

Semenya, S., Tshisikhawe, M.P., Potgieter, M.T., 2012. Invasive alien plant species: A case study of their use in the Thulamela Local Municipality, Limpopo Province, South Africa. Scientific Research and Essays 7, 2363-2369.

Shackleton, C.M., McGarry, D., Fourie, S., Gambiza, J., Shackleton, S.E., Fabricius, C., 2007. Assessing the effects of invasive alien species on rural livelihoods: Case examples and a framework from South Africa. Human Ecology 35, 113-127.

Shackleton, R.T., Le Maitre, D.C., Richardson, D.M., 2015. Stakeholder perceptions and practices regarding *Prosopis* (mesquite) invasions and management in South Africa. Ambio 44, 569-581.

Shackleton, R.T., Novoa, A., Shackleton, C.M., Kull, C.A., (Eds). 2020. The social dimensions of biological invasions in South Africa, in: van Wilgen, B.W., Measey, J., Richardson, D.M., Wilson, J.R., Zengeya, T.A. Biological Invasions in South Africa pp. 701-729. Springer, Cham.

Shackleton, R.T., Richardson, D.M., Shackleton, C.M., Bennett, B., Crowley, S.L., Dehnen-Schmutz, K., Estévez, R.A., Fischer, A., Kueffer, C., Kull, C.A., Marchante, E., Novoa, A., Potgieter, L.J., Vaas, J., Vaz, A.S., Larson, B.M.H., 2019. Explaining people's perceptions of invasive alien species: A conceptual framework. Journal of Environmental Management 229, 10-26.

Shackleton, R.T., Witt, A.B., Aool, W., Pratt, C.F., 2017a. Distribution of the invasive alien weed, *Lantana camara*, and its ecological and livelihood impacts in eastern Africa. African Journal of Range and Forage Science 34, 1-11.

Shackleton, R.T., Witt, A.B., Nunda, W., Richardson, D.M., 2017b. *Chromolaena odorata* (Siam weed) in eastern Africa: Distribution and socio-ecological impacts. Biological Invasions 19, 1285-1298.

Shackleton, S., Kirby, D., Gambiza, J., 2011. Invasive plants–friends or foes? Contribution of prickly pear (*Opuntia ficus-indica*) to livelihoods in Makana Municipality, Eastern Cape, South Africa. Development Southern Africa 28, 177-193.

Shackleton, S.E., Shackleton, R.T., 2018. Local knowledge regarding ecosystem services and disservices from invasive alien plants in the arid Kalahari, South Africa. Journal of Arid Environments 159, 22-33.

Shah, P. S., Makhambera, L., 2019. Impacts of plant invasive species on local farming communities around Mulanje Mountain Forest Reserve, Malawi. Journal of Sustainability, Environment and Peace, 1, 68-75.

Sharma, G.P., Raghubanshi, A.S., Singh, J.S., 2005. *Lantana* invasion: An overview. Weed Biology and Management 5, 157-165.

Sharma, O.P., 1988. How to combat *Lantana* (*Lantana camara L.*) menace? A current perspective. Journal of Scientific and Industrial Research 47, 611-616.

Sharma, O.P., Makkar, H.P.S., Dawra, R.K., 1988. A review of the noxious plant *Lantana camara*. Toxicon 26, 975-987.

Simba Y.R., Kamweya A.M., Mwangi P.N., Ochora J.M., 2013a. Impact of the invasive shrub, *Lantana camara L.* on soil properties in Nairobi National Park, Kenya. International Journal of Biodiversity and Conservation 5, 803–809

Simba, Y.R., Kamweya, A.M., Mwangi, P.N., Ochora, J.M., 2013b. Impact of the exotic weed, *Lantana camara L.* on abundance of native plants in Nairobi National Park, Kenya: Implications for the conservation of wildlife. International Journal of Science and Research 2, 294-300.

Simelane, D.O., 2002. Biology and host range of *Ophiomyia camarae*, a biological control agent for *Lantana camara* in South Africa. BioControl 47, 575-585.

Sundaram, B., Krishnan, S., Hiremath, A.J., Joseph, G., 2012. Ecology and impacts of the invasive species, *Lantana camara*, in a social-ecological system in South India: Perspectives from local knowledge. Human Ecology 40, 931-942.

Taylor, S., Kumar, L., 2013. Potential distribution of an invasive species under climate change scenarios using CLIMEX and soil drainage: A case study of *Lantana camara L.* in Queensland, Australia. Journal of Environmental Management 114, 414-422.

