



RHODES UNIVERSITY

Where leaders learn

**Developing a community of practice to promote the
use of biological control in the integrated
management of *Prosopis* in South Africa**

A thesis submitted in the fulfilment of the requirements for the degree of

MASTER OF SCIENCE

of

RHODES UNIVERSITY

GRETHA VAN STADEN

December 2023

ABSTRACT

Prosopis spp. are non-native species present in the arid parts of southern Africa. These trees originated in the Americas and were first introduced as a source of fodder, shade, and wood, but have become invasive, negatively impacting local biodiversity, and disrupting the delivery of ecosystem services. Some species of *Prosopis* hybridise freely, complicating identification and subsequent control. The control of *Prosopis* in the Northern Cape Province of South Africa is still contentious, because of the perceived benefits to some landowners. The effectiveness of biological control agents to control the spread of *Prosopis* has been quantified, more damaging agents have been considered in recent years because of the continued increase in *Prosopis* density. Research into the establishment of a Community of Practice (CoP) to address the differences in perceptions regarding the control of *Prosopis* in the Northern Cape Province is considered an appropriate starting point to conceptualise the challenges to the successful integrated management of *Prosopis*. As farmers are the main stakeholders involved with *Prosopis* control, understanding the role of farmers and the functioning of farming enterprises in the Northern Cape is imperative for the development of both a CoP as well as the appropriate management of *Prosopis*. To foster engagement with as many stakeholders as possible, workshops dealing with biological control as part of an integrated approach to the control of *Prosopis* were held in towns in the Northern Cape Province: Groblershoop, Brandvlei, Kenhardt, Upington, Prieska and Williston. Some of the main concerns of the landusers include the host specificity of the released biocontrol agents, as well as increased transparency and communication. This is especially in regards to the research on present and future biological control agents that will possibly improve the perceptions of stakeholders. The mechanical harvesting and use of biomass as a control method was supported, especially where farmers were removing *Prosopis* from their properties, leaving large amounts of biomass in the veld. Continued research into *Prosopis* in the Northern Cape needs to consider the possibility of secondary invasions, especially in areas where native bush encroachment is already a concern. The impact of clearing in terms of natural grazing and animal improvement needs to be quantified, to conceptualise the importance of maintaining better veld quality versus using *Prosopis* for fodder. Biological control targeting not only the reproductive output of the trees, but also the standing biomass has support from the majority of the land users in the Northern Cape Province following these workshops and this study shows the importance of a socio-ecological approach to the control of landscape scale invasion.

OPSOMMING

Prosopis spp. is spesies van uitheemse bome wat teenwoordig is in die semi-woestyn en woestyn gebiede van Suid-Afrika. Die bome kom oorspronklik vanaf Noord- en Suid-Amerika en was oorspronklik in Suid-Afrika ingebring as 'n bron van veevoer, skadu en hout. Die bome het vinnig ander areas begin indring, wat die plaaslike biodiversiteit geaffekteer het, en die voorsiening van ekosisteme dienste ontwrig het. Sommige spesies van *Prosopis* baster vrylik met mekaar, wat identifisering en beheer baie bemoeilik. Die beheer van *Prosopis* in die Noord-Kaap is steeds omstrede, gegewe die feit dat daar voordele geassosieer word met die spesies. Baie boere ag die gebruik van *Prosopis* as een van die redes dat hul dit deur die onlangse droogte gemaak het. Die implementering van biologiese beheer agente vir die beheer van die verspreiding van *Prosopis* is gekwantifiseer en meer beskadigende opsies is eers in onlangse jare oorweeg, vanweë die verdigting van die *Prosopis* indringing in die Noord-Kaap. Navorsing in die vestiging van 'n "Community of Practice" (gemeenskap van aksie) om die verskillende persepsies en vaardighede rakende die beheer van *Prosopis* in die Noord-Kaap te adresseer word as 'n gepaste begin geag. Sodoende kan die uitdagings vir die suksesvolle en geïntegreerde beheer van *Prosopis* gekonseptualiseer word. Sien dat baie van die belanghebbendes betrokke met die beheer van *Prosopis* boere is, is dit krities om die rol en funksionering van boerderye in Suid-Afrika en die Noord-Kaap te verstaan, om sodoende die gemeenskap van aksie suksesvol tot stand te kan bring. Om soveel interaksie as moontlik met belanghebbendes te bevorder, is aanlyn kommunikasie gebruik om die projek aan die begin van 2021 te adverteer asook om 'n aanvanklike vraelys te versprei, om belangstellendes na 'n werkswinkel in Groblershoop te nooi sowel as alle daaropvolgende kommunikasie vir die werkswinkel reeks met sessies in Brandvlei, Kenhardt, Upington, Prieska en Williston. Belangstelling het toegeneem met die werksinkels. Een van die hoof bekommernisse van die grondeienaars en -gebruikers was die gasheer spesifisiteit van die biologiese beheer agente. Verhoogde deursigtigheid en kommunikasie rakende die navorsing en ontwikkeling van huidige en toekomstige biologiese beheer agente sal die uitsien daarna verbeter, so ook verbeterde vertrouwe verhoudings. Die gebruik van biomassa as 'n metode van *Prosopis* beheer was entoesiasties oorweeg, veral deur boere wat reeds besig is met meganiese verwydering van *Prosopis* vanaf hul eiendom. Volgehoue navorsing in *Prosopis* in die Noord-Kaap moet die voorkoms van sekondêre indringing oorweeg, met 'n fokus op areas waar daar reeds voorkoms van inheemse bos verdigting is. Die impak van *Prosopis* verwydering in terme van natuurlike weiding en vee kwaliteit moet gekwantifiseer word, om sodoende die belang van beter natuurlike veld onderhoud teenoor die gebruik van *Prosopis* te konseptualiseer. Dit sal die geïntegreerde beheer van *Prosopis* op boerdery grond as deel van 'n plaas gebaseerde benadering ondersteun.

ACKNOWLEDGEMENTS

My deepest gratitude to:

- Prof. Martin Hill, my supervisor, for kindly answering all questions, encouraging my work, and acting as a calm guide to the completion of this thesis.
- Mr. Philip Ivey, my supervisor, for your unrelenting belief in the work you do.
- Ms. Kim Weaver, my supervisor, for understanding the intricacies of social sciences far better than I ever could.
- The National Research Fund for their provision of the Community of Practice funding.

Thank you each for your support and kindness, especially in the world of academics.

I would also like to thank:

- All the respondents who completed many or a single survey and your interest in the workshops, even if some could not attend.
- Everyone who took the time and braved the kilometres to attend the workshops in Groblershoop, Brandvlei, Kenhardt, Upington, Prieska and Williston.
- Dr Graham Harding, Fritz Heystek, Carien Kleinjan and Eben Anthonissen, the presenters at the Groblershoop Workshop, for conducting with kindness and calm.
- The presenters for the workshop series, Dr Graham Harding, Dirk Oosthuizen and Brandt Coetzee, your enthusiasm and industry knowledge is fascinating.
- KLK for their valued assistance in the distribution of the first project poster and consequent support.
- RPO for the distribution of the workshop details and various surveys.
- AgriNK for communicating details to their members and continued interest and investment in *Prosopis* management in the Northern Cape.
- Fritz Heystek, Carien Kleinjan and Blair Cowie for inviting me along for their field trip for their research in biological control agent release.
- Guy Sutton for his valuable contribution to the statistical analysis aspect of this study.

Aan my gesin, nie net gee julle om nie, julle versorg ook.

“So wie geleer het om vas te trap, het daarby geleer om nie op sand te staan nie”

- C. J. Langenhoven

TABLE OF CONTENTS

CHAPTER ONE.....	1
1. Introduction.....	1
1.1. <i>Prosopis</i> in South Africa.....	2
1.1.1. Introduction of <i>Prosopis</i> into South Africa.....	2
1.1.2. Range and spread of <i>Prosopis</i> in South Africa.....	3
1.1.3. Impact of <i>Prosopis</i> in South Africa.....	6
1.1.4. Impact of <i>Prosopis</i> on water availability.....	7
1.1.5. Economic impact of <i>Prosopis</i>	9
1.2. <i>Prosopis</i> in Africa.....	11
1.3. Failures and success in <i>Prosopis</i> control.....	12
1.3.1. South Africa.....	13
1.3.2. Africa.....	15
1.4. Biological control of <i>Prosopis</i>	16
1.4.1. Africa.....	17
1.4.2. South Africa.....	18
1.5. Community of Practice in environmental programmes.....	24
1.6. Stewardship, landscapes and collaboration in environment programmes.....	25
1.7. Management strategies for invasive alien control programmes.....	28
1.8. Project aims.....	30
CHAPTER TWO.....	31
2. Introduction.....	31
2.1. Farming in South Africa and the Northern Cape.....	31
2.2 Materials and Methods.....	33
2.2.1. Questionnaire.....	33
2.2.2. Statistical analysis.....	34
2.3. Results.....	35
2.3.1. Response volume.....	35
2.3.2. Age.....	36
2.3.3. Property.....	36
2.3.4. <i>Prosopis</i> control.....	39
2.3.5. Biological control.....	41
2.3.6. Statistical analysis.....	45
2.4 Discussion.....	47
CHAPTER THREE.....	48

3. Introduction	48
3.1. Invasive species stakeholder engagement and their impact	48
3.2. Materials and Methods	52
3.2.1. Groblershoop workshop	52
3.2.2. <i>Prosopis</i> ‘roadshow’	54
3.3. Results	54
3.3.1. Groblershoop workshop	54
3.3.2. Groblershoop workshop outcomes	55
3.3.3. Groblershoop post-workshop actions	56
3.3.4. <i>Prosopis</i> roadshow results	58
3.4 Discussion	67
CHAPTER FOUR	72
4. Introduction	72
4.1. The role of a Champion	72
4.2. Stakeholder engagement in invasion science	73
4.3. Social learning and stakeholder engagement	75
4.4. Public perception of invasion	77
4.5. Public perception of biological control	78
4.6. Critique of science communication	80
4.7. The Role of Workshops	81
4.8. Future work	82
4.9. Conclusion	83
References	85

GLOSSARY OF TERMS

IAS	Invasive Alien Species.
Champion	An individual who informally emerges to promote an idea with conviction, persistence and energy, and willingly risks their position and reputation to ensure the success of the innovation.
Collaboration	The pooling of appreciations and/or tangible resources, e.g., information, money, labour, etc., by two or more stakeholders, to solve a set of problems which neither can solve individually.
ISM	Invasive Species Management.
Stakeholder	Any individual, group or organisation who is affected (positively or negatively) by invasive species, or who has the capacity to promote or limit the spread of invasive species.
Stakeholder engagement	The process of involving stakeholders (actors) in decision making, management actions and knowledge creation surrounding invasive species.
Sustainable	Capable of being maintained at a certain rate or level.

LIST OF FIGURES

Figure 1.1. Southern African biomes.	4
Figure 1.2. Seed-feeding bruchids. A) <i>Nelitimius arizonensis</i> , B) <i>Algorobius prosopis</i> .	20
Figure 1.3. <i>Coelocephalapion gandolfoi</i> adult weevil.	21
Figure 1.4. <i>Evippe</i> sp. #1 adult moth	23
Figure 2.1. Northern Cape local municipalities.	32
Figure 2.2. A) Municipal district wherein respondents reside; B) Age of respondents; C) Total size of property ownership; D) Size of the residing property; E) Primary farming practice; F) Main use of <i>Prosopis</i> biomass on property/in farming practice; G) Estimated density of <i>Prosopis</i> on property; H) Primary <i>Prosopis</i> control methods used on property.	43
Figure 2.3. A) Frequency of <i>Prosopis</i> control; B) Frequency of follow-up treatment application; C) Feed type used during the drought; D) The likelihood that biological control insects will survive on indigenous trees and have a negative impact on the environment; E) The likelihood of suggesting the use of biological control methods to manage <i>Prosopis</i> to others; F) General use of <i>Prosopis</i> biomass on respondent property; G) Financial priority on respondent property; H) Response volume.	44
Figure 2.4. The relationship between the likelihood of considering <i>Prosopis</i> a nuisance and (A) property size; (B) <i>Prosopis</i> density; (C) <i>Prosopis</i> biomass use; (D) <i>Prosopis</i> fodder use; (E) frequency of <i>Prosopis</i> control and (F) stock type on property	46
Figure 3.1. Location of Groblershoop, Northern Cape.	53
Figure 3.2. Locations of Brandvlei, Kenhardt, Upington, Prieska and Williston.	55
Figure 3.3. Groblershoop workshop registration response volume.	59
Figure 3.4. Likelihood of satisfaction with the speakers at the session attended in A) Brandvlei; B) Kenhardt; C) Upington; D) Prieska; E) Williston.	61
Figure 3.5. Likelihood that biological control agents would be considered successful for <i>Prosopis</i> management in at A) Brandvlei; B) Kenhardt; C) Upington; D) Prieska; E) Williston.	62
Figure 3.6. The likelihood that respondents were busy with <i>Prosopis</i> management on their properties in A) Brandvlei; B) Kenhardt; C) Upington; D) Prieska; E) Williston.	63
Figure 3.7. The likelihood that respondents were busy with <i>Prosopis</i> management on their properties in A) Brandvlei; B) Kenhardt; C) Upington; D) Prieska; E) Williston.	65
Figure 3.8. General factors that hinder the control of <i>Prosopis</i> on respondents' property in A) Brandvlei; B) Kenhardt; C) Upington; D) Prieska; E) Williston.	66

APPENDICES

A: Advertisement poster	103
B: 2021 survey	104
C: Groblershoop registration	113
D: Newsletter July 2022 issue	114
E: Post workshop survey	141
F: Future workshop suggestions survey	146
G: <i>Prosopis</i> roadshow survey	147
H: Newsletter November 2022 issue	150
I: Follow-up questionnaire 2023	163
J: Groblershoop workshop programme	168

CHAPTER ONE

GENERAL INTRODUCTION

1. Introduction

Biological invasions are a critical factor of human-induced global change, alongside other factors such as habitat transformation and climate change (Vitousek, 1990; Shackleton *et al.*, 2017). The growing number of destructive invasive alien species (IAS), including disease-causing organisms, fungi, agricultural weeds, and insect pests, is increasing pressure on both human communities and natural ecosystems (Richardson *et al.*, 2004). IAS erode natural capital, compromise ecosystem stability and could be a threat to economic productivity (Richardson *et al.*, 2004). In addition to their impact on agriculture, forestry and human health, biological invasions are widely recognized as the second-largest global threat to biodiversity, after direct habitat destruction (Wilcove *et al.*, 1998; Walker *et al.*, 1999; Richardson *et al.*, 2004).

Studies on the majority of consequences of IAS for the delivery of ecosystem goods and services to people of the affected regions are limited, but the impact of IAS on water availability in some regions is relatively well understood (Richardson *et al.*, 2004). In South Africa, most of the available information on site-specific impacts originates from the fynbos biome, and is largely absent for other biomes (Richardson *et al.*, 2004). The problems caused by IAS are growing in severity and geographical extent, in particular because of the acceleration of trade and travel, as well as increased ecosystem disruption (which makes these ecosystems more susceptible to invasion) (Richardson *et al.*, 2004).

Invasive alien trees were not widely recognised as a major threat to biodiversity and ecosystem productivity in comparison to cacti and waterweeds, for example, but this outlook has changed in the last 30 years, where they are now considered to be among the most widespread and damaging of global invasive species (Richardson *et al.*, 2011; Shackleton *et al.*, 2016). Invasive trees, including *Prosopis* spp. (the topic of this thesis), are believed to be a major contributor to global change, while also having a negative effect on biodiversity, ecosystem services and the livelihoods of affected human populations (Shackleton *et al.*, 2014, 2016).

31 **1.1. *Prosopis* in South Africa**

32 *Prosopis* Leguminosae (Fabaceae) Linnaeus emend. Burkart (from (Burkart, 1976)),
33 is a group of deep-rooted leguminous trees with numerous species. The International
34 Union for the Conservation of Nature (IUCN) has declared *Prosopis* as one the worst
35 global invasive species (Mwangi *et al.*, 2005; Bromilow, 2010; Dzikiti *et al.*, 2013).
36 Species in the genus are considered an invasive weed in Ethiopia, Kenya, Sudan,
37 Eritrea, Iraq, Pakistan, India, Australia, South Africa, the Caribbean, the Atlantic
38 Islands, Bolivia, Brazil, the Dominican Republic, El Salvador, Nicaragua, the United
39 States and Uruguay (Pasiecznik *et al.*, 2001; Abdulahi *et al.*, 2017).

40 Van Wyk *et al.* (1997) describe *Prosopis* as a multi-stemmed shrub or small tree,
41 growing up to 10m tall (Zimmermann, 1991). Branches are reddish brown, with straight
42 spines located at the nodes. Leaves are widely spaced, with 1 pair of dark green
43 pinnae, with 7-18 leaflet pairs per pinna (Van Wyk *et al.*, 1997). Yellow flowers are
44 present in many-flowered auxiliary spikes, and slender woody pods form after
45 flowering concludes (Van Wyk *et al.*, 1997).

46 Several species of this desert adapted woody weed (Shackleton *et al.*, 2014; Dzikiti *et*
47 *al.*, 2017) have become invasive in the arid north-western parts of South Africa
48 (Zachariades *et al.*, 2011), including *Prosopis velutina* Wooton, *P. glandulosa* var.
49 *glandulosa*, *P. glandulosa* var. *torreyana* Torrey and *P. chilensis* (Molina) Stuntz
50 emend. Burkhart, all of which are classified as section *Algorobia* (Burkart, 1976; Van
51 den Berg *et al.*, 2013)

52 **1.1.1. Introduction of *Prosopis* into South Africa**

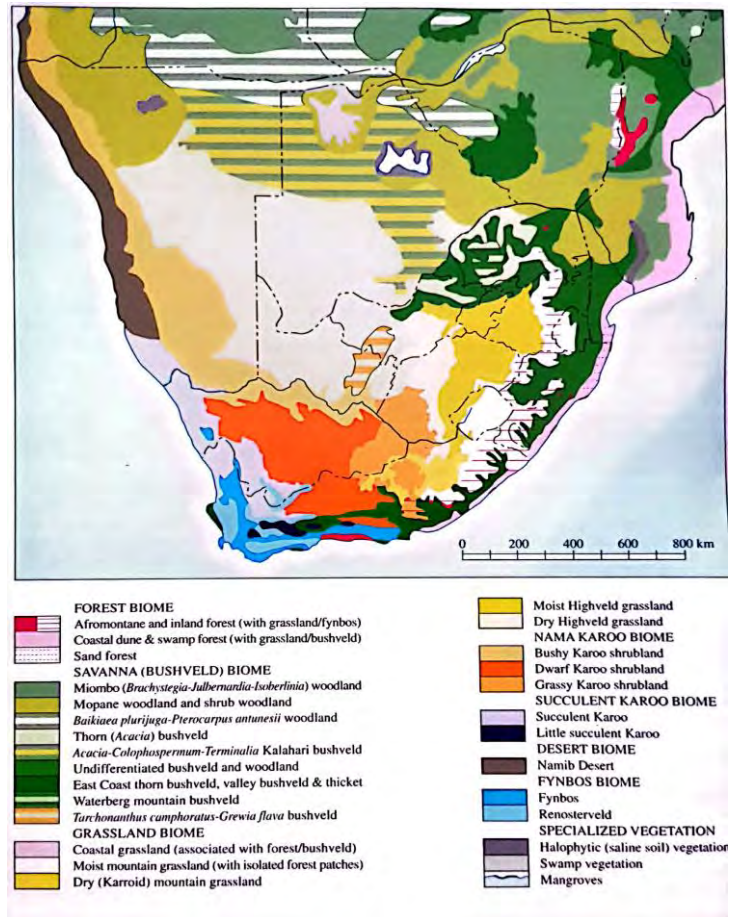
53 Originally forestry and farming officials introduced *Prosopis* species from North
54 America in the late 1800's, to provide shade for livestock, timber for construction, pods
55 for fodder, wood for fuel and as nectar source for honey production (Zimmermann,
56 1991; Zimmermann *et al.*, 2006; Zachariades *et al.*, 2011). The identity of much of the
57 *Prosopis* material brought into South Africa in the late 19th and 20th centuries is
58 uncertain, with mixtures of seed from a minimum of three species imported from North
59 America, resulting in hybridization and taxonomic uncertainty (Harding, 1987;
60 Zachariades *et al.*, 2011).

61 According to Poynton (1990) the first reported introduction of this species was
62 *P. glandulosa* var. *torreyana*, under the name *P. dulcis* Kunth (Zimmermann, 1991).
63 Alston (1914) stated that he received a consignment of seed from John Marquard for
64 trials on his farm near Vanwyksvlei, although the origin of the seeds was not recorded
65 (Zimmermann, 1991). A Cape of Good Hope Departmental Forest Commission report
66 from 1884 mentions *P. chilensis*, and the raising thereof in the Hanover Forest,
67 although Poynton (1990) suggested that these specimens may have been *P. juliflora*
68 (Zimmermann, 1991).

69 In the period of 1897 to 1916, the Cape and Transvaal Forestry Administrations
70 obtained 63 kg of seeds of supposedly *P. juliflora*, in 23 different consignments from
71 various public and private sources in both the USA and Mexico (Poynton, 1990;
72 Zimmermann, 1991). It is, however, highly unlikely for only *P. juliflora* to have been
73 represented in the consignments, which makes it highly probable that these seeds are
74 the source of most of the *Prosopis* species and their variants present in South Africa
75 (Zimmermann, 1991).

76 **1.1.2. Range and spread of *Prosopis* in South Africa**

77 The Northern Cape is South Africa's largest and most arid province, covering 363 203
78 km², nearly a third of the country's land area. It is a dry region with fluctuating
79 temperatures and varying topographies (Van den Berg *et al.*, 2013). The province
80 consists of 6 biomes (Mucina *et al.*, 2006). The northern part is dominated by the
81 Savanna and Desert biomes, and the west by the Succulent Karoo biome. The central
82 part of the Northern Cape is primarily the Nama Karoo biome (Van den Berg *et al.*,
83 2013) (Fig. 1.1).



84

85 **Figure 1.1:** Southern African Biomes (Van Wyk *et al.*, 1997).

86 Widespread planting of *Prosopis* across the province was encouraged, resulting in
 87 multiple sources of seeds. The seeds have been spread deliberately by humans,
 88 through animals grazing pods and along rivers during floods (Dzikiti *et al.*, 2013, 2017).
 89 The historical rate of spread of *Prosopis* species in South Africa is estimated to range
 90 from 3.5-18% per annum, although this can increase to 30-40% at times (Zachariades
 91 *et al.*, 2011; Wise *et al.*, 2012). Once *Prosopis* is established in an area, the density of
 92 the infestation increases at annual rates of 2.5-10% (Zachariades *et al.*, 2011; Wise
 93 *et al.*, 2012).

94 All *Prosopis* species in South Africa are exotic and as a result, virtually free of insect
 95 herbivores, however, in their natural habitat in North America, more than 657 species
 96 of phytophagous insects have been recorded on various *Prosopis* species (Ward *et al.*
 97 *et al.*, 1977; Zimmermann, 1991). The absence of damaging insects that inhabit these
 98 trees have undoubtedly facilitated the invasion and rapid spread of *Prosopis* in South
 99 Africa, differing greatly from the situation in their native habitat in the America's
 100 (Zimmermann, 1991).

101 *Prosopis* species are naturalised in South Africa, mainly occurring in the arid western
102 parts of the country (Zimmermann, 1991). Extensive *Prosopis* invasions occur in three
103 major South African biomes: the Savanna, the Nama-Karoo and the Succulent Karoo.
104 Small *Prosopis* populations are present in both the Fynbos and Arid grasslands
105 (Shackleton *et al.*, 2015, 2016). Henderson (2007) ranked invasive alien plants in
106 South Africa using a biome-based approach, *Prosopis* species were the most
107 prominent in the Nama-Karoo Biome (the second largest biome in South Africa) and
108 the third most prominent in the Succulent Karoo Biome. *Prosopis* species were within
109 the top ten invasive species in riparian and wetland habitats (Zachariades *et al.*, 2011;
110 Wise *et al.*, 2012). Other assessments also rank *Prosopis* species among the most
111 problematic of the invasive plant species in South Africa (Robertson *et al.*, 2002; Nel
112 *et al.*, 2004).

113 The Nama-Karoo covers an estimated 22.7% of the interior of southern Africa (Palmer
114 *et al.*, 1997; Ndhlovu *et al.*, 2011). This biome supports an important industry of small-
115 stock rearing that is based in its entirety on natural pasture and groundwater (Palmer
116 *et al.*, 1997; Ndhlovu *et al.*, 2011). The biggest threat to these indigenous pastures is
117 various IAS, including cacti (*Opuntia* spp.), saltbushes (*Atriplex* spp.), and most
118 notably *Prosopis* in low-lying alluvial plains and seasonal watercourses (Richardson
119 *et al.*, 2004; Ndhlovu *et al.*, 2011).

120 Factors that make *Prosopis* such a successful invader are: “1) rapid growth rate, 2)
121 the production of a large number of seeds that remain viable for decades, 3) the ability
122 to coppice after damage (Shiferaw *et al.*, 2004; Forsyth *et al.*, 2012; Ng *et al.*, 2017;
123 Felker, 2019), 4) a deep root system that taps into the groundwater table (Nilsen *et al.*,
124 1983; Dzikiti *et al.*, 2013; Ng *et al.*, 2017), 5) a high tolerance to climate extremes,
125 6) a high tolerance to various soil types and 7) negative allelopathic effects on
126 competing plants” (Elfadl *et al.*, 2006; Ng *et al.*, 2017). Recent studies estimate that
127 invasive *Prosopis* trees cover 1.8 million ha of South Africa, 83% of which is in the
128 Northern Cape Province (Versfeld *et al.*, 1998; Van den Berg *et al.*, 2013; Shackleton
129 *et al.*, 2017). This includes a majority of drought prone regions, where communities
130 are almost fully reliant on groundwater (Dzikiti *et al.*, 2017). Using compounded annual
131 spread rates of 8% (Van den Berg *et al.*, 2013) in conjunction with recent distribution
132 records, Shackleton *et al.* (2017) estimated that present *Prosopis* invasions cover over
133 6 million ha in South Africa, 43% of which is in the Northern Cape.

134 The spread of *Prosopis* and the formation of dense thickets have been enhanced by
135 livestock and game, which consume the ripe pods and disperse seeds. According to
136 Martin (1970), *Prosopis* seeds are long-lived and accumulate over time in large seed
137 banks, which can persist for at least 20 years. The size of seed banks in South Africa
138 varies across the distributional range of *Prosopis* and is affected by the presence or
139 absence of livestock, with accumulations of as many as 2500 seeds/m² in some areas
140 (Roberts, 2006; Zachariades *et al.*, 2011).

141 The use of remote sensing provides researchers with a cost-efficient means to assess
142 the distribution of IAS as well as monitoring the spread of their invasion in both
143 populated areas and remote areas that are difficult to access (Aplin, 2005; Huang *et al.*,
144 2009; Ng *et al.*, 2017). *Prosopis* invasions in Ethiopia amount to an estimated 1.1
145 million ha and about 500 000 ha in Kenya (Witt *et al.*, 2013; Dzikiti *et al.*, 2017). Wakie
146 *et al.* (2014) used Moderate Resolution Imaging Spectroradiometer (MODIS)
147 vegetation indices as well as topo-climatic predictors to map the present *Prosopis*
148 distribution in Ethiopia using maximum entropy modelling software (Maxent) (Ng *et al.*,
149 2017). The results of this study readjusted the approximate extent of the Ethiopian
150 invasion to 5024 km². Van den Berg *et al.* (2013) used a combination of Landsat
151 satellite and topographic data and developed a decision tree and threshold-based
152 approach to map *Prosopis* in the Northern Cape Province of South Africa (Ng *et al.*,
153 2017).

154 **1.1.3. Impact of *Prosopis* in South Africa**

155 Studies have shown that invasive alien plant species directly or indirectly affect the
156 food security of local and agricultural communities (Admasu, 2008; Van den Berg *et al.*
157 *et al.*, 2013). Global reviews on the effects that plant invasions have on the areas they
158 invade suggest that the species that cause the most damage, transform ecosystems
159 by altering the use of resources through the excessive use of available resources
160 (including water, light and oxygen) or the addition of resources (such as nitrogen).
161 Damage is also caused by the ability of IAS to promote or suppress fire, the
162 stabilization of sand movement or the encouragement of erosion as well as their ability
163 to accumulate litter and redistribute salt (Richardson *et al.*, 2000, 2004). Changes such
164 as these to an ecosystem can potentially alter the flow, availability and quality of

165 nutrient resources as well as possibly modifying trophic resources within food webs
166 (Vitousek, 1990; Richardson *et al.*, 2004).

167 Expanding *Prosopis* invasions can result in the destruction of natural pastures as well
168 as the displacement of native trees, shrubs and grasses, (Admasu, 2008; Van Wilgen
169 *et al.*, 2008; Visser, 2009; Van den Berg *et al.*, 2013). The largest density of *Prosopis*
170 invasions presently occur in the alluvial floodplains of the Northern Cape (Dzikiti *et al.*,
171 2013). These invasions compete with the dominant vegetation types such as the
172 native grasses and dwarf shrubs (Mucina *et al.*, 2006; Dzikiti *et al.*, 2013). Large areas
173 of riparian habitats are severely degraded by invasive alien plant species, especially
174 tree communities on riverbanks (Van den Berg *et al.*, 2013). In the arid savanna
175 biome, the widespread replacement of native *Acacia* (= *Vachellia*) -dominated
176 communities by alien *Prosopis* species radically changes bird habitats, which causes
177 a reduction in species richness and diversity. These changes also include the
178 elimination of raptors and a decrease in frugivore and insectivore bird populations
179 (Dean *et al.*, 2002; Richardson *et al.*, 2004).

180 *Prosopis* trees can form dense thickets, which dominate grazing land, having a
181 negative impact on groundwater and reduce indigenous biodiversity (Zachariades *et*
182 *al.*, 2011). These stands can lead to altered soil properties, with extensive effects on
183 herbivores and soil fauna (Richardson *et al.*, 2004). The *Prosopis* plants within the
184 dense infestations no longer provide the services for which they were imported,
185 meaning they have fewer flowers and fewer pods; their dense thorns prevent livestock
186 from accessing the few pods that are produced; they are too small to provide shade;
187 their trunks are too thin to be useable, (Zachariades *et al.*, 2011), and the thickets
188 provide cover for predators.

189 **1.1.4. Impact of *Prosopis* on water availability**

190 Limited water resources in arid and semi-arid regions are under increasing pressure
191 from growing human populations, climate change and invasive alien plants that
192 consume massive quantities of water (Le Maitre, 1999; Dzikiti *et al.*, 2017). Impacts of
193 *Prosopis* species on water, resources and biodiversity in Southern Africa have recently
194 received heightened recognition (Zachariades *et al.*, 2011). The need for fresh water
195 for both human and animal consumption, agriculture, manufacturing and other uses in
196 the Northern Cape has resulted in the increased use of groundwater, causing severe

197 competition between humans, the native environment and *Prosopis* (Fourie *et al.*,
198 2007; Dzikiti *et al.*, 2013). *Prosopis* invasions alter the hydrology of water-
199 impoverished ecosystems (Dzikiti *et al.*, 2013).

200 In South Africa, the invasive *Prosopis* population uses approximately 192 million m³
201 of water annually (Le Maitre *et al.*, 2000; Zachariades *et al.*, 2011). This is the
202 equivalent to approximately 1100mm of rainfall, which is four times the average
203 amount received in the affected areas (Versfeld *et al.*, 1998; Zimmermann *et al.*, 2006;
204 Zachariades *et al.*, 2011). The plants cope with the resulting deficit by using
205 groundwater, lowering the water table and increasing the impact their presence has
206 on the ecology of the affected areas. This is especially noticeable by the increased
207 effect *Prosopis* presence has on the mortality of *Acacia* (= *Vachellia*) *erioloba* E.Mey.
208 (Fabaceae), a keystone indigenous species, (Robertson *et al.*, 2002;
209 Schachtschneider, 2010; Zachariades *et al.*, 2011). Both botanical and avian diversity
210 were lower in dense *Prosopis* stands, especially compared with the native *Vachellia*
211 woodland along drainage lines in the Kalahari region of South Africa (Dean *et al.*,
212 2002; Zachariades *et al.*, 2011). *Prosopis* infestations reach a much greater density in
213 floodplains and drainage lines, with incremental water usage higher in these areas
214 compared with native vegetation as well as compared with *Prosopis* stands not in
215 drainage lines (Zachariades *et al.*, 2011; Wise *et al.*, 2012).

216 The clearing of alien invasive plants such as *Prosopis* as a way of maintaining
217 groundwater is a common management practice used in various countries, including
218 Australia, China, USA and South Africa (Richardson *et al.*, 2004; Doody *et al.*, 2011;
219 Dzikiti *et al.*, 2013). This clearing is done to reduce excess water-use by the invasive
220 species to better provide for the water demands of people and the environment with
221 return of groundwater and streamflow (Dzikiti *et al.*, 2013). A review by Doody *et al.*
222 (2011) concluded that the definite volume of water retained by clearing invasive alien
223 plants depends on: “(1) the eco-hydrological setting of the aquifer; (2) the water use
224 characteristics of the vegetation that replaces the invasions once they have been
225 cleared, and; (3) the hydrogeological properties of the aquifer” (Dzikiti *et al.*, 2017).
226 Studies by Hart *et al.* (2005) and McDonald (2010) showed that, in arid regions,
227 decreases in evapotranspiration because of removal of alien vegetation did not
228 translate to increased streamflow (Dzikiti *et al.*, 2013). According to Wise *et al.* (2012)
229 the quantity of water retained after the removal of alien plant invasions depends on

230 the characteristics of the native vegetation that re-establishes after clearing (Dzikiti *et*
231 *al.*, 2013).

232 Dzikiti *et al.* (2017) hypothesised that groundwater uptake increased with increasing
233 tree density, therefore dense *Prosopis* invasions had larger impacts on groundwater
234 than sparsely spread indigenous trees such as *Vachellia karroo* (Hayne) Banfi &
235 Galasso, family Fabaceae. These authors determined that, at stand scale, *Prosopis*
236 uses substantially more water than *V. karroo*. This suggests that the “adverse
237 hydrological impacts of *Prosopis*” are because of its ability to form dense stands rather
238 than higher transpiration rates of individual trees. Thus, if *V. karroo* is allowed to form
239 dense stands (similar to those formed by *Prosopis*), they are likely to have similar
240 significant impacts on groundwater because of high individual transpiration rates
241 (Dzikiti *et al.*, 2017). The impact and presence of natural enemies that reduce the
242 spread and impact of native trees need to be considered when comparing a native
243 species with an invasive species. This provides insight on the potential hydrological
244 impacts of bush encroachment/thickening because of indigenous trees recolonizing
245 poorly managed or abandoned farmland (Dzikiti *et al.*, 2017). This highlights the
246 importance of monitoring water levels post clearing as well as understanding the water
247 use characteristics of the vegetation that replace the invasions (Doody *et al.*, 2011;
248 Dzikiti *et al.*, 2016, 2017) as well as understanding the importance of groundwater for
249 managing and maintaining healthy ecosystems while also providing water for human
250 needs (Dzikiti *et al.*, 2013).

251 **1.1.5. Economic impact of *Prosopis***

252 In addition to the damaging effect *Prosopis* has on groundwater (Fourie *et al.*, 2007;
253 Dzikiti *et al.*, 2013, 2017; Ntshidi, 2015), invasions also have a substantial economic
254 effect (Zachariades *et al.*, 2011; Wise *et al.*, 2012). Prime grazing and irrigable lands
255 are taken over, while indigenous species are displaced with habitat destruction for
256 various fauna and avian species as well as an overall reduced human access to water
257 (Dean *et al.*, 2002; Dzikiti *et al.*, 2013, 2017; Schachtschneider *et al.*, 2013; Shackleton
258 *et al.*, 2015). This impact has a profound effect on the income generation capabilities
259 of communities that are dependent on agriculture as well as eco-tourism, with
260 increased pressure on ecosystems and the disruption of ecosystem goods and
261 services (Dzikiti *et al.*, 2013). The effects of climate change are also intensifying the

262 impact of *Prosopis* on water resources, with continued changes in climatic conditions
263 possibly accelerating the spread of invasion (Richardson *et al.*, 2004; Dzikiti *et al.*,
264 2013, 2017; Witt *et al.*, 2013). According to Witt *et al.* (2013) the increased atmospheric
265 evaporative demand because of rising air temperatures in certain regions are set to
266 increase the water requirements of already aggressive water consuming invasions
267 (Dzikiti *et al.*, 2013, 2017).

268 Much of the area invaded by *Prosopis* is natural rangeland (Richardson *et al.*, 2004;
269 Ndhlovu *et al.*, 2011). According to Milton *et al.* (2003) and MacDonald (2004) the
270 most widespread use of natural rangeland is livestock production, which contributes
271 substantially to national employment, local economic growth and *gross domestic*
272 *product* (Ndhlovu *et al.*, 2011). A study by Nqobizitha (2009) assessed the value sheep
273 farmers in the Northern Cape Province placed on *Prosopis* pods, as well as the
274 economic effects that a 50% and 100% reduction in pods would have on their farming
275 practice. Although the farmers did place some value on the pods, the general
276 consensus was that the negative impact of *Prosopis* regarding water loss was of much
277 greater importance (Nqobizitha, 2009; Zachariades *et al.*, 2011).

278 Ndhlovu *et al.* (2011) conducted research on the impact *Prosopis* invasion and
279 clearing has on the grazing capacity of degraded, heavily grazed Nama-Karoo
280 rangeland in the Beaufort West district of the Western Cape Province. Their study was
281 conducted on two sheep farms in the district, with the aims of: “1) assessing and
282 quantifying the impact of *Prosopis* invasion and clearance on rangeland grazing
283 capacity, 2) identifying and describing the vegetation dynamics that underlay the
284 changes in grazing capacity following both invasion and clearance, and, 3) describing
285 and quantifying the response of rangeland grazing capacity in response to increasing
286 *Prosopis* cover” (Ndhlovu *et al.*, 2011). Their study concluded that the presence of
287 *Prosopis* can lower the grazing potential of invaded overgrazed and degraded Nama-
288 Karoo rangeland. The clearing of *Prosopis* from such a rangeland can substantially
289 increase the grazing potential of the area within 4-6 years, even under heavy grazing
290 (Ndhlovu *et al.*, 2011). The presence of both grazing-resilient grasses and perennial
291 grasses increases in the absence of living *Prosopis*, while the branches of felled
292 *Prosopis* may be used to protect these grasses and enable establishment (Ndhlovu *et*
293 *al.*, 2011).