Urban, A.J., Simelane, D.O., Retief, E., Heystek, F., Williams, H.E., Madire, L.G., 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, B.W., Forsyth, G.G., Le Maitre, D.C., Wannenburgh, A., Kotzé, J.D.F., 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.

van Wilgen, B.W., Measey, J., Richardson, D.M., Wilson, J.R., Zengeya, T.A., 2020. Biological invasions in South Africa: An overview, in: Biological Invasions in South Africa pp. 3-31. Springer, Cham

Wilson, J. R., Gaertner, M., Richardson, D. M., Van Wilgen, B. W., 2017. Contributions to the national status report on biological invasions in South Africa. Bothalia-African Biodiversity and Conservation, 47, 1-8.

Vardien, W., Richardson, D.M., Foxcroft, L.C., Thompson, G.D., Wilson, J.R., Le Roux, J.J., 2012. Invasion dynamics of *Lantana camara L.* (sensu lato) in South Africa. South African Journal of Botany 81, 81-94.

Vila, M., Weiner, J., 2004. Are invasive plant species better competitors than native plant species? – Evidence from pair-wise experiments. Oikos 105, 229-238.

Wise, R.M., van Wilgen, B.W., Le Maitre, D.C., 2012. Costs, benefits and management options for an invasive alien tree species: The case of mesquite in the Northern Cape, South Africa. Journal of Arid Environments 84, 80-90.

Zengeya, T., Ivey, P., Woodford, D.J., Weyl, O., Novoa, A., Shackleton, R., Richardson, D., van Wilgen, B., 2017. Managing conflict-generating invasive species in South Africa: Challenges and trade-offs. Bothalia-African Biodiversity and Conservation 47, 1–11.

Chapter 5: Conclusions and Recommendations

5.1 Introduction

This thesis reports on the perceptions and livelihood uses of *Lantana camara* by rural communities within the Vhembe Biosphere Reserve (VBR) of South Africa. The study was motivated by the need to bring together scientific knowledge and Traditional Ecological Knowledge (TEK) to examine the effects of *L. camara* on local livelihoods. The overall aim was to examine the effects of *L. camara* invasion on local communities in the VBR, while investigating *L. camara* invasion extent at household level and management practices employed by rural communities.

5.2 Summary of findings

Objective one: to determine the effects of *L. camara* on human well-being and rural livelihoods in Vhembe Biosphere Reserve communities.

Using the framework for interpreting the impacts of Invasive Alien Species (IAS) on rural livelihoods by Shackleton et al. (2007), and the Sustainable Livelihood Framework (SLF) (Scoones, 1998), *L camara* characteristics are classified as undesirable strongly competitive IAS. *Lantana camara* invasion in this study was found to have no substantial impacts to the livelihoods of the respondents. Shackleton et al. (2007) reported that some IAS have no apparent impacts or benefits and thus people have to live with them. This explains that despite the presence of *L. camara* there were no substantial negative impacts experienced. This supports the notion that IAS are not uniformly harmful or beneficial but are context specific and their perceived effects may be influenced by several factors. Thus, the findings of no substantial negative effects are different from other studies (e.g., Sundaram et al., 2012; Jevon and Shackleton, 2015; Shackleton et al., 2017) where *L. camara* was reported to cause significant negative impacts on community livelihoods (in India, Kenya and South Africa) including, toxicity to livestock, blocking of pathways and access to land.

Furthermore, there was a small number of *L. camara* users amongst the six villages and these findings concur with Semenya et al. (2012) who deduced that there were people using *L. camara* in the Thulamela Local Municipality for medicinal and ornamental purpose. Their study mainly focused on traditional healers as the primary users of *L. camara*, and this combined with this study's results suggests that people who are knowledgeable about *L. camara* will derive most use from it. Furthermore, other studies from different parts of the world (e.g., Day et al., 2003; Mbambala et al., 2017) also listed uses of *L. camara* which include use for ornamental and medicinal purposes.

Objective two: To assess the local knowledge and perceptions to *L. camara* by Vhembe Biosphere Reserve communities.

There is a high level of *L. camara* knowledge across the six villages. The respondents knew *L. camara* and were able to identify it. *Lantana camara* was referred to using different local names (i.e., Tshidzimbambule, Tshidzimbampotole) across all six villages. However, most of the respondents were not aware that *L. camara* was an Invasive Alien Plant (IAP). This is because rural people categorise species based on their cultural significance and ability to contribute towards their livelihoods. This has been argued by many authors (e.g., Shackleton et al., 2007; Pejchar and Mooney, 2009; dos Santos et al., 2014). Consequently, the species being present over a longer period of the time in the area would have caused respondents to perceive it as a native species (Shackleton et al., 2007). van Wilgen et al. (2012) posits that perceptions towards IAS may change as more knowledge about IAS is acquired.

This is further reinforced by Shackleton et al. (2007) who argues that effects of IAS are context specific, temporarily, and spatially differentiable. This means that perceived effects of IAS are cultivated by a plethora of factors and do not follow a uniform suit. There is a decline in TEK, which is defined as a collection of beliefs, practices and knowledge about ecological associations which are gained through immense personal observation and interaction with local ecosystems, which is shared among local resource users (Charnley et al., 2007). The decline in TEK in the context of this study is attributed to changes in livelihoods and household preferences, and knowledge which is not passed on to the young generations, and in some instance's ignorance from the youth due to technological advancements and better free healthcare and the inadequate documentation of this knowledge. Perceptions are influenced by several factors such as abundance of species, time since invasion, personal experiences and observation. This means that perceptions are not static and may potentially change with time.

Objective 3: To examine *L. camara* invasion extent at household level within the Vhembe Biosphere Reserve.

Lantana camara was present in all the households across the six villages and was found to be spreading within the area. Jauni et al. (2015) highlighted that habitat disturbance whether natural or anthropogenic was making ecosystems more vulnerable and susceptible to invasions. Munir (1996) argued that *L. camara* grows well in disturbed areas such as roads, railway tracks and abandoned fields. The spread of *L. camara* across the six villages is due to a number of factors such as anthropogenic disturbances: (1) construction which often involved transporting soil from one area to another, (2) clearing of land for construction and agricultural activities, and (3) abandoned fields (specifically home gardens) which were observed to have high densities of *L. camara*. Other factors that favour *L. camara* expansion are climate and pollination by birds (Vardien et al., 2012). Respondents were of the view that birds were also causing the spread of *L. camara* in the area through the consumption of the fruit and dispersing the seeds in new areas.

Objective 4: To examine *L. camara* management options used in Vhembe Biosphere Reserve.

There was management of L. camara at local and government level, with the most common method used by local communities being clear-cutting. Most of the respondents highlighted that although *L. camara* was not causing any negative substantial effects to their livelihoods they would still like to see a decrease in its population densities. Despite control measures put in place by rural communities at household level *L. camara* remains a problem, this because there is a need for constant intervention in the management of the species. While, Working for Water (WfW) has success in managing IAS, it has had some challenges in managing *L. camara* in the area, such as inadequate monitoring programmes due to limited budget, prioritising certain projects which will yield greatest returns on the investment made, and conflict of interest for species with dualistic impacts (van Wilgen and Wannenburgh, 2016). At national level, current control methods (i.e., mechanical, chemical), although effective, still prove costly to implement and have not successfully stopped or killed *L. camara* but only reduced its growth rate. Consequently, biological control only acts as a supplement to current control methods. Perhaps the current clearing being done by communities at household level should be valued by WfW and such control mechanisms should be financially supported if the problem of *L. camara* invasion is to be managed in South Africa.

5.3 Recommendations

The recommendations from this study are that policies around management of *L. camara* should involve local community members as they possess an immense wealth of knowledge and are the ones directly affected by the decisions taken to manage *L. camara*. Removal of *L. camara* in the area would be detrimental for the users and thus consulting with users is key in making sure their livelihoods are not degraded. Alternative native species that provide same uses and roles which are already present in the area should be considered and encouraged. For instance, for medicinal uses such as treating of toothaches the native *Senna petersiana* (Mabogo, 1990) should be used in the place of *L. camara*. The uses of *L. camara* were not enough to consider utilisation of the plant as a technique for management. Shackleton et al. (2014) argued that utilisation of IAS as a standalone management technique in absence of other techniques is highly controversial and might not contribute to meeting the national IAS control targets. Therefore, it should be acknowledged that utilisation of IAS by communities has a role to play towards containing the rapid spread of IAS. However, it should be noted that utilisation can also significantly increase the spread of *L. camara* as people will be dispersing it and thus caution needs to be practiced when taking this approach.