294 **1.2. *Prosopis* in Africa**

295 *Prosopis* species originating from the Americas have been promoted as agroforestry
296 species in the tropical, arid and semi-arid regions of Africa since the early 20th century
297 (Babiker, 2006; Choge *et al.*, 2006; Zachariades *et al.*, 2011). These species have
298 become highly invasive, but according to Geesing *et al.* (2004) can still be useful if
299 exploited optimally (Pasiiecznik *et al.*, 2006; Zachariades *et al.*, 2011).

300 The Food and Agriculture Organisation (FAO) working in Kenya introduced *Prosopis*
301 spp. in the early 1980's (Lenachuru, 2003; Anderson, 2005; Ng *et al.*, 2017). This was
302 done with the aims of preventing desertification, providing an alternative to fuelwood
303 (to try and curb the high demand for *Vachellia*) and reducing the stress placed on
304 indigenous flora by the human population (Kariuki, 1993; Lenachuru, 2003; Ng *et al.*,
305 2017). A large number of *Prosopis* plantations were established around Lake Baringo,
306 with smaller scale plantations created for ornamental plants (Anderson, 2005; Ng *et*
307 *al.*, 2017). The hybrids originating from these plantations form part of *the Prosopis*
308 *juliflora-Prosopis pallida* complex, as described by (Pasiiecznik *et al.*, 2001), and is
309 listed by the World Conservation Union as one of the 100 'world's worst invasive alien
310 species' (Lowe *et al.*, 2000; Ng *et al.*, 2017). In Ethiopia, the most adversely affected
311 areas, in terms of coverage, include the Afar and Somali regions in the east and
312 southeast as well as the area around Dire Dawa city in Ethiopia. Other areas of
313 concern include the Amhara, Oromia, Southern Nations Nationalities and Peoples
314 (SNNP) and Tigray regions (Steele *et al.*, 2007; Abdulahi *et al.*, 2017). Historically
315 Namibian authorities also encouraged the large-scale planting of *Prosopis* spp. on
316 farmed properties (Zimmermann, 1991).

317 Negative impacts of *Prosopis* invasion in East Africa include the formation of
318 impenetrable thickets, invasion of water courses, the lowering of the water table
319 (starving other plants of water and nutrients) and negatively impacting biodiversity
320 (Abdulahi *et al.*, 2017). The formation of 'green deserts', areas largely devoid of life
321 (other than the presence of *Prosopis* invasions), are especially concerning for the
322 continuation of pastoralist livelihoods (Abdulahi *et al.*, 2017). Soil erosion and loss in
323 livestock productivity because of *Prosopis* invasion of rangelands have resulted in the
324 reduction in overall availability and quality of rangelands (Angassa *et al.*, 2008; Nkonya
325 *et al.*, 2011; Wakie *et al.*, 2012; Abdulahi *et al.*, 2017). Injuries to both humans and
326 livestock from *Prosopis* thorns in East Africa may also result in infection, amputation

327 or in extreme cases death (Mwangi *et al.*, 2005; Maundu *et al.*, 2009; Abdulahi *et al.*,
328 2017).

329 **1.3. Failures and success in *Prosopis* control**

330 Managing invasive species is often challenging and complicated, primarily because
331 many invaders are considered to also provide benefits as well as having negative
332 impacts on the invaded area. This often results in a conflict of interest regarding their
333 use and management between different stakeholders (Vitousek *et al.*, 1997;
334 Shackleton *et al.*, 2017). According to Zachariades *et al.* (2011) present clearing
335 efforts have not had a measurable impact on *Prosopis* invasions in South Africa. Wise
336 *et al.* (2012) suggest that, to maintain net economic gain from perceived *Prosopis*
337 benefits, it would be better to focus clearing efforts on drainage lines and floodplains
338 as well as developing cheaper control methods.

339 Understanding the various social, ecological and economic aspects of invasions, and
340 the implications these aspects have for various stakeholders, are important for guiding
341 best-management practices (Brown *et al.*, 2004; Shackleton *et al.*, 2017). An
342 integrated understanding of this nature also requires a transdisciplinary approach
343 which exceeds the existing knowledge systems' ability to incorporate different actors
344 to develop solutions which are acceptable to a diverse collection of stakeholders
345 (Brown *et al.*, 2004; Shackleton *et al.*, 2017).

346 Historically, managers have investigated several methods for control of *Prosopis*.
347 These include mechanical removal, felling, herbicide treatment of cut stumps, foliar
348 spraying of saplings and burning (Harding, 1987; Van Klinken *et al.*, 2009;
349 Zachariades *et al.*, 2011). Overall, chemical management methods in combination with
350 manual and mechanical clearing can be successful in addressing *Prosopis* invasion in
351 an area (Direba Balcha, 2022). Systemic herbicides will gradually affect tree health
352 and eventually kill the tree. Depending on the active ingredient used, the herbicides
353 are extremely targeted, with little to no non-target effects (Witt *et al.*, 2013; Direba
354 Balcha, 2022).

355 None of these methods are considered to be affordable or practical on a large scale,
356 and costs of control generally far exceed the value of invaded land (Zachariades *et al.*
357 *et al.*, 2011). Zimmermann *et al.* (2006) discussed the use of *Prosopis* pods and wood

358 as management tools. They concluded that this is largely uneconomical because of
359 the remote areas in which *Prosopis* grows and the lack of harvestable material
360 (Zachariades *et al.*, 2011).

361 The negative impacts of invasive species have led to the global establishment of
362 control programs, occasionally referred to as natural resource management. Some
363 initiatives of note include the 'Weeds of National Significance (WONS) programme in
364 Australia, the Working for Water (WfW) programme in South Africa (Van Wilgen *et al.*,
365 2016) and the U.S. Department of Agriculture's invasive-species clearing programme
366 in the United States of America (Shackleton *et al.*, 2017).

367 **1.3.1. South Africa**

368 The requirements and regulations for invasive species management in South Africa
369 are set out in broad terms in the National Environmental Management: Biodiversity
370 Act (NEM:BA) (DEA, 2014). Present legislation provides "that the Department of
371 Forestry, Fisheries and the Environment must produce and coordinate strategies to
372 avert new introductions and control or eradicate present invasive species" (Shackleton
373 *et al.*, 2017). The act also stipulates that "all organs of state must prepare plans for
374 eradication, control and monitoring of the assorted listed invasive species on state
375 owned land" (Shackleton *et al.*, 2017). However, different IAS require different control
376 knowledge and different management approaches to be effective (Shackleton *et al.*,
377 2017). The present NEM: BA regulations are widely considered to be ambitious and
378 unrealistic for many widespread taxa, including *Prosopis*, especially where
379 management success is determined by effective cooperation between stakeholders
380 and organisers (Shackleton *et al.*, 2017).

381 *Prosopis* in the Northern Cape is listed as a Category 3 invasive taxon, meaning that
382 existing plants do not have to be removed, though propagation, use and trade is
383 prohibited (Shackleton *et al.*, 2017). The utilisation of *Prosopis* pods for fodder
384 specifically is exempt from the prohibitions. While this allows farmers to use pods as
385 a resource for livestock feed, it may promote the spread of the plant and increase the
386 negative ecosystem impacts associated with *Prosopis* invasions (Shackleton *et al.*,
387 2017). In all other South African provinces, *Prosopis* is listed as a Category 1 invasive
388 species. This means that all invasive populations must be controlled (Shackleton *et*
389 *al.*, 2017).

390 Working for Water (WfW) (now referred to as the National Resources Management
391 Programme of the Department of Forestry, Fisheries and the Environment, but
392 hereafter still referred to as WfW because of its internationally recognized brand) is a
393 government-funded public-works programme tasked with two primary goals, “1)
394 provide employment to and develop skills of disadvantaged communities, and 2)
395 manage invasive species to reduce the negative impact they have on the environment
396 and restore ecosystem services delivery to improve human well-being” (Van Wilgen
397 *et al.*, 2012; Van Wilgen *et al.*, 2016; Shackleton *et al.*, 2017).

398 WfW projects are managed on behalf of the Department of Forestry Fisheries and the
399 Environment by implementing agents (including government departments,
400 municipalities, national and provincial conservation authorities, agricultural and water
401 management organizations) (Van Wilgen *et al.*, 2016; Shackleton *et al.*, 2017). The
402 projects are contracted out to local service providers, primarily from previously
403 disadvantaged backgrounds, and supervised by regional managers who are employed
404 by the implementing authority (Van Wilgen *et al.*, 2016; Shackleton *et al.*, 2017). WfW
405 receives an annual budget to manage invasive alien species nationally. Compared
406 with other natural resource management and ecosystem restoration projects in South
407 Africa, the WfW programme was relatively well-funded (Van Wilgen *et al.*, 2012;
408 Shackleton *et al.*, 2017). Despite this substantial investment in invasive species
409 management, the effort has failed to prevent the spread and densification of *Prosopis*
410 in South Africa (Shackleton *et al.*, 2017). This has resulted in increased negative
411 impacts on ecosystem services and human well-being. The ineffectiveness of the WfW
412 programme may be partially attributed to the lack of effective prioritisation and
413 strategic planning, particularly because the main focus of the programme is job
414 creation rather than ecological outcomes (Shackleton *et al.*, 2017).

415 The success of WfW initiatives is primarily measured by their socioeconomic worth,
416 rather than their role in environmental conservation (Turpie, 2004; Ndhlovu *et al.*,
417 2011). Unfortunately, this means that the funding for WfW is dependent on
418 successfully competing with other government initiatives likewise concerned with
419 addressing certain socioeconomic concerns and problems (Turpie, 2004; Ndhlovu *et*
420 *al.*, 2011). This drastically shifts the focus of WfW from environmental to
421 developmental, where the WfW programme must demonstrate their full

422 socioeconomic worth, instead of adequately addressing the problem of IAS (Turpie,
423 2004; Ndhlovu *et al.*, 2011).

424 According to Richardson *et al.* (2004) priorities for future research should include “the
425 development of achievable goals for ecosystem repair after clearing”. This includes
426 measurable criteria to assess the success of restoration in cleared areas (Richardson
427 *et al.*, 2004). Understanding several of the broader aspects of invasion ecology also
428 require improvement. Unfortunately, in many parts of the world conservation biologists
429 are tasked with controlling alien species and preventing impacts, while also
430 increasingly having to repair systems damaged by IAS (Byers *et al.*, 2002; Richardson
431 *et al.*, 2004).

432 Control efforts by a single entity are unlikely to have the desired effect on *Prosopis*
433 invasions in the Northern Cape. This is especially true when considering the
434 dependence of government to either obligate control via the issue of directives for
435 landowners to either satisfactorily control *Prosopis* invasions or risk a fine, which
436 reduces the ability of the landowner to control the invasion on their property, or to
437 single-handedly control *Prosopis* via WfW and National Resource Management
438 (NRM). The unified provision of accurate information, new developments and support
439 should put landowners in a much better position to address the invasion on their
440 properties.

441 **1.3.2. Africa**

442 *Prosopis juliflora* was first introduced in Eastern Africa to be used as an ecosystem
443 engineer for the stabilisation of dune systems and the rehabilitation of degraded land
444 (Pasiiecznik *et al.*, 2001; Meroni *et al.*, 2017). Despite the negative effects of *Prosopis*,
445 the invasions also generate environmental, social and economic benefits (Wise *et al.*,
446 2012; Abdulahi *et al.*, 2017). This has resulted in contentious issues surrounding the
447 genus and the control thereof, with some advocates promoting *Prosopis* as a ‘wonder
448 plant’, while others call for total eradication (Van Wilgen *et al.*, 2014; Abdulahi *et al.*,
449 2017). Being a drought-tolerant plant, it threatens the native desert and semi-desert
450 shrubland ecosystems (Tessema, 2012), many harbouring valuable animal and plant
451 species (Meroni *et al.*, 2017). *P. juliflora* has been recorded to have been successfully
452 used to fight desertification, because of its ability to reduce soil erosion (Steele *et al.*,
453 2007; Meroni *et al.*, 2017).

454 The Kenyan government is making use of a utilisation strategy, despite contrary
455 indications that successful containment is unlikely to be achieved with this approach
456 (Zimmermann *et al.*, 2006; Shackleton *et al.*, 2014; Kleinjan *et al.*, 2021). Employing
457 a utilisation strategy to control IAS was suggested by Tessema (2012) in an effort to
458 illustrate the economic exploitation of invasive plants as a way of meeting basic human
459 needs as well as controlling the spread of the invasive species (Abdulahi *et al.*, 2017).
460 Tessema (2012) reviewed the Ecological and Economic Dimensions of Paradoxical
461 Invasive Species *Prosopis juliflora* and Policy Challenges in Ethiopia, noting that there
462 has not been a clear policy or strategy towards *Prosopis* or towards general invasive
463 species management (Abdulahi *et al.*, 2017). *Prosopis* is recognized in Ethiopia as a
464 key threat to biodiversity and economic wellbeing by initiatives such as the
465 Environmental Policy of Ethiopia (EPE) and the Biodiversity Strategy and Action Plan
466 (NBSAP) and Forest Resource Strategy (Institute of Biodiversity Conservation (IBC),
467 2005; Abdulahi *et al.*, 2017). Nonetheless, the National Action Plan of Ethiopia
468 recommends *Prosopis* as a potential option to combat desertification, illustrating the
469 existing policy dilemma concerning *Prosopis* (Anagae *et al.*, 2004; Abdulahi *et al.*,
470 2017).

471 Practices of *Prosopis* eradication and utilization in Ethiopia include conversion of
472 invaded rangelands into irrigated agriculture, charcoal production and flour production
473 (Admasu, 2008; Abdulahi *et al.*, 2017). Contrasting views, contradictory perceptions
474 as well as unclear policies are all limiting factors influencing the effective control of
475 *Prosopis* in Africa. This, in conjunction with taxonomic confusion, general lack of
476 distribution information and scale of the invasion hamper effective *Prosopis*
477 management (Abdulahi *et al.*, 2017).

478 **1.4. Biological control of *Prosopis***

479 Classical biological control programmes make use of scientifically selected, host
480 specific, natural enemies of invasive alien plants in hopes to mitigate the impact of IAS
481 (Van Wilgen *et al.*, 2020). These natural enemies are usually plant-feeding arthropods
482 or fungal pathogens. The risks associated with biological control are moderated by
483 means of well-established, global screening protocols that are based on risk analysis,
484 reducing the risks to minimal levels (Sheppard *et al.*, 2003; Van Wilgen *et al.*, 2020).
485 The regulatory and risk perception hurdles in accordance with biological control use

486 are increasing, even if biological control is relatively cost effective compared with
487 conventional mechanical and chemical control, as well as being considered more
488 sustainable (Van Wilgen *et al.*, 2020). Although biological control does not eradicate
489 the IAS, it can result in weakened competitiveness with native plant species,
490 repressing its density, environmental impacts and allowing the native vegetation to
491 recover (Witt *et al.*, 2013; Abdulahi *et al.*, 2017).

492 The use of highly specific biological control agents to control IAS is also in stark
493 contrast (Clewley *et al.*, 2012; Suckling *et al.*, 2014; Schwarzländer *et al.*, 2018) to the
494 historic use of unregulated generalist vertebrate predators or herbivores in misguided
495 attempts to control either pests or vegetation (Santha *et al.*, 1991; Peacock *et al.*,
496 2010; Van Wilgen *et al.*, 2020). A report by Suckling *et al.* (2014) shows that more
497 than 99% of 512 agents introduced for classical biological control of IAS around the
498 world have no known significant adverse non-target effects (Van Wilgen *et al.*, 2020).

499 **1.4.1. Africa**

500 The use of classical biological control on *Prosopis* species in African regions remains
501 controversial (Zachariades *et al.*, 2011). Primarily because of concern that control
502 agents will attack *Prosopis* species indigenous to Africa and Asia (Pasiiecznik *et al.*,
503 2006; Zachariades *et al.*, 2011), despite the large phylogenetic distance between the
504 American and Old World taxa (Catalano *et al.*, 2008; Zachariades *et al.*, 2011). For
505 example, *Prosopis africana* (Guill. & Perr.) Taub. is an important but over-exploited
506 agroforestry species through the Sahel region (Tchoundjeu *et al.*, 1997; Zachariades
507 *et al.*, 2011). During the approval for the release of more damaging agents in South
508 Africa, due consideration was given to the possibility that species are likely to spread
509 to other African countries (Kleinjan *et al.*, 2021). Several recent studies from the
510 broader African community have emphasised the profound negative impacts as a
511 result of *Prosopis* invasion, recognising the need for more effective management
512 interventions (Maundu *et al.*, 2009; Haregeweyn *et al.*, 2013; Mbaabu *et al.*, 2019;
513 Sintayehu *et al.*, 2020; Kleinjan *et al.*, 2021).

514 Further management strategies aimed at achieving effective control through the sole
515 intensive use of *Prosopis* biomass has now considered to be unlikely to alleviate the
516 problem at large spatial or prolonged temporal scales (Shackleton *et al.*, 2014; Wakie
517 *et al.*, 2016; Mbaabu *et al.*, 2019; Kleinjan *et al.*, 2021). With all indications being that,

518 even with highly effective biological control, *Prosopis* will remain relatively abundant
519 with decreased density, and able to provide the services and benefits for which it is
520 valued (Van Klinken *et al.*, 2009; Shackleton *et al.*, 2017; Kleinjan *et al.*, 2021).

521 *Algarobius prosopis* (LeConte) (Coleoptera: Bruchidae) is already present in north
522 eastern Africa and the Arabian Peninsula, and although it attacks the seeds of
523 introduced *Prosopis* species, it has not been recorded from *P. africana* or *P. cineraria*
524 (L.) Druce. (Ali *et al.*, 2006; Babiker, 2006; Zachariades *et al.*, 2011). It is likely that
525 one of the new agents, the green podlet borer, *Coelocephalopion gandolfoi* (Kissinger)
526 (Coleoptera: Brentidae: Apioninae) will attack *P. pallida*, since it was collected off *P.*
527 *affinis* Spreng. (series Pallidae) in Argentina. Several indigenous insect species attack
528 *P. juliflora* in Ethiopia, however classical biocontrol is still needed (Zachariades *et al.*,
529 2011).

530 There is also concern that the introduction of biological control agents will lead to a
531 reduction in introduced species of *Prosopis*, in particular less invasive species such
532 as *P. pallida*, possibly compromising their usefulness (Zachariades *et al.*, 2011).
533 However, the seed-attacking agents are unlikely to reduce the value of the trees, as
534 is the case for most classical biological control projects using such agents. They may
535 even increase usefulness by reducing propagule production, resulting in thinning of
536 stands with increases in flower and pod production as well as wood quality
537 (Zachariades *et al.*, 2011).