Education and awareness are of paramount importance for both local communities and the local government. This is largely due to the knowledge possessed on both sides, scientific and TEK, which would help improve current methods (mechanical and chemical) and offer opportunities for the creation and implementation of new sound and sustainable techniques for management. The control of *L. camara* requires concerted efforts as no single technique is effective when used alone. An integrated approach that includes education and awareness, and current management techniques is required at local, regional and national levels. Additional research is needed at local scales to implement techniques best suited for the area. Without any improvements to current techniques, *L. camara* will continue to spread and with it the detrimental effects.

5.4 Conclusion and suggestion for further research

In conclusion, the study highlighted the complex nature of conflict-generating species. How an IAS is perceived will always differ amongst the users, non-users and those affected by the species. Understanding these complexities is significant for all stakeholders involved. *Lantana camara* is useful to only a few individuals for various livelihood uses. Its usefulness to these individuals shapes their perception of it in a positive light. Similarly, negative impacts and non-use of *L. camara* shapes people's perceptions in a negative way. It is therefore of paramount importance to include all the relevant stakeholders when undertaking policy, decisions and activities related to *L. camara* that may disrupt livelihoods.

While this study and many other studies show the presence and use of IAS in the area, the suggestions for further research are for researchers to explore more native alternative species which are present or easily accessible to the community members which may offer the same or superior value than IAS. This may reduce reliance on exotic species and alleviate the environment from the plight of IAS. Furthermore, additional research at local level is required to discover, implement, and strengthen techniques best suited for the area.

References

Charnley, S., Fischer, A.P., Jones, E.T., 2007. Integrating traditional and local ecological knowledge into forest biodiversity conservation in the Pacific Northwest. Forest Ecology and Management 246, 14-28.

Day, M.D., Broughton, S., Hannan-Jones, M.A., 2003. Current distribution and status of *Lantana camara* and its biological control agents in Australia, with recommendations for further biocontrol introductions into other countries. Biocontrol News and Information 24, 63-76.

dos Santos, L.L., do Nascimento, A.L.B., Vieira, F.J., da Silva, V.A., Voeks, R., Albuquerque, U.P., 2014. The cultural value of invasive species: A case study from semi–arid Northeastern Brazil. Economic Botany 68, 283-300.

Jauni, M., Gripenberg, S., Ramula, S., 2015. Non-native plant species benefit from disturbance: A meta-analysis. Oikos 124, 122-129.

Jevon, T., Shackleton, C.M., 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.

Mbambala, S.G., Tshisikhawe, M.P., Masevhe, N.A., 2017. Invasive alien plants used in the treatment of HIV/AIDS-related symptoms by traditional healers of Vhembe municipality, Limpopo Province, South Africa. African Journal of Traditional, Complementary and Alternative Medicines 14, 80-88.

Munir, A.A., 1996. A taxonomic review of *Lantana camara L.* and *L. montevidensis* (Spreng.) Briq. (Verbenaceae) in Australia. Journal of the Adelaide Botanic Garden 17, 1-27.

Pejchar, L., Mooney, H.A., 2009. Invasive species, ecosystem services and human well-being. Trends in Ecology and Evolution 24, 497-504.

Scoones, I., 1998. Sustainable rural livelihoods. A framework for analysis. IDS Working Paper 72. Institute of Development Studies, University of Sussex.

Semenya, S.S., Tshisikhawe, M.P., Potgieter, M.T., 2012. Invasive alien plant species: A case study of their use in the Thulamela Local Municipality, Limpopo Province, South Africa. Scientific Research and Essays 7, 2363-2369.

Shackleton, C.M., McGarry, D., Fourie, S., Gambiza, J., Shackleton, S.E., Fabricius, C., 2007. Assessing the effects of invasive alien species on rural livelihoods: Case examples and a framework from South Africa. Human Ecology 35, 113-127.

Shackleton, R.T., Le Maitre, D.C., Pasiecznik, N.M., Richardson, D.M., 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.

Shackleton, R.T., Witt, A.B., Aool, W., Pratt, C.F., 2017. Distribution of the invasive alien weed, *Lantana camara*, and its ecological and livelihood impacts in eastern Africa. African Journal of Range and Forage Science 34, 1-11.

Sundaram, B., Krishnan, S., Hiremath, A.J., Joseph, G., 2012. Ecology and impacts of the invasive species, *Lantana camara*, in a social-ecological system in South India: Perspectives from local knowledge. Human Ecology 40, 931-942.

van Wilgen, B.W., Forsyth, G.G., Le Maitre, D.C., Wannenburgh, A., Kotzé, J.D.F., 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.