538 **1.4.2. South Africa**

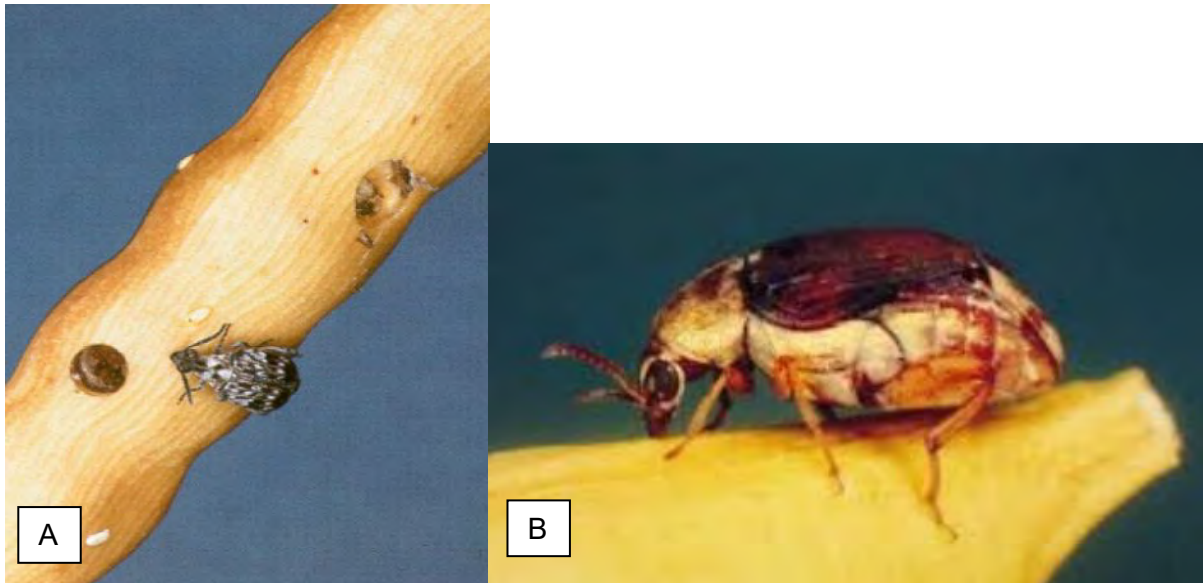
539 Taxonomic confusion was heightened and prolonged because of difficulty identifying
540 individual *Prosopis* species (Pasiiecznik *et al.*, 2006; Zachariades *et al.*, 2011).
541 Properly identifying the invasive *Prosopis* species in South Africa may have
542 implications for successful biological control, especially in terms of ensuring
543 compatibility of biocontrol agents with their host-plant species (Zwölfer *et al.*, 1971;
544 Volchansky *et al.*, 1999; Lym *et al.*, 2002; Manrique *et al.*, 2008; Mathenge *et al.*, 2010;
545 Zachariades *et al.*, 2011).

546 The majority of the invasive *Prosopis* species present in South Africa are members of
547 section *Algarobia*, series *Chilensis*. This explains the hybridization, which has
548 complicated both taxonomy and control measures in South Africa (Zachariades *et al.*,
549 2011). The development of biocontrol measures can be focused on the species in the

550 section Algarobia, because of any oligophagous agents that feed across several
551 species within this section alone having great promise for controlling the mix of
552 invasive *Prosopis* species present in South Africa. These oligophagous biocontrol
553 agents present no risk to the Old-World species of the genus (Zachariades *et al.*,
554 2011).

555 **1.4.2.1. Historical biological control agents**

556 In the mid-1980s a biological control programme was initiated against *Prosopis*. To
557 date the focus of the programme was seed-feeding insects, which curbs spread while
558 allowing the exploitation of the perceived assets and services (Zachariades *et al.*,
559 2011). Biological control researchers instigated the reduction of seed production, and
560 therefore recruitment rates of young plants, with the intent of creating sparse
561 populations of useful trees without the formation of dense thickets. This strategy
562 resulted in the introduction and release of three beetle species, *Algarobius prosopis*
563 (LeConte) (Fig. 1.2 (B)) and *Algarobius bottimeri* Kingsolver, in 1987 and 1990,
564 respectively (Zimmermann, 1991; Zachariades *et al.*, 2011) and *Neltumius arizonensis*
565 (Schaeffer) (Fig. 1.2 (A)) in 1992 (all Coleoptera: Chrysomelidae: Bruchinae) (Impson
566 *et al.*, 1999; Zachariades *et al.*, 2011). *A. bottimeri* persisted for a short period after
567 release, but eventually failed to establish (Hoffmann *et al.*, 1993; Impson *et al.*, 1999).
568 Both Moran *et al.* (1993) and Impson *et al.* (1999) reviewed biological control in SA in
569 the 1980's and 1990's, collectively control efforts in South Africa have not been
570 successful in alleviating the *Prosopis* problem.



571

572 **Figure 1.2:** Seed feeding bruchids. A) *N. arizonensis*. B) *A. prosopis*. (Credit: Carien
573 Kleinjan, UCT).

574 Both *A. prosopis* and *N. arizonensis* persist on *Prosopis* throughout SA, with *A.*
575 *bottimeri* absent (Impson *et al.*, 1999; Zachariades *et al.*, 2011). This may be because
576 of the release of *A. bottimeri* in areas (Free State Province) that are unfavourable for
577 the beetles, suggested by the low populations *A. prosopis* populations in these areas
578 (Roberts, 2006; Zachariades *et al.*, 2011). *Neltimius arizonensis* seldom accounts for
579 more than 10% of the total seed destruction by bruchines in a year (Roberts, 2006).
580 The scarcity of *N. arizonensis* can be attributed to competition with *A. prosopis*
581 (Impson *et al.*, 1999) and indigenous egg and larval parasitoids particularly the egg
582 parasitoid *Uscana* sp. (Hymenoptera: Trichogrammatidae), which may account for as
583 much as 80% egg loss at certain times (Coetzer *et al.*, 1997; Roberts, 2006).

584 The variable nature of the interactions between livestock, climate and biological control
585 contribute to the difficulty in establishing the degree of effect, if any, *A. prosopis* is
586 having on the population dynamics of *Prosopis* species in South Africa (Zachariades
587 *et al.*, 2011). Both *A. prosopis* and *N. arizonensis* are now widespread in the field in
588 South Africa in the invasive range of *Prosopis*, *A. prosopis* being by far the most
589 abundant and accounting for the majority of seed destruction (Zachariades *et al.*,
590 2011). In the more arid parts of the invasive range of *Prosopis* in South Africa, *A.*
591 *prosopis* appears to have the potential to have a significant impact on the size of soil
592 seed banks (Zachariades *et al.*, 2011).

593 **1.4.2.2. More damaging biological control agents**

594 While there are still concerns on the release of more damaging biological control
595 insects to try and address the continuing spread of *Prosopis* invasion, nine beetle, four
596 moth and one gall midge species collected from *Prosopis* species in Argentina within
597 the section Algarobia, series Chilensis (six species), Sericanthae (one species),
598 Pallidae (one species) and Ruscifoliae (two species), were assessed (McKay *et al.*,
599 2007). One of these, the straight-snouted weevil *Coelocephalapion gandolfoi*
600 Kissinger (Kissinger, 2005) (Coleoptera: Brentidae: Apioninae), whose larvae attack
601 seeds within green pods on the trees, was considered especially promising (Fig. 1.3)
602 (Zachariades *et al.*, 2011). Concurrent with this, a study was conducted in the USA on
603 aspects of the biology, ecology and host range of the flowerbud galler *Asphondylia*
604 *prosopidis* Cockerell (Diptera: Cecidomyiidae), also considered a promising agent.
605 Pathogens were investigated as both classical biological control agents and as
606 mycoherbicides. Further assessment of the agents already established in the field was
607 also conducted (Roberts, 2006; Van Klinken *et al.*, 2009; Zachariades *et al.*, 2011).

608 The apionid, *Coelocephalapion gandolfoi*, was collected from nine *Prosopis* species
609 (all section Algarobia) over a latitudinal gradient of 1500 km in Argentina under
610 contract between the ARC-PPRI and the South American Biological Control
611 Laboratory of the United States Department of Agriculture (USDA-SABCL) in Buenos
612 Aires (Zachariades *et al.*, 2011). Adult *C. gandolfoi* weevils are small and brown to
613 black in colour. Mature reproducing adults first appear at the beginning of spring (late
614 September), feeding on the young green pods and leaves. They oviposit near the
615 seeds inside the tender pod tissues (McKay *et al.*, 2007; Zachariades *et al.*, 2011).



616

617 **Figure 1.3:** *Coelocephalapion gandolfoi* adult weevil (Credit: Carien Kleinjan, UCT).

618 After an array of no-choice and paired choice tests relating to host-specificity and
619 feeding preferences, it appears that *Coelocephalapion gandolfoi* is adequately host
620 specific for release in South Africa (Zachariades *et al.*, 2011). Given the concerns
621 regarding the ability to continue using *Prosopis* pods as fodder, *C. gandolfoi* appears
622 well placed to reduce seed viability without reducing pod production (Zachariades *et*
623 *al.*, 2011). By utilizing the pods still attached to the trees, *C. gandolfoi* will avoid the
624 problem of having to compete with livestock and wildlife for pods that are on the ground
625 faced by the *Algarobius* bruchine beetles (Zachariades *et al.*, 2011).

626 Permission to release *Coelocephalapion gandolfoi* was conditionally approved in
627 2014, subject to confirmation that *Xerocladia viridiramis* (a native tree closely related
628 to American *Prosopis*) was not a suitable host (Kleinjan *et al.*, 2021). A small
629 consignment of reproductively mature *C. gandolfoi* was imported into the Agricultural
630 Research Council-Plant Health and Protection (ARC-PHP) quarantine facility in
631 Stellenbosch, South Africa in October 2019 (Kleinjan *et al.*, 2021). With host specificity
632 tests proving unambiguously that *X. viridiramis* is not a suitable host for *C. gandolfoi*
633 (Kleinjan *et al.*, 2021).

634 There are no conflicts of interest regarding the biological control of *Prosopis* species
635 in Australia (Zachariades *et al.*, 2011). This has allowed the release of two foliar-
636 feeding agents, *Evippe* sp. #1 (Lepidoptera: Gelechiidae) (Fig.1.4) and
637 *Prosopidopsylla flava* Burckhardt (Hemiptera: Psyllidae) (Van Klinken *et al.*, 2009;
638 Zachariades *et al.*, 2011). Although both species have established populations, *Evippe*
639 sp. #1 is by far the more successful agent (Zachariades *et al.*, 2011).



640

641 **Figure 1.4:** *Evippe* sp. #1 adult moth (Credit: Fritz Heystek, ARC).

642 *Evippe* sp. #1 is an undescribed 'leaf-tying' gelechiid, originating from Argentina,
643 recorded to inhabit *Prosopis* species from the *Algarobia* s.s. clade (Kleinjan *et al.*,
644 2021). A consignment of *Evippe* sp. #1 was sourced from the Pilbara region of
645 Australia through collaboration with Australian colleagues in December 2014, and
646 imported into the quarantine facility at the ARC-PHP in Pretoria (Kleinjan *et al.*, 2021).
647 This was done to establish an insectary colony with which to conduct additional host
648 specificity tests. Specificity tests concluded that although *Evippe* sp. #1 oviposit
649 indiscriminately in no-choice tests, complete development was limited to the *Prosopis*
650 taxa tested (Kleinjan *et al.*, 2021).

651 *Evippe* sp. #1 is considered to have the greatest impact in the Pilbara region, the
652 hottest site in Australia (Van Klinken *et al.*, 2002; Van Klinken, Fichera and Cordo,
653 2003; Kleinjan *et al.*, 2021). Substantial reductions in rates of both plant growth and
654 seed production as well as mortality of trees have been documented in this region
655 (Van Klinken, 2012; Kleinjan *et al.*, 2021). Although the release of *Evippe* sp. #1 for
656 biocontrol in hotter regions globally has been suggested, in South Africa the areas
657 where *Prosopis* has invaded is characterised by hot summers and mean winter
658 temperatures considerably less than those occurring in the Pilbara region (Kleinjan *et*
659 *al.*, 2021). Nevertheless, an application to release *Evippe* sp. #1 from quarantine was
660 lodged with the South African regulating authorities in September 2020. Clearance
661 was granted in December 2020, with releases commencing in February 2021 in the
662 Northern Cape and North West Provinces of South Africa (Kleinjan *et al.*, 2021).

663 **1.5. Community of Practice in environmental programmes**

664 The term Community of Practice (CoP) is relatively recent, and as a concept it has
665 provided a useful perspective on knowing and learning (Wenger, 2011). A CoP is
666 formed, and thus defined by, “a group (or groups) of people who share a concern or a
667 passion for something they do and learn how to do it better as they regularly interact”
668 (Wenger, 2011). These individuals engage in a process of communal learning in a
669 shared domain of human enterprise (Wenger, 2011). CoP in accordance with invasion
670 science and invasive species management can lead to more responsible and ethical
671 engagement by humans with their fellow man and the planet (Cockburn *et al.*, 2018).

672 With present global funding for invasive species management insufficient, especially
673 given the expected rates of invasion expansion (Lodge *et al.*, 2006; Hellmann *et al.*,
674 2008), there are concerns regarding the sustainability of effective invasive species
675 management (Larson *et al.*, 2011). Sustainable management may result in minimised
676 environmental, social, and economic costs, with restored ecosystem resilience and
677 increased social and economic support for the implementation of management plans,
678 without depleting financial and social capital (Larson *et al.*, 2011). Sustainable invasive
679 management is dependent on three pillars, (as shown by (Pope *et al.*, 2004)), namely
680 environmental, social, and economic. This suggests the fundamentals of integrated
681 pest management (Kogan, 1998; Larson *et al.*, 2011).

682 Clear and inclusive objectives are critical for the outset and duration of the execution
683 of ISM (invasive species management) programmes (Larson *et al.*, 2011). These
684 objectives function as measurable benchmarks to assess the progress toward a
685 management goal. Measurable, meaningful, and understandable objectives are
686 imperative for the successful implementation of a sustainable programme (Larson *et al.*
687 *et al.*, 2011). All stakeholders should acknowledge and if possible, support these
688 objectives. Objectives are also adaptable because of re-evaluation to assess progress
689 and determine the relevancy of the stated objectives in the changing environmental,
690 social and economic contexts (Larson *et al.*, 2011).

691 Researchers and managers must consider the temporal and spatial scale of an
692 invasion to develop environmentally sustainable management plans (Denslow, 2007;
693 Larson *et al.*, 2011). These management plans should consider the most effective
694 control methods, based on the stage of invasion, while also limiting non-target effects

695 and promoting the recovery and restoration of native species diversity and ecosystem
696 functioning (Denslow, 2007; Larson *et al.*, 2011).

697 The increased interest in a more integrated way of studying human and natural
698 systems has resulted in the development of frameworks in different fields and
699 disciplines (Binder *et al.*, 2013; Cockburn *et al.*, 2018) The social-ecological systems
700 (SES) framework originated in ecology, arising out of the development of resilience
701 theory for the adaptive analysis and management of ecosystems (Holling, 1973;
702 Cockburn *et al.*, 2018). The concept of SES is used to describe an integrated
703 perspective of humans and nature (Berkes and Folke, 1998; Folke *et al.*, 2016), and
704 the application thereof has resulted in increased interest in the concept of stewardship
705 (Cockburn *et al.*, 2018). A core principle of SES is that human systems are embedded
706 in, and entirely dependent on, the biosphere (the global ecological system) (Folke *et al.*
707 *et al.*, 2016; Cockburn *et al.*, 2018).

708 There has also been an increase in global calls for stewardship of the biosphere in
709 support of social-ecological sustainability for present and future generations (Chapin
710 *et al.*, 2010; Steffen *et al.*, 2011; Cockburn *et al.*, 2018). This, in conjunction with the
711 recognition that global ecological destruction and social inequalities continue to rise
712 (Steffen *et al.*, 2011; Leach *et al.*, 2013; ISSC IDS; UNESCO, 2016), suggests that the
713 ideals of stewardship are not being realised in practice. The study of stewardship
714 within the SES framework raises questions about how to support the ethical and
715 responsible human interactions within dynamic social-ecological systems towards
716 interlinked social-ecological sustainability outcomes, benefitting the planet as a whole
717 (Cockburn *et al.*, 2018).

718 **1.6. Stewardship, landscapes and collaboration in environment programmes**

719 Increasing interest in both the idea and use of stewardship in the sustainability
720 discourse has most likely arisen from the growing global recognition of the coupled
721 challenges of rapidly increasing ecological degradation and social inequalities
722 (Raworth, 2012; ISSC IDS; UNESCO, 2016; Cockburn *et al.*, 2018). To address some
723 of these concerns, stewardship has been widely used as a call for more responsible
724 and ethical engagement by humans for humans and the planet (Cockburn *et al.*, 2018).
725 In the study of social-ecological systems (SES), landscapes can offer an appropriate
726 unit of analysis to investigate stewardship in practice (Angelstam *et al.*, 2013; Bieling
727 *et al.*, 2017; Cockburn *et al.*, 2018).

728 Stewardship has an ethical basis, connected to a moral imperative, with the result that
729 humans who practise stewardship manage ecosystems out of moral concern (Worrell
730 *et al.*, 2000; Welchman, 2012; Raymond *et al.*, 2013; Cockburn *et al.*, 2018).
731 Stewardship is a concept that directs individual and collective action (Ridings, 2018),
732 with possible influence from underlying political and ideological aspects (Cockburn *et*
733 *al.*, 2018; Mathevet *et al.*, 2018). Recent interpretations of stewardship illustrate the
734 global sustainability discourse (Worrell *et al.*, 2000; Welchman, 2012), indicating a
735 move towards more integrated and systemic understandings of the interactions
736 between humans and nature (Cockburn *et al.*, 2018). This is in contrast to previous
737 interpretations of the concept of stewardship, which were based on a more
738 dichotomous relationship of humans having either dominion (Peterson *et al.*, 2010)
739 over nature or fulfilling the role of nature protectors (McArthur, 2012; Cockburn *et al.*,
740 2018).

741 The recent conceptualisations of stewardship emerge from two distinct perspectives:
742 environmental stewardship and ecosystem stewardship (Cockburn *et al.*, 2018).
743 Environmental stewardship expresses the classic and intuitive understanding of the
744 concept, namely the illustration of a moral-ethical basis (Welchman, 2012; Cockburn
745 *et al.*, 2018). Welchman (2012) also states that, because stewardship is a role played
746 by a person, the moral justification of stewardship is a function of its overall
747 consistency with common moral norms. These moral norms include justice, tolerance
748 and equity in the distribution of social benefits and burdens (Cockburn *et al.*, 2018).

749 Ecosystem stewardship is associated with an SES approach in accordance with
750 resilience thinking, and is outlined in the context of rapid global change (Chapin *et al.*,
751 2010; Cockburn *et al.*, 2018). As an action-oriented framework, ecosystem
752 stewardship aims to bring about better management and governance of complex
753 social-ecological systems (Cockburn *et al.*, 2018). Ecosystem stewardship is a model
754 based on resource management, proposed to guide human interactions with SES
755 (Chapin *et al.*, 2009; Cockburn *et al.*, 2018).

756 Cockburn *et al.* (2018) suggest the use of social-ecological stewardship as descriptive
757 term as a middle ground, recognising the value of SES framing while incorporating the
758 moral-ethical basis and enduring understanding of stewardship as offered by
759 environmental stewardship (Welchman, 2012; Cockburn *et al.*, 2018). Social-

760 ecological stewardship is defined by Cockburn *et al.* (2018) as “the ethical and
761 responsible interaction of humans with social-ecological systems to sustain the supply
762 of diverse ecosystem services and values for the sake of present and future
763 generations of humans and other life on earth”. The practical applications of
764 stewardship are relatively diverse, e.g., policy-driven initiatives (private land
765 conservation approaches, agri-environmental schemes, catchment management
766 initiatives) as well as more bottom-up stewardship practices such as community-based
767 natural resource management initiatives and, integrated landscape approaches
768 (Cockburn *et al.*, 2018).

769 Landscapes as place-based social-ecological systems (Minang *et al.*, 2014; Robinson
770 *et al.*, 2017) are multifunctional and heterogeneous terrestrial regions. They connect
771 in a particular place the ‘many multiples’ which characterise SES, and also challenge
772 governance and management (Poteete, 2012; Lescourret *et al.*, 2015; Cockburn *et al.*
773 *et al.*, 2018). They emerge from the interactions between people, through their values,
774 with land-based ecosystems and the natural resources they generate (Minang *et al.*,
775 2014; Robinson *et al.*, 2017; Cockburn *et al.*, 2018). Landscapes include stakeholders,
776 ecosystem services, land uses, institutions and organisations, scales of action and
777 decision-making (Poteete, 2012; Lescourret *et al.*, 2015; Cockburn *et al.*, 2018). The
778 boundaries of landscapes are defined in various ways, for instance by catchment
779 areas or as a subunit of a natural jurisdictional region (Prager, Reed and Scott, 2012;
780 Cockburn *et al.*, 2018).

781 Landscapes generate a flow of ecosystem services, which support and influence
782 human well-being (Cockburn *et al.*, 2018). This includes the provision, regulation and
783 support of ecosystem services (De Groot *et al.*, 2002; Millennium Assessment, 2005;
784 Cockburn *et al.*, 2018). A higher diversity of ecosystem services in a particular
785 landscape indicates a higher multifunctionality, which correlates with higher levels of
786 regulating and cultural ecosystem services (Raudsepp-Hearne *et al.*, 2010; Lescourret
787 *et al.*, 2015; Cockburn *et al.*, 2018). In many rural landscapes, such as the Northern
788 Cape Province, agricultural production is one of the most important human utilisations
789 of the landscape (for both commercial and subsistence purposes) (Scherr *et al.*, 2008;
790 Penker *et al.*, 2013; Minang *et al.*, 2014; Cockburn *et al.*, 2018). Agricultural
791 production typically increases provisioning ecosystem services in a landscape, while
792 also altering the structure and functioning of ecosystems. This can result in the

793 reduced production of regulating and cultural ecosystem services (Gordon *et al.*,
794 2010), although healthy functioning ecosystems and biodiversity are important for the
795 long-term sustainability of agriculture (Cockburn *et al.*, 2018).

796 All landscapes are inherently multifunctional (Fischer *et al.*, 2014), with the
797 understanding of multifunctionality based on the diversity of delivered ecosystem
798 services (Cockburn *et al.*, 2018). This suggests that multifunctionality is typically higher
799 in near-natural or natural landscapes than in intensively farmed and simplified
800 agricultural landscapes, and that managing for multifunctionality can result in
801 ecosystem services being produced in more balanced proportions. This leads to more
802 sustainable landscapes (O'Farrell *et al.*, 2010; Cockburn *et al.*, 2018). The spatial
803 configuration of ecosystems in agricultural landscapes is critical to the supply of many
804 ecosystem services (Cockburn *et al.*, 2018). The landscape is the primary level at
805 which the actions and decisions of individual farmers, managing companies or local
806 research-user groups, intersect with those of other stakeholders and decision-makers
807 (Frost *et al.*, 2006; Cockburn *et al.*, 2018). This requires that farms be managed
808 (stewarded) in a coordinated way at landscape level rather than as individual units
809 (Goldman *et al.*, 2007; Stallman, 2011; Cockburn *et al.*, 2018).

810 **1.7. Management strategies for invasive alien control programmes**

811 Due to the variable nature of plant invasions, there is a range of available options for
812 invasion containment and protecting the investment of property ownership
813 (Shackleton *et al.*, 2017). This includes combinations of mechanical and chemical
814 control, control by means of utilisation, biological control and cultural control.
815 Stakeholder involvement in assessing wants, needs, efficacy and practicality is
816 imperative in deciding upon a method of control and the degree of integration needed
817 for success (Van Wilgen *et al.*, 2011; Shackleton *et al.*, 2014, 2017). Understanding
818 the mechanisms that facilitate or inhibit invasion, as well as the identification of the
819 harm invasive species are causing (Evans *et al.*, 2008) is central in assessing threats
820 and defining control options (Larson *et al.*, 2011).

821 Present invasive species management (ISM) funding is clearly insufficient to address
822 the accelerating rates of global invasion (Lodge *et al.*, 2006; Hellmann *et al.*, 2008;
823 Larson *et al.*, 2011). This brings into question the sustainability of effective ISM, given
824 the high costs of ISM and increasing rates of invasion. The aim therefore must be to
825 sustain management efforts in the future while also supporting financial and social

826 capital (Larson *et al.*, 2011). Managers must consider the temporal and spatial scale
827 of an invasion to develop management plans that are environmentally sustainable.
828 These management plans have to consider the most effective control methods in
829 regards to the stage of invasion and type of system invaded (Larson *et al.*, 2011). Non-
830 target effects have to be limited, while promoting the recovery and restoration of
831 endangered- and native species, diversity and ecosystem processes (Denslow, 2007;
832 Larson *et al.*, 2011). Keeping in mind that in some cases, where eradication is
833 successful, vacated niches are often filled by another invader (Ogden *et al.*, 2005;
834 Larson *et al.*, 2011).

835 Objective spatial prioritisation, ranking areas by importance and invasive potential,
836 must be implemented to effectively guide management and expenditure to optimally
837 allocate both time and financial aid (Van Wilgen *et al.*, 2012; Shackleton *et al.*, 2017).
838 Lack of strategic planning and objective prioritisation for specific species and land
839 areas has reduced the effectiveness of large-scale invasive species management
840 programs such as WfW (Kull *et al.*, 2011; Shackleton *et al.*, 2017). Monitoring and
841 evaluation are crucial to environmental management programmes and strategies,
842 since these are methods of assessment that can be used to determine if the
843 management plans are implemented correctly and working. This is also an easy way
844 to identify successes and failures (Stem *et al.*, 2005; Shackleton *et al.*, 2015).

845 Objectives as “measurable benchmarks by which progress toward a management goal
846 will be assessed” are crucial in the likelihood of an implemented management plan
847 succeeding (Larson *et al.*, 2011). The goal of the management area is also critical, for
848 example if the goal is to increase dominance of native species to improve ecosystem
849 services, the stated objectives need to reflect this (Larson *et al.*, 2011). To improve
850 the sustainability of the management framework, stated objectives should be
851 measurable, meaningful and understandable to all stakeholders. Clear objectives also
852 have the ability to demonstrate progress throughout the life of the management plan
853 (Larson *et al.*, 2011).

854 Under their WONS programme, Australia has plans for 20 species (Thorp *et al.*, 2000),
855 whereas South Africa has case-study examples for Australian *Acacia* species and
856 *Parthenium hysterophorus* invasions (Van Wilgen *et al.*, 2011; Terblanche *et al.*, 2016;
857 Shackleton *et al.*, 2017). Apart from Australia and Ascension Island, the

858 implementation of detailed management plans remains largely absent (Shackleton *et*
859 *al.*, 2014).

860 **1.8. Project aims**

861 *Prosopis* invasion in the Northern Cape of South Africa is a problem, posing a real
862 threat to biodiversity, the delivery of ecosystem services and the welfare and continued
863 existence of both subsistence and family farms that support a large part of the
864 provinces' economy. Presently there is increased interest and research into utilising
865 the available resources in an integrated manner, to benefit all involved parties and
866 stakeholders. The integrated management of *Prosopis* using biological control,
867 chemical control, mechanical control in conjunction with management plans and
868 improved regulations has the possibility of making a marked difference in the
869 concentrated efforts of containing and managing the continued invasion of *Prosopis* in
870 the Northern Cape. Thus, the three main aims of this project are to:

- 871 1. improve the understanding and implementation of biological control as part of an
872 integrated management approach for *Prosopis* in the Northern Cape by the involved
873 stakeholders, including farmers and researchers
- 874 2. identify the most appropriate approach to a community of practice, which effectively
875 addresses the integrated management of *Prosopis*.
- 876 3. assess the role and impact of a coordinator to promote an engaged community of
877 practice for *Prosopis* management in the Northern Cape.

878

879
880
881

882
883
884
885
886
887
888
889
890

891
892
893
894
895
896
897

898

899
900
901
902
903
904
905
906

907
908
909

CHAPTER TWO

FARMERS' PERCEPTIONS OF *PROSOPIS* INVASION AND ITS MANAGEMENT

2. Introduction

The agricultural sector accounts for a relatively small share of the global economy, although it remains central to the lives and livelihoods of a large number of people (Alston *et al.*, 2014). According to the World Bank, an estimated 1.3 billion people were directly engaged in farming in 2012, although agriculture (including hunting/fishing and forestry sectors) represented just 2.8% of the overall income (World Bank, 2012; Alston *et al.*, 2014). Most of the world's farmers are found in middle- and low-income countries, where agriculture plays a much larger part in national income and employment (Alston *et al.*, 2014; Martín-Retortillo *et al.*, 2021).

Agricultural production mostly increases provisioning ecosystems in a landscape (such as food, fibre and fuel) whilst altering the structure and function of ecosystems, which can result in reduced production of regulating and cultural ecosystem services (Gordon *et al.*, 2010; Cockburn, 2018). The long-term sustainability of agriculture is dependent on functioning, healthy ecosystems and biodiversity, especially regarding pest control, pollination, water provision and soil formation (Zhang *et al.*, 2007; Cockburn, 2018).

2.1. Farming in South Africa and the Northern Cape

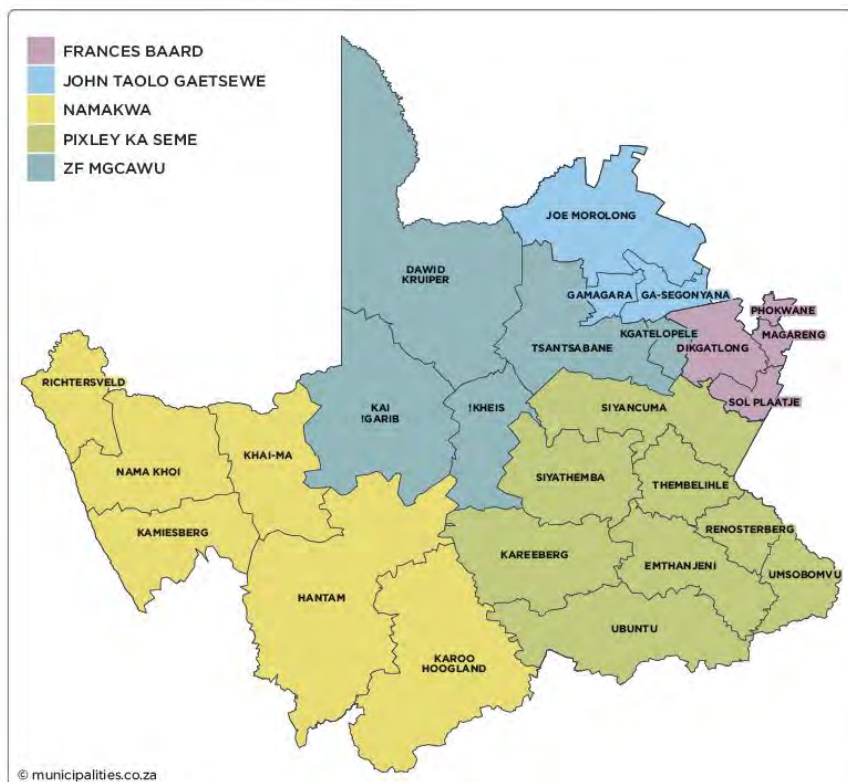
South Africa has a rich biodiversity and a wealth of natural resources (Cadman *et al.*, 2010), although unsustainable use and degradation of these resources are of increasing worry (Wynberg, 2002; Cockburn, 2018). The unsustainable usage of resources in agriculture is of particular concern to the science community (Scotcher, 2009), especially in terms of intensive cropping systems (Van der Laan *et al.*, 2017) and on extensive rangelands (Hoffman and Todd, 2000; Cockburn, 2018). These agricultural activities play an important role in addressing food security and provide critical employment in rural areas (Musvoto *et al.*, 2015; Cockburn, 2018).

With 372 882 km² land, the Northern Cape is the largest of South Africa's nine provinces, accounting for up to 30.5% of the landmass of South Africa, but it is the most sparsely populated with just over 2% of the total population living in the Northern

910 Cape in 26 municipalities (Jordaan *et al.*, 2013) (Fig 2.1). The annual mean
911 precipitation for the province is 200mm, with extreme cold and frost (< -10°C) in the
912 winter and extreme heat (> 40°C) during the summer (Jordaan *et al.*, 2013).

913 The primary farming system in the Northern Cape is extensive livestock farming, with
914 (Jordaan *et al.*, 2013). The Northern Cape Province has fertile agricultural land along
915 the Orange River valley, where high value agricultural products are produced under
916 irrigation, further inland away from this major river are arid grasslands where extensive
917 livestock production is the main source of farming income (Jordaan *et al.*, 2013).
918 Commercial livestock production farms are primarily family-owned and inherited by the
919 next generation. Some families have been on their properties for more than 150 years.

920 The aim of this chapter was to contextualise the impact of *Prosopis* invasion and the
921 perceptions of local stakeholders towards invasive species in the rural farming
922 background of the Northern Cape, towards the possible establishment of a Community
923 of Practice. The student was considered to play a pivotal non-threatening role in both
924 communicating with interested parties and stakeholders as well as organising the
925 workshops and drafting the newsletters.



926

927 **Figure 2.1:** Northern Cape local municipalities (Northern Cape Municipalities, 2022).

928 **2.2 Materials and Methods**

929 The student grew up near Groblershoop, her family has been established and active
930 in the area for many generations. It was considered to be a good starting point to
931 establish initial contact with possible stakeholders and other interested parties,
932 especially considering the perceived suspicion towards researchers and biological
933 control. Hence why the initial poster was put-up in the area, as well as hosting the
934 first workshop in the area. The locales for the *Prosopis* roadshow were decided
935 following from feedback from stakeholders who completed the questionnaires and
936 attended the Groblershoop workshop.

937 The *Prosopis* WhatsApp group had been established before the project, for the
938 purpose of communicating general *Prosopis* news with a diverse group of
939 stakeholders. The group is open to anyone interested in developments regarding
940 *Prosopis* management, legislation etc. The group was initially established by Mr.
941 Philip Ivey. From the inception of the project, the group numbers have increased
942 from 70 individuals to 100.

943 The project has an overall ethical clearance, covering both the workshops and all
944 questionnaires.

945 **2.2.1. Questionnaire**

946 The survey entitled, "*Prosopis in die Noord-Kaap: 'n MSc studie*" (Appendix B), with
947 ethical clearance number SCI2018/033 (issued by the head of the Rhodes University
948 Ethical Standards Committee), was opened on 23 August 2021 and shared on a
949 *Prosopis* WhatsApp-group with 70 members. The survey consisted of 45 questions,
950 including text answers, multiple selection and single selection answer styles, taking an
951 estimated 15 minutes to complete. The survey was designed and distributed using the
952 Survey Monkey programme (Name: Momentive Inc. Location: San Mateo, California,
953 USA Main Website: www.momentive.ai, Survey Monkey Website:
954 <https://www.surveymonkey.com/>). The answers were anonymous and the respondent
955 information kept confidential. A separate English version of the survey was also
956 distributed after a request was received to do so, but no respondents completed it.

957 Responses were either collected using a weblink to the survey or via a QR-code
958 included in the poster. The poster (Appendix A) was distributed through the KLK
959 Landbou Beperk (*Karakoel- en Lewendehawe Kooperasie*) main office, located in

960 Uppington, Northern Cape. KLK is a cooperative supplying fuel, feed and other farming
961 implements and supplies as well as the marketing of livestock via auctions. The poster
962 was sent to the KLK branches that deal with farming supplies across the province. It
963 is unsure how many were actually put up, although email communication was received
964 from a few parties who saw the poster in the Deben and Hotazel branches.

965 **2.2.2. Statistical analysis**

966 To evaluate which factors influence a respondent's likelihood of scoring *Prosopis* as a
967 nuisance, a general linear model (GLM) was used. Originally, respondents were asked
968 how likely they were to classify *Prosopis* as a pest into four categories, namely: "Not
969 at all", "Unlikely", "Likely" and "Highly likely". However, due to low sample sizes (< 5)
970 in some categories, we collapsed this variable into a single Boolean vector, defined
971 as whether the respondent was "Highly likely" or "not" (encompassing the remaining
972 categories) to classify *Prosopis* as a pest. We modelled this vector as a function of the
973 answers to six questions extracted from the questionnaire data, based on *a priori*
974 hypotheses of potential factors affecting respondents' perceptions of *Prosopis*. These
975 six variables included: (1) property size (<100 ha, 100-1999 ha, 2000-3999 ha, 4000-
976 5999 ha, 6000-7999ha, 8000-9999 ha and >10000 ha), (2) *Prosopis* densities on these
977 properties ("None", "1-9 trees p/ha", "10-29 trees p/ha", "30-59 trees p/ha", "60-100
978 trees p/ha" and ">100 trees p/ha"), (3) the frequency of implementing control of
979 *Prosopis* ("Not at all", "Yearly", "Monthly", "Seasonal", "Quarterly" and "Full time"), (4)
980 the frequency of *Prosopis* biomass use on these properties ("Not at all", "Only in times
981 of drought", "Sometimes", "Regularly" and "Daily"), (5) the likelihood of using *Prosopis*
982 as feed ("Not at all", "Unlikely", "Likely" and "Highly likely"), and (6) the stock type run
983 on these properties ("Sheep" or "Other", whereby "Other" could be mixed flocks (e.g.
984 sheep and cattle) or cattle alone. All variables barring the stock type variable were
985 converted into ordered factors to preserve the information provided by the
986 frequency/likelihood variables which would otherwise be lost treating them as
987 categorical predictors.

988 Initially, a simple logistic GLM was specified using a binomial error distribution and a
989 logit link function. However, this model encountered convergence issues due to the
990 low sample size in the negative (i.e. "not" likely to score *Prosopis* as a pest the
991 response variable categories [n = 6] versus "Highly likely" to score *Prosopis* as a pest
992 [n = 36]). As such, we implemented the mixed bias-adjustment correction of Kosmidis

993 *et al.* (2020), and refit the model using penalized maximum likelihood (Kosmidis and
994 Firth, 2009). Models were specified using the 'brglm2' R package. To evaluate the
995 hypotheses of a significant effect of the six predictor variables on the likelihood of
996 classifying *Prosopis* as a pest or not, a Likelihood Ratio Test (LRT) was performed
997 using the 'car' R package (Fox and Weisberg, 2019).

998 **2.3. Results**

999 **2.3.1. Response volume**

1000 Most responses were received in August, with ten responses received by 24 August
1001 (24 hours after distribution of the survey on WhatsApp) (Figure 2.3 (H)). In total 24
1002 surveys were completed in August 2021, accounting for 57.1% of the survey response
1003 volume. The posters were handed over to the head secretary of the KLK main office
1004 on 14 September 2021. This had relatively little impact on survey response, with most
1005 communication received in response to the poster being some variation of "I have a
1006 lot of trees, you can come and spray herbicide anytime". By 23 September the total
1007 survey number of responses received was 29, meaning 5 surveys were completed in
1008 September (accounting for 11.9% of the total responses volume). No surveys were
1009 completed in October.

1010 On 2 November 2021, there was a call on the *Prosopis* WhatsApp group for areas with
1011 green pods, in an effort to release the green podlet weevil (*Coelocephalpon*
1012 *gandolfoi*). This elicited a small response, with several famers in contact for release of
1013 this biological control agent. The number of insects available for release was very
1014 limited, and eventually five sites were identified based on climate mapping and the
1015 likelihood of successful establishment of the green podlet weevil.