Vardien, W., Richardson, D.M., Foxcroft, L.C., Thompson, G.D., Wilson, J.R., Le Roux, J.J., 2012. Invasion dynamics of *Lantana camara L*. (sensu lato) in South Africa. South African Journal of Botany 81, 81-94.

Appendices

Appendix 1: Questionnaire survey

I am Edward Mhlongo from Rhodes University, Department of Environmental Science. I am conducting research for my MSc project titled "role of *L. camara* invasion on local communities in Vhembe biosphere reserve, South Africa". Your household was selected to participate in this research. Participation is not mandatory, and you may pull out of the interview or elect not to provide an answer at any time. There are no right or wrong answers. All information will be confidential and will not be shared with any other person. Additionally, all data will be pooled and so no individuals will be revealed. There will be no payments or harm caused by participating. Should you desire to know more about this research project and or seek further clarification, please contact my supervisor Dr. S. Ruwanza at 046 603 7009 P.O. Box 94, Department of Environmental Science, Rhodes University, Grahamstown, South Africa.

<u>(1) Knowledge and perceptions regarding *L. camara*</u>

1.1) Do you know what *L. camara* is Yes [ ] No[ ]

1.2) Do you have *L. camara* on your property Yes[ ] No[ ] Don't know[ ]

1.3) Is it very common[ ] common[ ] moderate[ ] scarce[ ] very scarce[ ] on your property

1.4) If yes, did you plant it Yes[ ] No[ ], if no, was it was it there when you moved onto the property[ ] or did it germinate naturally on your property[ ]

1.5) If no, would you like to plant it Yes[ ] No[ ]. Reason.
………..

………..

1.6) Is it spreading on your property [Yes] [No] [Don't know]

1.7) Is it spreading in the area Yes[ ] No[ ] Don't Know[ ]

1.8) Has the plant increased [ ] or decreased [ ] over the last 5-10 years, don't know [ ]

1.9) Is *L. camara* a beneficial[ ], harmful[ ], no impact[ ] or both harmful and beneficial [ ] species for you and your livelihood

1.10) Does it cause any negative impacts Yes[ ] No[ ].If yes, what
……….

………

1.11) Does it provide any benefits Yes[ ] No[ ].If yes, what

……….

……….

1.12) Do you think the benefits of *L. camara* outweigh the costs Yes[ ] No[ ] Don't know[ ]

1.13) Is *L. camara s* more beneficial to you than indigenous/native/local trees Yes[ ] No[ ] Don't know[ ]

Reason.……

………..

1.14) Are you aware that it is an invasive alien species Yes[ ] No[ ]

1.15) Does *L. camara* displace any other indigenous plants, insects, birds, animals or plants important for your livelihood Yes[ ] No[ ] If yes, what.
……….

………..

………..

1.16) Would you be happy if *L. camara* densities decreased in your area Yes[ ] No[ ] Don't mind[ ]

<u>(2) Management and uses of *L. camara*</u>

1.1) Does your household have any use for *L. camara* Yes[ ] No[ ] if yes, please state them

………..

………..

………..

………..

1.2) Is it for own consumption[ ], sale[ ] or both[ ]

1.3) How do you manage the plant?

………..

………..

………..

1.4) Do you receive any assistance from the government in managing the plant Yes[ ] No[ ] if yes please state how.

………..

……

…….

1.5) Do you receive any information or news about the use of invasive species if yes through which medium.

……

1.6) Would you like the government to assist you in managing *L. camara* if so please state how

………..

……

(3) Background Information

1.1) Gender: [Male] [Female]

1.2) Age; 20-30 [ ] 30-40 [ ] 40-50 [ ] 50-60 [ ] 60-70 [ ] 70+ [ ].

1.3) Race: [Black] [Coloured] [Asian] [White]

1.4) Education; Primary [ ] Highschool [ ] Matric [ ], University Undergraduate [ ], Postgraduate [ ].

1.5) Number of people in the household? Adults……………. Children………………………..

1.6) Source of Income; Grants [ ], Employed [ ], Self-employed [ ], Pension [ ].

(4) Ecological survey per household.

	Abundance	Height (m)	Diameter (cm)	Cover
1				
2				
3				
4				
5				
6				
7				