1016 The survey and advertisement poster were shared for a second time on the *Prosopis*
1017 WhatsApp group on 3 November 2021, with 35 responses noted the same day. On 24
1018 November 2021 the survey and poster were shared on the Rhodes University Centre
1019 for Biological Control official Facebook page. The post was shared six times. At the
1020 end of November, a total number of 41 surveys were completed, with the 12 responses
1021 noted in November accounting for 28.6% of the survey responses volume.

1022 One survey was completed in December 2021, accounting for 2.4% of the survey
1023 responses volume. No interventions occurred in December before the survey was
1024 closed on 12 December 2021. Technology exposure is not as large a factor in survey

1025 distribution as it once was, the problem is the cost of data and availability of signal
1026 from cell phone towers. In the Northern Cape, MTN has the largest network, although
1027 dead zones are relatively common and farmers have to install their own infrastructure
1028 in their homes, such as signal repeaters and home Wi-Fi. This situation has an
1029 important bearing on the dissemination of information.

1030 **2.3.2. Age**

1031 Out of the 42 respondents, 28.6% were between the ages of 50-59, and only one
1032 person (2.4%) was older than 80 years of age. There was also a single person aged
1033 between 20-29 (2.4%, light green in the below graph) (Fig 2.2 (B)). A possible reason
1034 for this division is that almost all farmers aged 80 and older have retired, with the
1035 children (aged 50-59) taking over. Their children, in the 20-29 group, have yet to take
1036 over, hence the lack of respondents in this group. Farming is also not as financially
1037 viable an occupation as it once was, with many of the younger generation working in
1038 cities while their parents continue on the farm (despite being of retirement age).

1039 The age groups 60-69 years and 30-39 years have both the second largest number of
1040 respondents, 9 each, 21.4% respectively. This could indicate the beginning of the
1041 transfer of farming responsibility from the older generation to the younger generation.
1042 The farming enterprise can also be structured in such a manner, or large enough, that
1043 a few generations can feasibly be present on the farm.

1044 **2.3.3. Property**

1045 The Northern Cape is divided into five larger district municipalities, namely Frances
1046 Baard District Municipality, John Taolo Gaetsewe District Municipality, Namakwa
1047 District Municipality, Pixley Ka Seme District Municipality and the ZF Mgcawu District
1048 Municipality. These district municipalities are then divided into a number of local
1049 municipalities (Fig 2.1).

1050 Municipal services are not delivered to the majority of the farms in the Northern Cape,
1051 including police and emergency services. During the drought, aid forms were used as
1052 a way to determine the ownership of properties, their size and carrying capacity as
1053 well as the local municipality in which it lies. This was used to divide the aid received
1054 in accordance with the size and capabilities of the individual farm. Due to this, more
1055 people are now aware of their municipal district and local municipality.

1056 The largest number of respondents live in Emathanjeni and Siyatemba local
1057 municipalities, with 20.4% (10 respondents) respectively. Both Emathanjeni and
1058 Siyatemba form part of the Pixley Ka Seme District Municipality, the second largest
1059 district in the province (Municipalities of South Africa, 2022). Single respondents live
1060 in the Ga-Segonyana, Sol Plaatjie, Richtersveld and !Kheis local municipalities (2%
1061 each). Three respondents each live in the Thembelihie, Renosterberg, Karoo
1062 Hoogland and Tsantsabane local municipalities, 6.1 % respectively (Fig 2.2 (A)).

1063 The average farming property size in the Northern Cape is generally larger than those
1064 found elsewhere in South Africa, because of the low carrying capability of the native
1065 vegetation present in these areas as well as the limited availability of underground
1066 water. Smaller holdings are found near the Orange River, where irrigation and the
1067 production of high value crops allow for smaller, more valuable property than further
1068 away from this perennial river. In the graph below, 28.6% of respondents' home
1069 property is between 2 000 and 3 999 ha, accounting for 12 of the 42 respondents who
1070 answered the question "What is the estimated size of the property that you live on".
1071 No one skipped this question. 11.9% of respondents live on a property that is larger
1072 than 10 000 ha and 4.8% of respondents live on a property smaller than 100 ha,
1073 accounting for 5 and 2 respectively, of the total responses (Fig 2.2 (D)).

1074 Property size and the size of the farming enterprise also differs in most cases,
1075 especially as family farms usually consist of more than one property. This is done to
1076 ensure that the sons can farm in partnership with the father, as well as serving as
1077 home and livelihood in cases where the offspring rely on the income from the farm.
1078 Family farms as a farming enterprise are also the insurance policy and inheritance for
1079 the present and following generations. The continued heritage of family farms is
1080 critical.

1081 The majority of respondents own between 5 000 and 9 999 ha, accounting for 12
1082 respondents (Fig 2.2 (C)). This is an average ownership for the centre of the province,
1083 with property ownership in the Karoo usually much larger. This is closely followed by
1084 27.5% of respondents owning a total property size of 1 000 to 4 999 ha, accounting
1085 for 11 responses from the total response for this question. Ten percent, 4 respondents,
1086 of the total question response volume have a total property ownership size of less than
1087 1 000 ha. Three respondents, 7.5%, own more than 20 000 ha. A quarter of the

1088 respondents own between 10 000 and 20 000 ha, with 10% owning between 10 000
1089 and 14 999 ha and 15% owning 15 000 to 19 999 ha.

1090 As is the case with all individuals, priorities differ from person to person. In farming
1091 enterprise priorities are linked to the overall farming enterprise and the future success
1092 thereof. In some cases, a large singular objective becomes the heritage of a farmer,
1093 for instance repairing the fences of the whole farming enterprise in an effort to spare
1094 the following generation. The following generation then has to deal with the pipe
1095 infrastructure, now that the fences are not the most pressing concern. In this way
1096 family farms shift some of the responsibility from a single generation, to not have to
1097 build the warehouses, but improve the livestock, for example. The problem comes in
1098 when one generation slacks, or “*boer uit*”, resulting in loss of generations of hard work
1099 or leaving the next generation with massive sustainability issues.

1100 Farming infrastructure is indicated as a first priority for 3.03 % of respondents, a
1101 second priority for 18% of respondents and a third priority for 7% of respondents. No-
1102 one considered it to be a fourth priority. Farming infrastructure is critical in the grand
1103 scheme of a farming enterprise, having warehouses to store feed, appropriate animal
1104 handling facilities to make herd management easier, strong fences, stable water
1105 provisioning through clean boreholes and pipes and tools such as water pumps and
1106 horn burners (Fig 2.3 (G)).

1107 Animals and general animal health (including medicine) is rated as a first priority by
1108 3.11% of respondents, a second priority by 10% of respondents, a third priority by 2%
1109 of respondents and a fourth priority by 11% of respondents. Animal purchasing is not
1110 the goal of a farming enterprise, livestock quality is important to the eventual sale of
1111 the animals or for breeding purposes. Healthy and genetically sound, animals produce
1112 better offspring and maintain better condition on the veld, resulting in a better income
1113 for the farmers. Thus, investing in animals and animal health is important, but
1114 artificially selecting for better livestock can save money in the long run. There is a
1115 trade-off for both good quality animals and investing more money in their health.
1116 *Prosopis*- and bush encroachment management was considered to be a first priority
1117 by 2.19% of respondents, even though it is not, for example, as pertinent to the
1118 immediate survival of a farm as water infrastructure. Management of *Prosopis*- and
1119 bush encroachment was considered a second priority by 4% of respondents, a third

1120 priority by 15% of respondents and a fourth priority by 11% of respondents (Fig. 2.3
1121 (G))

1122 Security and vehicles were considered to be a first priority by 1.91% of respondents,
1123 a second priority by 5% of respondents, a third priority by 7% of respondents and a
1124 fourth priority by 18% of respondents. It is interesting to note that security is overall a
1125 fourth priority, after *Prosopis*- and bush encroachment management, even though
1126 rural safety is a growing concern with the increased occurrences of farm attacks and
1127 farm murders. Overall, farming infrastructure and animal health was the first priority
1128 for the respondents who answered this question.

1129 The use of *Prosopis* biomass in farming is a known occurrence, and concern. Feeding
1130 pods to livestock is one of the ways the trees have invaded such a large part of the
1131 Northern Cape. To the question "What is the frequency of *Prosopis* biomass use in
1132 your farming practice?", 29.3% (the majority) of respondents answered 'none'. This is
1133 closely followed by 26.8% of respondents who indicated that they regularly use
1134 *Prosopis* biomass. 14.6% of respondents indicated they only use *Prosopis* biomass
1135 during periods of drought, while 19.5% of respondents use *Prosopis* biomass only
1136 sometimes. Daily use of *Prosopis* material was indicated by 9.8% of respondents. This
1137 question did not differentiate between the use of wood, leaves or pods, and does not
1138 therefore provide an accurate picture of the needs of *Prosopis* material on farms (Fig
1139 2.2 (F)).

1140 While 14.6% of respondents indicated that they use *Prosopis* biomass during times of
1141 drought, 10.9% of respondents indicated that during the drought they made use of the
1142 official 'Bos tot Kos' method. The majority of respondents made use of drought feed
1143 aid in the form of feed bales (wheat, oats and grass) as well as drought feed mixtures
1144 sold in lick or pill form by feed companies. Lick (a feed with mineral supplementation)
1145 with ruminant additives, to enhance the functioning livestock rumen to enable them to
1146 eat dryer and more rough plant material, was used by 29.1% of respondents (Fig 2.3
1147 (C)).

1148 **2.3.4. *Prosopis* control**

1149 In the survey, 36 respondents answered the question "what is the ideal density of
1150 *Prosopis* on your property" with variations of zero trees being the ideal, "*nul, ek wil*
1151 *hulle nie hê nie*", "*niks, ek haat 'n Prosopis*" while three respondents indicated one

1152 large tree for shade every 1-9ha, and three respondents skipped the question. One
1153 respondent also had the opinion that the project was useless and that this script
1154 (unseen) was theoretical and irrelevant.

1155 Unfortunately wanting zero trees and the reality thereof is relatively different. 41
1156 respondents answered the question “What is the estimated density of *Prosopis* on
1157 your property?”, and one person skipped the question. Of the 41 respondents, 7
1158 (17.1%) answered that they do not have *Prosopis* on their property and 11 (26.8%)
1159 answered that they estimate the *Prosopis* density on their property to be more than
1160 100 trees per ha (Fig 2.2 (G)). 26.8 % of respondents indicated that they estimate to
1161 have between 1 and 9 *Prosopis* trees per ha, which is a lot closer to actuality than
1162 having none at all, as there could be seedling trees unnoticed on properties. 12.2% of
1163 respondents indicated that they have 10 to 29 trees p/ha and 60 to 100 trees p/ha,
1164 respectively.

1165 To address the increasing density of *Prosopis* invasion on farming properties, control
1166 measures need to be implemented. These control methods vary according to the
1167 financial position of the owner, the terrain of their property and the density of the stands
1168 of *Prosopis*. The question, “Which control methods do you mainly use” was a multiple
1169 answer question, where respondents could select more than one option. In response,
1170 49.3% of respondents indicated that the primary control method they use is herbicide
1171 application. Herbicide application is used in conjunction with other methods, such as
1172 workers with chainsaws (33.3%) and a tractor with a hydraulic saw attached (9.3%).
1173 The use of a bulldozer, 6.7% of respondents, is a relatively more expensive option
1174 compared with the rest, with concerns raised as to the impact this method has on the
1175 environment compared with other control methods. One respondent indicated that no
1176 control method was used on his property (Fig 2.2 (H)).

1177 The frequency of *Prosopis* control on a farm is critical to curb the spread of *Prosopis*,
1178 as well as keeping momentum and not losing hope. It is important to note that
1179 expecting full-time *Prosopis* control at the cost of a successful farming enterprise is
1180 not sustainable nor fair. Sustainable *Prosopis* control is achieved when consistent
1181 progress is made in such a manner that the goals of the property owner can be
1182 achieved in the timeframe they set out.

1183 Although 1% of respondents indicated in the above figure that they do not use any
1184 control methods, 7.1% of respondents reacted to the question asking “What is the
1185 frequency of *Prosopis* control method application” with no control being applied. Just
1186 over a quarter of respondents (26.2%) indicated that *Prosopis* control on their property
1187 was controlled full-time, while 7.1% indicated they control *Prosopis* on a monthly basis.
1188 Seasonal control of *Prosopis* was indicated by the majority of the respondents, at
1189 35.7%, and 7.1% of respondents control *Prosopis* on a yearly basis (Fig 2.3 (A)).

1190 *Prosopis* control is more effective when accompanied with timely and correct follow-
1191 up treatment. Noticeably 26.2% of respondents indicated that they control *Prosopis*
1192 full-time, with follow-up treatments also indicated to be full-time by 26.2% of
1193 respondents. Worryingly, 16.7% of respondents do not use follow-up treatments,
1194 possibly in the case where a bulldozer was used to remove the tree stump, although
1195 this does not account for the growth of seedlings in the absence of the larger trees.
1196 Both seasonal and yearly follow-up treatments, respectively, are used by 23.8% of
1197 respondents. Monthly follow-up treatments were indicated by 9.5% of the survey
1198 respondents who answered this question (Fig 2.3 (B)).

1199 Using the biomass of the dead and or removed trees is considered to be a method to
1200 try and alleviate some of the costs of *Prosopis* control. There is value in large, single
1201 trees on homesteads, where 4.2% of respondents indicated they use such trees for
1202 shade. Some respondents, 2.1%, dry out the pods before feeding it to livestock,
1203 whereas 16.7% of respondents do not dry out the pods before using these to feed their
1204 livestock. Thus, pod use alone accounts for 18.8% of *Prosopis* use by the
1205 respondents. 18.8% of respondents do not use any *Prosopis* biomass, while 12.5%
1206 indicated the use of *Prosopis* biomass (leaves, twigs and pods) for feeding livestock.
1207 One respondent uses *Prosopis* biomass for groundcover, while another uses it for
1208 compost. The overall primary use for *Prosopis* material is wood (41.7%), for braais
1209 and fireplaces as well as cooking fires (Fig 2.3 (F)).

1210 **2.3.5. Biological control**

1211 The use of biological control as part of an integrated approach to *Prosopis* invasion on
1212 farming properties may go a long way to mitigate the need for aggressive follow-up
1213 treatments. Unfortunately, 52.5% of respondents consider it highly likely and 12.5% of
1214 respondents consider it likely that the biological agents presently used in response to
1215 *Prosopis* invasion can and will attack native plants, having a negative impact on the

1216 environment. The largest number concerns are for the native thorny trees, including
1217 camel thorn (*Vachellia erioloba*) and grey camel thorn (*Vachellia haematoxylon*). A
1218 quarter of respondents (25%) consider it unlikely that biological control agents will
1219 attack native plants, while 10% are not concerned (Fig 2.3 (D)).

1220 Even though more than half of respondents are concerned with the likelihood that the
1221 biological control agents used to address *Prosopis* invasion in the Northern Cape will
1222 have a negative environmental effect by attacking native thorny trees, 40% indicated
1223 that they were highly likely to recommend the use of biological control to their friends,
1224 neighbours and colleagues (Fig 2.3 (E)). 42% of respondents indicated that they were
1225 likely to recommend the use of biological control agents to their friends and colleagues,
1226 whereas 15% were unlikely to recommend biological control and 2.5% were not likely
1227 to at all.

1228

1229

1230

1231

1232

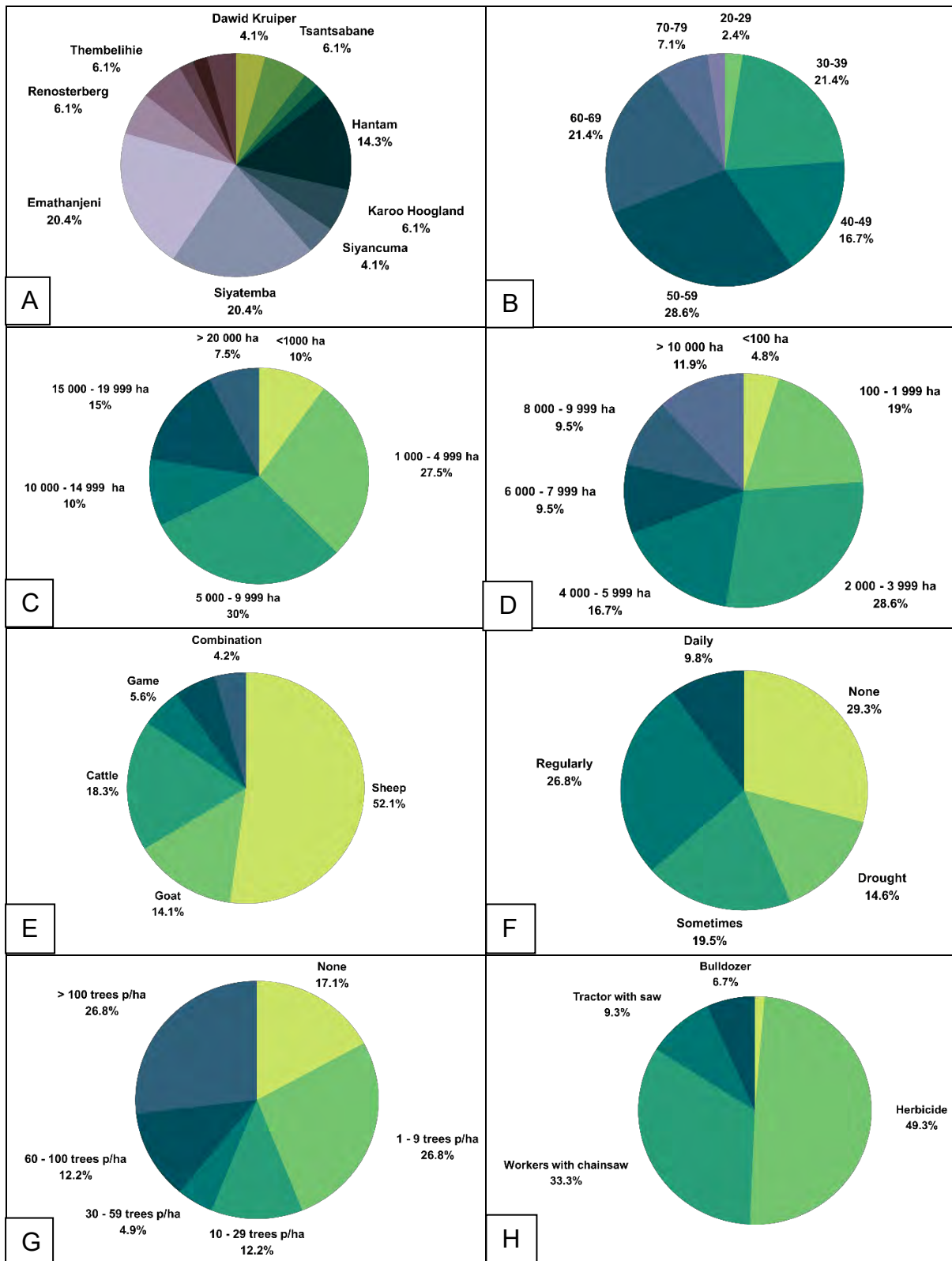
1233

1234

1235

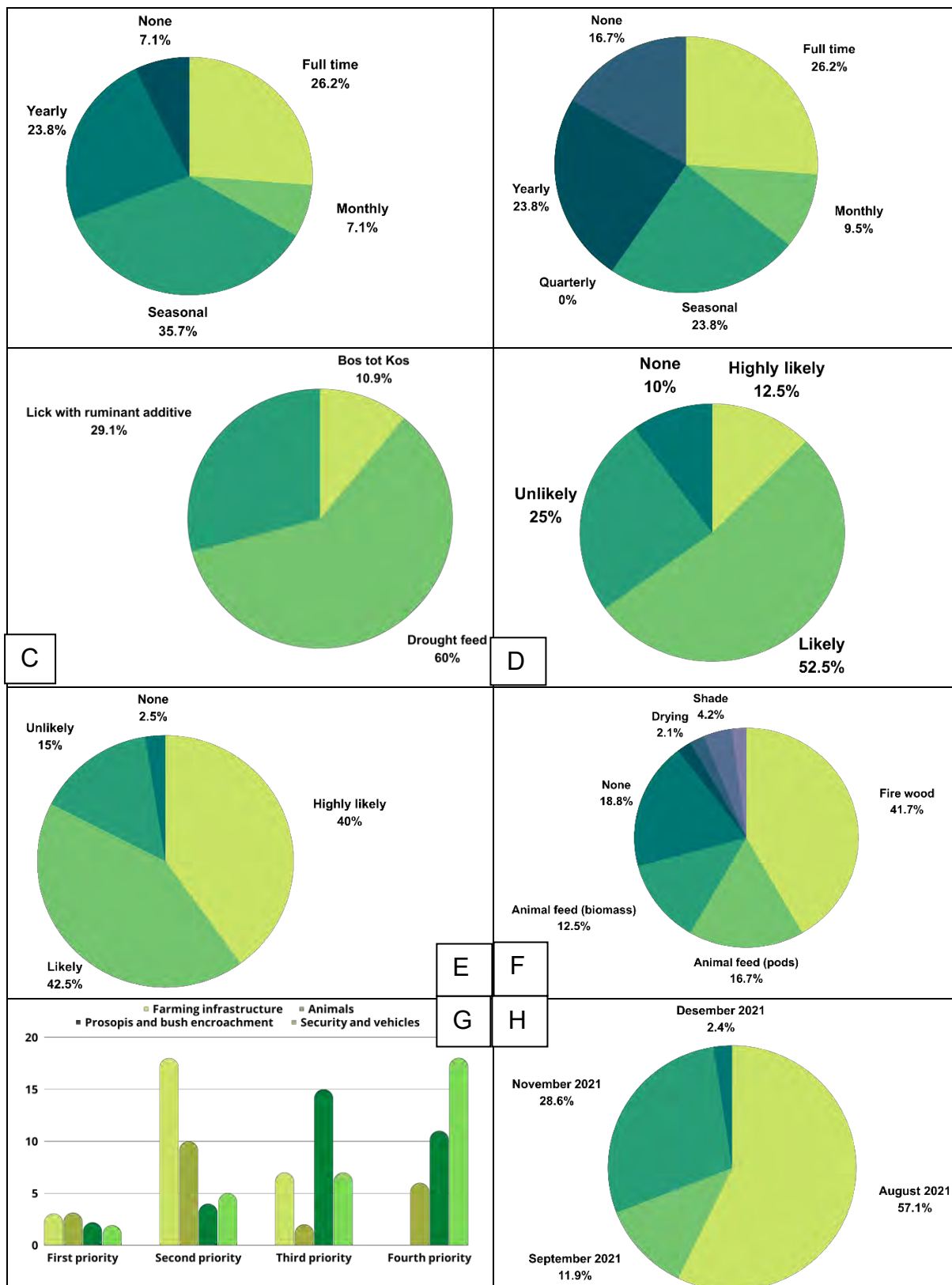
1236

1237



1238 **Figure 2.2:** A) Municipal district wherein respondents reside; B) Age of respondents;
 1239 C) Total size of property ownership; D) Size of the residing property; E) Primary
 1240 farming practice; F) Main use of *Prosopis* biomass on property/in farming practice;
 1241 G) Estimated density of *Prosopis* on property; H) Primary *Prosopis* control methods
 1242 used on property.

1243

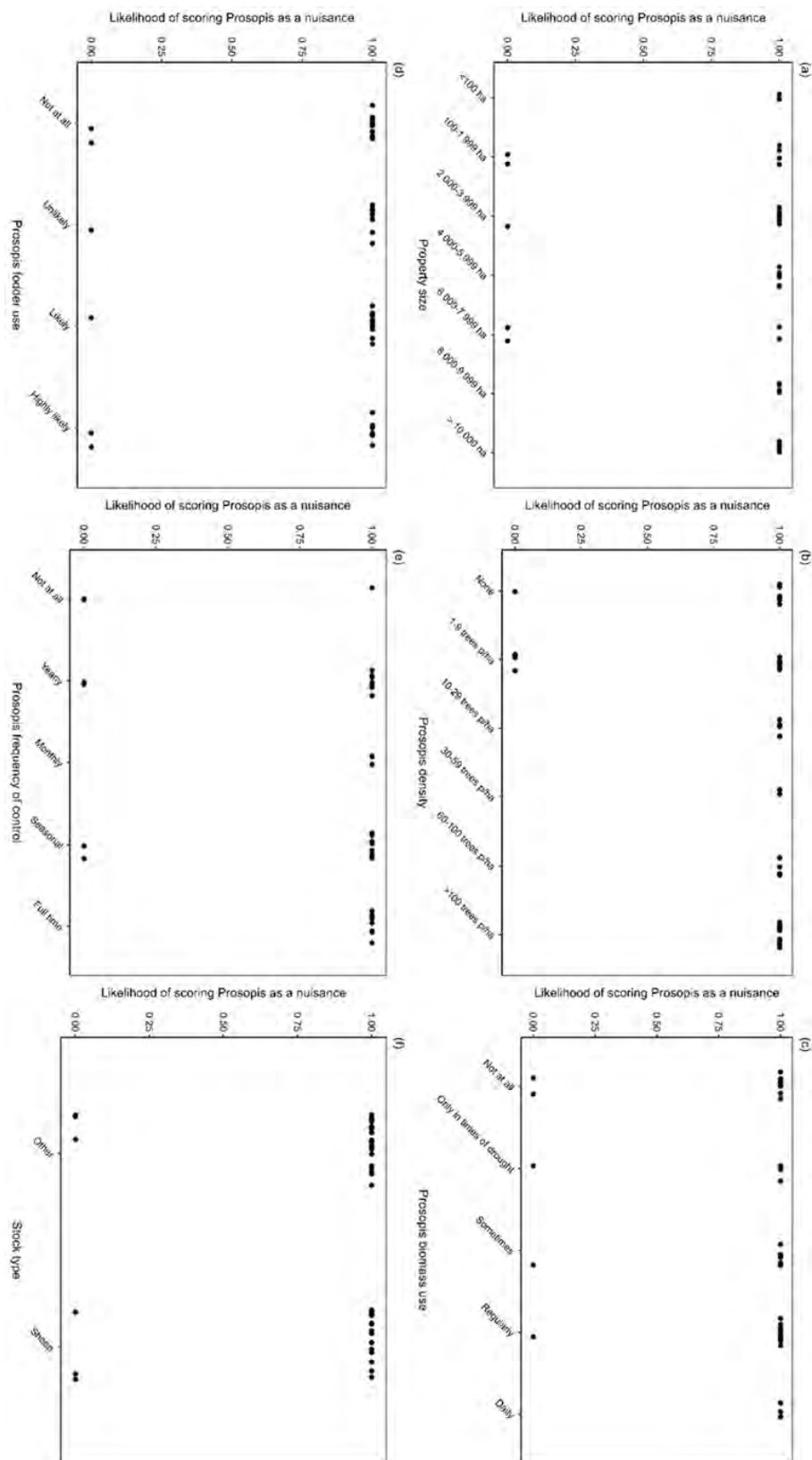


1244 **Figure 2.3.** A) Frequency of *Prosopis* control; B) Frequency of follow-up treatment
 1245 application; C) Feed type used during the drought; D) The likelihood that biological
 1246 control insects will survive on indigenous trees and have a negative impact on the
 1247 environment; E) The likelihood of suggesting the use of biological control methods to
 1248 manage *Prosopis* to others; F) General use of *Prosopis* biomass on respondent
 1249 property; G) Financial priority on respondent property; H) Response volume.

1250 **2.3.6. Statistical analysis**

1251 We found no evidence for a statistically significant effect of any of the six predictor
1252 variables in explaining the likelihood of a respondent scoring *Prosopis* as a nuisance
1253 or not. Even with applying bias-adjustments to the baseline statistical model to try to
1254 improve the accuracy and reduce the bias of the estimated regression coefficients,
1255 there are several reasons why the regression parameters presented above may still
1256 be biased (see ‘Discussion’). As such, below we highlight several specific comparisons
1257 and potential associations based on visual inspection and scrutiny of the raw data,
1258 while cautioning against overinterpreting these data and making any significant
1259 inference from these possible associations.

1260 In contrast, there is a potentially positive relationship between the estimated *Prosopis*
1261 density on a property and the likelihood of a respondent scoring *Prosopis* as a
1262 nuisance or not, with all five respondents who did not score *Prosopis* as being “Highly
1263 likely” to be a nuisance coming from either the no *Prosopis* density category or the
1264 lowest density category (1-9 trees p/ha) (Fig. 2.4 (B)). On the other hand, the
1265 frequency of *Prosopis* biomass may potentially influence respondents’ perceptions of
1266 *Prosopis*, with only respondents who reported using *Prosopis* biomass on a ‘daily’
1267 basis consistently being “Highly likely” to score *Prosopis* as a nuisance (Fig. 2.4 (C)).
1268 Similarly, only respondents who reported to control *Prosopis* on a full-time basis
1269 consistently were “Highly likely” to score *Prosopis* as a nuisance (Fig. 2.4 (E)). Lastly,
1270 only respondents who owned properties in the largest two property size classes (8000-
1271 9999 p/ha and >10000 trees p/ha) were consistently “Highly likely” to score *Prosopis*
1272 as a nuisance (Fig. 2.4 (A)).



1273

1274 **Figure 2.4.** The relationship between the likelihood of considering *Prosopis* a nuisance
 1275 and (A) property size; (B) *Prosopis* density; (C) *Prosopis* biomass use; (D) *Prosopis*
 1276 fodder use; (E) frequency of *Prosopis* control and (F) stock type on property.

1277

1278 **2.4 Discussion**

1279 The role of a Champion is to facilitate the move towards, and implementation, of
1280 actions that benefit the Community of Practice wherein they function. A unidirectional
1281 survey may not be the most accurate way of determining the value a Champion can
1282 have in invasion science in the Northern Cape, as it distances both the Champion and
1283 the stakeholders from the CoP. This results in the inability for both parties to make
1284 lasting impressions on each other, to realise the purpose of this project and to change
1285 perceptions regarding biological control in the area. A CoP can only be considered as
1286 such when all involved parties have a common aim before them, control of *Prosopis*,
1287 although many of the stakeholders disagree on the degree and method of control.
1288 Without coming to a respectful accord, the establishment and continued existence of
1289 a CoP in this area will be greatly hampered. A database of stakeholders and
1290 information needs to be established from which to move forward. Considering this, the
1291 initial questionnaire served the purpose of re-starting the conversation on *Prosopis*
1292 management post-draught and garnering interest in the information available on
1293 *Prosopis* in the Northern Cape.

1294 Unfortunately, most of the interest gained at the start of this project was because of
1295 the misunderstanding the project was involved in the physical control of *Prosopis* in
1296 the study area, and when this was proven to be wrong, some interest was lost. Some
1297 interested parties also believed that being part of the project would allow them to shift
1298 the responsibility of *Prosopis* control onto either researchers or biological control
1299 agents.

1300

1301
1302
1303
1304
1305
1306
1307
1308
1309
1310
1311
1312
1313
1314
1315
1316
1317
1318
1319
1320
1321
1322
1323
1324
1325
1326
1327
1328
1329
1330
1331
1332

CHAPTER THREE

STAKEHOLDER WORKSHOPS AND ENGAGEMENT

3. Introduction

Since the 1980's, stakeholder participation has become increasingly important in the international development discourse (Mohan *et al.*, 2000; Easterly, 2006; Sachs, 2006; Denney *et al.*, 2018). Participation refers to the inclusion of stakeholders in the planning and/or implementation of projects. The aim of doing this is to enhance outcomes, often by integrating local socio-economic knowledge and implementation capacity (Wheeler *et al.*, 1998; Glicken, 2000; Maathai, 2011; Denier *et al.*, 2015; Denney *et al.*, 2018). With participatory processes also receiving renewed attention in the sustainability science literature (Heras *et al.*, 2014; Wittmayer *et al.*, 2014; Steelman *et al.*, 2015; Hara *et al.*, 2016; Leventon *et al.*, 2016; Denney *et al.*, 2018), there has been an increased focus on interdisciplinarity (Polk, 2014; Steelman *et al.*, 2015; Leventon *et al.*, 2016) and participation of non-academic stakeholders in terms of problem definition, solution identification and policy formation (Lang *et al.*, 2012; Heras *et al.*, 2014; Miller *et al.*, 2014; Denney *et al.*, 2018).

The use of participation as part of sustainable and conservation projects is based on the reasoning that the detailed understandings of the local socio-ecological system are essentially different between local stakeholders and outsiders. The incorporation thereof can provide valuable information and perspectives for the success of sustainability interventions (Berkes *et al.*, 2000; Walker *et al.*, 2002; Folke *et al.*, 2005; Denney *et al.*, 2018). Unfortunately, development interventions and research often rely on existing top-down networks facilitated by local governmental institutions. The institutions often treat local beneficiaries as victims who do not understand their own problems (Nuijten, 2004; Denney *et al.*, 2018).

3.1. Invasive species stakeholder engagement and their impact

To achieve effective and sustainable invasive species management, barriers that hinder the implementation of long-term integrated management plans should be identified and addressed (Larson *et al.*, 2011), whilst understanding that perspectives on the environmental, social, and economic importance of invasive species management will differ among stakeholders (Lodge *et al.*, 2003; Maguire, 2004; Stokes *et al.*, 2006; Larson *et al.*, 2011).

1333 When stakeholders are excluded from decision making processes, potential allies may
1334 become potential adversaries (Van Driesche *et al.*, 2004; Larson *et al.*, 2011). Thus,
1335 great care must be taken to involve all possible stakeholders in invasive species
1336 management, developing outreach tools for translating scientific benchmarks into
1337 everyday language as well as communicating measurable progress to the community
1338 (Larson *et al.*, 2011). Assessing people's perceptions can provide insights into the
1339 negative impacts of the invasive species (Witt *et al.*, 2019).

1340 With management of IAS necessary to mitigate negative impacts associated with alien
1341 invasions (Hulme, 2006; Pyšek *et al.*, 2010), it is often assumed that native biodiversity
1342 recovery will follow the removal of IAS from invaded ecosystems (Wittenberg *et al.*,
1343 2005; Blanchard *et al.*, 2008; Nsikani *et al.*, 2020). Invasive plant management,
1344 however, is inherently complex with the knowledge that the removal of invaders may
1345 not always result in full or even partial recovery of native biodiversity (Zavaleta *et al.*,
1346 2001; Pearson *et al.*, 2016; Mangachena *et al.*, 2017, 2019; Nsikani *et al.*, 2020).
1347 Some proposed reasons for the lack of biodiversity recovery after the removal of IAS
1348 include the depletion of native seed banks (Le Maitre *et al.*, 2011), re-invasion
1349 (Richardson *et al.*, 2008) as well as secondary invasion and dominance of native
1350 weedy species (bush encroachment) (Pearson *et al.*, 2016; Nsikani *et al.*, 2018), with
1351 secondary invasion broadly defined as "the proliferation of non-target alien species
1352 following effort to suppress dominant target invaders" (Pearson *et al.*, 2016; Nsikani
1353 *et al.*, 2018; Nsikani *et al.*, 2019, 2020).

1354 Nsikani *et al.* (2020) conducted a study to try and address the absence of country-
1355 specific reviews on secondary invasion and weedy native species dominance in South
1356 Africa. Their research consisted of a literature review as well as a participatory
1357 interactive expert workshop. The workshop, intended to evaluate the knowledge on
1358 secondary invasion and weedy native species dominance in South Africa was hosted
1359 by Nsikani *et al.* (2020) at the 46th National Symposium on Biological Invasions in
1360 Tulbagh, Western Cape. The workshop was attended by 52 participants, mostly
1361 researchers. The delegates were from the Agricultural Research Council,
1362 CapeNature, Centre for Biological Control, Centre for Invasion Biology, Department of
1363 Environment, Forestry and Fisheries, South African National Biodiversity Institute and
1364 several universities (Nsikani *et al.*, 2020).

1365 The workshop recognised that grasses, herbs, shrubs and trees can be secondary
1366 invaders after clearing target invaders, and that while secondary invasion is often
1367 observed after primary clearing, they are seldom focused on or identified (Nsikani *et*
1368 *al.*, 2020). They also indicated that the nature and severity of the effects of secondary
1369 invasion are dependent on context with secondary invasions hindering native species
1370 recovery. The workshop recognised that little to no management efforts target
1371 secondary invasions in South African ecosystems, which was attributed to the present
1372 policy regulating IAS, the NEM: BA act. This lists IAS requiring management, with most
1373 secondary invaders not included as they are not considered high-impact weeds
1374 (Nsikani *et al.*, 2020). Some participants also expressed the strong view that
1375 secondary invaders give way to native species after a few years, while other
1376 expressed concerns for arrested succession (where early and mid-successional
1377 species dominate the plant community). Relatively little global research has been
1378 conducted on either of these points (Nsikani *et al.*, 2020).

1379 Due to the lack of knowledge on secondary invasions and weedy native species
1380 dominance in South Africa, there is a definite need for more research to inform a policy
1381 shift towards appropriate management of secondary invaders and weedy native
1382 species (Nsikani *et al.*, 2020). The creation and maintenance of comprehensive
1383 noxious weed lists that include both alien and native species would be useful inputs to
1384 formal policies for dealing with this issue. Increased collaboration between
1385 researchers and practitioners may result in an enhanced understanding of the drivers
1386 and impacts of secondary invasion and weedy native species dominance (Nsikani *et*
1387 *al.*, 2020).

1388 In consultation with stakeholders in 2001, a decision was made to expand the
1389 development of biological control efforts against *Prosopis* by including potential agents
1390 that attack all reproductive components (Kleinjan *et al.*, 2021). Zachariades *et al.*
1391 (2011) reported on the preliminary developments of this, while in recent years a
1392 conclusion was reached to research potential agents that damage the vegetative
1393 components of *Prosopis* (Kleinjan *et al.*, 2021).

1394 Shackleton *et al.* (2017) developed a framework for a national strategy for the
1395 management of *Prosopis* in South Africa. Their process involved a series of steps,
1396 where the first two involved the gathering of background information on the positive

1397 and negative impacts of *Prosopis* in South Africa, distribution and ecology of *Prosopis*
1398 using existing literature which often involved different stakeholders. Their third step
1399 was to include a literature review, workshops and surveys to identify key barriers that
1400 hinder the effective management of *Prosopis*, as well as the identification of strategic
1401 and adaptive approaches that need to be applied to improve control of *Prosopis*
1402 (Shackleton *et al.*, 2016, 2017). The fourth step was to use various approaches to
1403 define components of a national strategy for the management of *Prosopis* (Shackleton
1404 *et al.*, 2017).

1405 Multi-stakeholder workshops involving farmers, academics and private and public
1406 managers were arranged to debate and develop an overarching goal for the strategy
1407 (Shackleton *et al.*, 2017). The workshops were also used to identify crucial needs and
1408 outcomes for the strategy. The effectiveness and role of different control options and
1409 approaches were discussed in the workshops and via interviews with key informants
1410 (Shackleton *et al.*, 2017). Decision tree models were used to assign appropriate
1411 control objectives to different parts of South Africa, allocating management priorities
1412 to each of the 234 municipalities in South Africa. Questionnaires were sent to farmers
1413 and managers to collect information on perception of the different control objectives
1414 (Shackleton *et al.*, 2017).

1415 The framework for the strategy outlines important factors needed to guide the
1416 management of *Prosopis* in South Africa (Shackleton *et al.*, 2017). It outlines how the
1417 management of *Prosopis* needs to be coordinated, which stakeholders need to be
1418 involved, mandates and legislation requirements, the assessment of different control
1419 options, the role and importance of spatial planning and monitoring and evaluation
1420 needs (Shackleton *et al.*, 2017). The goal of the management strategy developed by
1421 Shackleton *et al.* (2017) was agreed upon by multiple stakeholders, “to effectively
1422 control, contain, and monitor *Prosopis* invasions to reduce their costs to humans and
1423 the environment in South Africa over the next 20 years”. The stakeholders present at
1424 the workshop also emphasised the need for coordination and cooperation at different
1425 levels, especially in terms of alignment with South African legislation and to ensure the
1426 overall success of management initiatives (Shackleton *et al.*, 2017). To address this,
1427 Shackleton *et al.* (2017) suggested the establishment of a multiple stakeholder
1428 working group, consisting of WfW managers, representatives from different
1429 government departments and research institutions as well as private stakeholders.

1430 The working group would then direct *Prosopis* management implementation, the
1431 formulation of a research agenda and a best-practice manual for private landowners.
1432 They would also oversee stakeholder engagement, monitoring and performance
1433 evaluations and manage bureaucracy between stakeholders and in the WfW program
1434 (Shackleton *et al.*, 2017).

1435 Initiatives aimed at achieving a comprehensive national strategy for management of
1436 *Prosopis* in South Africa, as set out by Shackleton *et al.* (2017), were implemented in
1437 2018 with the appointment of a national coordinator by the Rhodes University Centre
1438 for Biological Control (Kleinjan *et al.*, 2021). Subsequently the Centre for Biological
1439 Control, in collaboration with Agri-Northern Cape, organised a stakeholder workshop
1440 in 2019. A working group with broad stakeholder representation was formed, to
1441 facilitate and develop a 'National Programme for Management of *Prosopis*' (Kleinjan
1442 *et al.*, 2021).

1443 The aim of this chapter was to illustrate a few of the different approaches in citizen
1444 sciences. The inclusion of a stakeholder project in South Africa about invasions of
1445 alien species is important so as to consider the effects of invasive control, for possible
1446 inclusion in management programs and legislation.

1447 **3.2. Materials and Methods**

1448 **3.2.1. Groblershoop workshop**

1449 Initially two workshops were planned, one in 2021 and one in 2022, unfortunately,
1450 because of the nation-wide COVID-19 pandemic restrictions, this was not possible,
1451 and thus one workshop was organised for 15 June 2022. The main aims of the
1452 workshop were to make the research into *Prosopis* management and the use of
1453 biological control more accessible to land users, as well as improving the transference
1454 of scientific knowledge and research to stakeholders. The workshop was held in
1455 Groblershoop (Fig 3.1), a small town in the Northern Cape situated along the Orange
1456 River, 116 km from Upington. An advertisement programme was distributed via the
1457 *Prosopis* Whatsapp group, which was then shared by individuals to other community
1458 groups (Appendix J).



1459

1460 **Figure 3.1:** Location of Groblershoop (red pin), and Upington, Prieska, Kenhardt,
 1461 Brandvlei and Williston indicated by the yellow pins.

1462 As a prelude to the workshop, a survey entitled, “*Prosopis in die Noord-Kaap*
 1463 *Registrasie*”, (Appendix C) was opened on 25 May 2022 and shared on a *Prosopis*
 1464 WhatsApp-group with 70 members. The survey consisted of 5 questions, with an
 1465 average completion time of 1 minute and 48 seconds. The survey was designed and
 1466 distributed using the Survey Monkey programme (Name: Momentive Inc. Location:
 1467 San Mateo, California, USA Main Website: www.momentive.ai, Survey Monkey
 1468 Website: <https://www.surveymonkey.com/>). The registration survey was distributed via
 1469 an array of other WhatsApp groups, including local agricultural organisations, women’s
 1470 organisations, and rural security groups in order to try and reach as many interested
 1471 parties as possible. In total 34 respondents completed the survey and indicated that
 1472 they would be attending the *Prosopis* workshop hosted in Groblershoop on 15 June
 1473 2022. The survey was only available in Afrikaans, due to the experience with the initial
 1474 questionnaire where the English questionnaire did not receive a single response.

1475 The workshop was attended by a diverse group of stakeholders, including farm
 1476 workers -and managers as well as family farmers from as far as Williston and
 1477 delegates from various governmental departments.

1478 **3.2.2. *Prosopis* ‘roadshow’**

1479 As a direct result of the reception of the Groblershoop workshop, a *Prosopis*
1480 ‘roadshow’ was organised. The speakers present for this series of workshops were
1481 invited because of a comment from a participant at the Groblershoop workshop,
1482 stating that they would like to hear something other than biological control of *Prosopis*.
1483 The goal of the workshop series was to discuss the utilization of *Prosopis* biomass to
1484 aid in control, be it through harvesting or through removal of biomass from properties
1485 to be used in construction. Emphasis was also placed on the importance of a
1486 management plan, to prevent overreaching, biodiversity damage and disruption of
1487 ecosystem services through harmful practices. The importance of *Prosopis* control in
1488 a ‘whole farm approach’ was also reiterated, with the utilization of *Prosopis* only
1489 considered as a way of eventually being able to farm in a more sustainable manner.

1490 Five workshops were held in five towns, starting on 26 October 2022 in Brandvlei,
1491 Kenhardt (27 October), Upington (28 October), Prieska (31 October) and ending on 1
1492 November in Williston (Fig. 3.1). The location decision was based on communications
1493 received from individuals from these towns, either for more information, aid or interest
1494 in the release of biological control agents. These areas all have a marked presence of
1495 *Prosopis* invasion, with most of the waterways clogged with impenetrable *Prosopis*
1496 thickets.

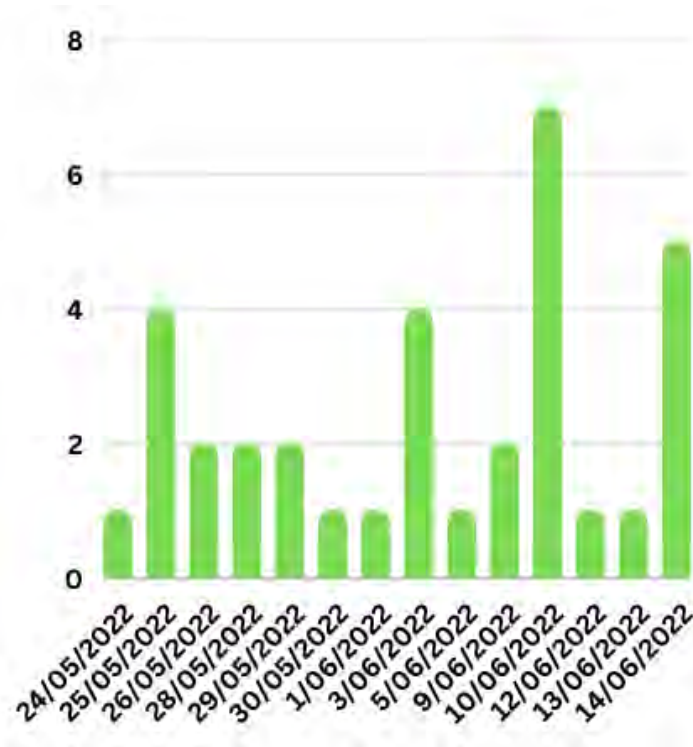
1497 **3.3. Results**

1498 **3.3.1. Groblershoop workshop**

1499 The response volume for the workshop showed the distribution of responses received
1500 by day from the survey that was opened on 24 May, until 14 June when the survey
1501 was closed (Fig 3.2). The highest number of registrations occurred on 10 June, after
1502 a reminder was sent on the *Prosopis* WhatsApp-group, as well as to a variety of other
1503 local groups with possible interested parties. The second highest number of
1504 registrations were received on 14 June. The main purpose of the registration survey
1505 was to gauge the number of people that would be attending the workshop, although
1506 no cut-off date was indicated in the invitation. Four respondents also indicated having
1507 trouble with the online registration, resulting in the student manually registering them
1508 on the Survey Monkey website.

1509 The workshop presentations were 20 minutes in duration, followed by discussion time
1510 and included; 1) the history of *Prosopis* invasion and control; 2) project presentation

1511 on small-scale management of *Prosopis* and perceptions on biological control; 3)
 1512 utilization of *Prosopis* biomass for fodder; 4) Seed-feeding *Prosopis* beetles; 5) *Evippe*
 1513 sp. #1 as *Prosopis* biological control and finally; 6) Small-scale management plans
 1514 and control of *Prosopis*. The workshop was in an informal setting, with farmers
 1515 comfortable to contribute to the discussion. Even though, the workshop was facilitated
 1516 by Mr. Philip Ivey and the student. The student was also the first point of welcoming,
 1517 administration, questions and general order.



1518
 1519 **Figure 3.2.** Registration response volume for the *Prosopis* workshop in Groblershoop.

1520 **3.3.2. Groblershoop workshop outcomes**

1521 Various stakeholders expressed their concern about the use of biological control and
 1522 the possible risks associated with it. Special attention was paid to the likelihood of the
 1523 released biological control agents utilising native thorny trees such as Camel thorn
 1524 (*Vachellia erioloba*) Fabaceae (E. May). It was concluded at the workshop that
 1525 researchers need to be more open with the general public and interested stakeholders
 1526 with the research and development process of biological control agents, as well as
 1527 being clearer on the ongoing and intended projects concerning the target species (in
 1528 this case *Prosopis*).

1529 Another great frustration discussed at the workshop concerns politics and funding,
1530 with many participants upset with projects starting with great promise, and then
1531 stopped, leaving them in the same (or sometimes worse) position than they were in
1532 before. The continuity of projects and researchers was also discussed, participants
1533 are frustrated with spending time and energy with a researcher on a project, while they
1534 complete their research, and then little to no effect is felt on the ground with the
1535 situation of the landowner unchanging. One landowner was very unsatisfied with the
1536 release of *Evippe* sp. #1 at the SKA near Carnarvon in February 2021, firstly because
1537 of land disputes in that area and the government considered responsible for the
1538 majority of *Prosopis*, and secondly because of lack of information on this release. The
1539 researcher responsible for the release indicated that while the area is not ideal for a
1540 release, it was considered relatively appropriate to garner both publicity and public
1541 interest, which results in better funding for the project and allows further releases in
1542 better areas. While the landowner seemed to consider the explanation, he was not
1543 satisfied, becoming withdrawn for the duration of the workshop and leaving directly
1544 after the workshop was concluded.

1545 **3.3.3. Groblershoop post-workshop actions**

1546 A post-workshop newsletter (Appendix D) was considered as a concise
1547 communication device to provide a summary of the workshop topics for those who
1548 could not attend, as well as other pertinent information such as developments in
1549 *Prosopis* biomass use and correct information on the biological control agents
1550 presently being utilised. The content of the newsletter was curated by the student, with
1551 input from the workshop speakers and general concern learned at the workshop. The
1552 newsletter was designed using Canva (Name: Canva Pty Ltd, Location: Sydney,
1553 Australia Main website: canva.com). It was distributed via email to all respondents who
1554 have completed either the first survey in 2021 or the workshop registration survey. It
1555 was also shared on the *Prosopis* WhatsApp-group. A total of 94 respondents were
1556 included in a mailing list for the distribution of the newsletter. Sixteen emails were not
1557 delivered because of inactivity on the account or the address being non-existent. As
1558 the newsletter was distributed via email, and WhatsApp, and open to share by all, this
1559 was not concerning. In the newsletter, two surveys were included, one being
1560 concerned with the organisation of other workshops and interest in the continuation of
1561 the newsletter, and the other concerned with workshops as a tool of stakeholder

1562 engagement. The surveys were completed by 7 and 5 respondents respectively, with
1563 one respondent having great difficulty completing the online surveys. This can be
1564 attributed to troubles hyperlinking information in the newsletter, the possibility of which
1565 was addressed in the email accompanying the newsletter sent out, and confusion of if
1566 they have already completed a survey or not. The results from the two post-workshop
1567 questionnaires were considered to be inadequate and not fit for further consideration.

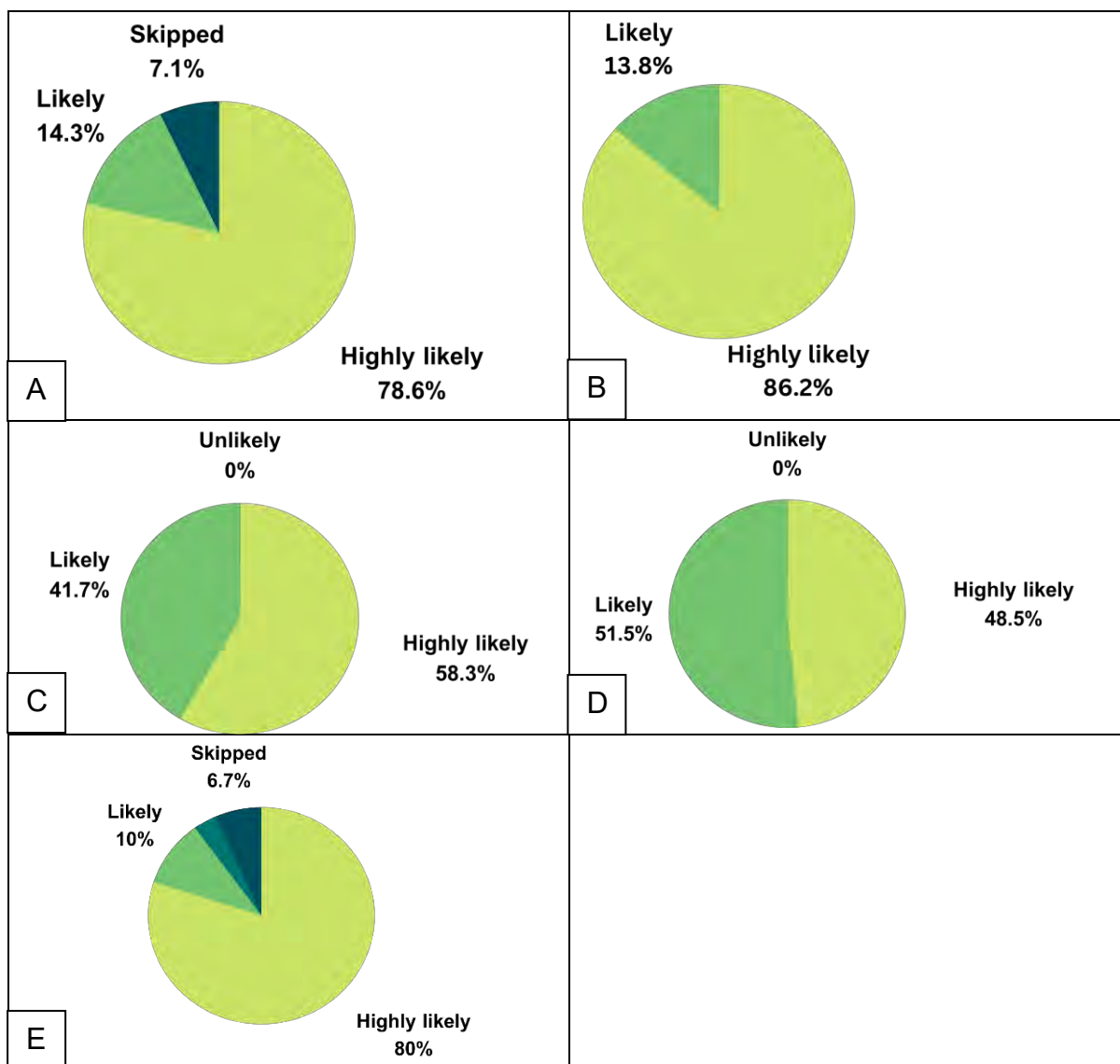
1568 Included in the newsletter was information leaflets from the ARC and other
1569 researchers, providing accurate information on the biocontrol agents discussed at the
1570 workshop. This was included as a way of strengthening communication between
1571 researchers and stakeholders, and to appease concerns on the utilisation of biological
1572 control agents and the environmental impact thereof. Communication details of the
1573 ARC was also included. It was realised that subsistence and communal farmers as
1574 well as smaller commercial farmers in the Northern Cape have no real scope of the
1575 work that the ARC is involved in, as well as the impact the organisation has on
1576 development in the Agricultural sector. Improving communication on this is important
1577 to the success of further endeavours. In future editions of the newsletter, it would be
1578 imperative to include small biographies of the organisations involved with *Prosopis*
1579 research and the control thereof.

1580 Another organisation included in the newsletter was ADTech (African Data
1581 Technologies (Pty) Ltd), a company in Stellenbosch, Western Cape, investigating
1582 carbon credits, biochar and carbon sequestration. This was included to show one of
1583 the possibilities of *Prosopis* biomass utilisation, as a means of both addressing the
1584 *Prosopis* biomass on landowner properties, but also possibly covering some of the
1585 costs associated with *Prosopis* control. Two landowners brought 1kg bags,
1586 respectively, of charcoal they produced on their properties from removed *Prosopis*
1587 biomass. The interest in biochar and the possible financial impacts thereof needs to
1588 be researched further, although interest therein is increasing. The transport of both the
1589 raw *Prosopis* mass and the biochar is the main concern impacting the probability of
1590 such a project. The production of kilns for charcoal and biochar production is being
1591 looked at, with researchers conversing with large irrigation farming companies. One
1592 of the landowners who produced their own charcoal, is also building a wood-gas
1593 machine, to use charcoal made from *Prosopis* to run a generator which can be used
1594 for electricity, drastically reducing his dependence on fuel for a generator.

1595 **3.3.4. *Prosopis* roadshow results**

1596 A message invitation regarding the workshop series was distributed via organised
1597 agriculture groups and meetings, with the majority of the questionnaire's respondents
1598 indicating they were made aware of the workshops via their agricultural union
1599 WhatsApp group. Some respondents indicated they were informed by agricultural
1600 extension officers or NAFU (National African Farmers Union). Word of mouth and
1601 private conversations was also one of the major communication ways used to inform
1602 parties of the workshop series. The workshops were arranged in various venues and
1603 attended by people of various demographics and backgrounds. In total 132 signatures
1604 were accounted for on the registers for each session (Fig. 3.3 (A)). The most attended
1605 session was the Prieska workshop, with 30.4% of the total attendees. The second
1606 most attended session was Kenhardt with 24.4% of the total attendees, followed by
1607 Williston (21.4%), Brandvlei (14.9%) and Upington (8.9%).

1608 A physical questionnaire was handed out at the beginning of each session during
1609 registration (Appendix G). There was also an option available to scan a QR code to
1610 complete the questionnaire online, which was not opted for. A total of 120 completed
1611 questionnaires were collected from 132 individuals over the 5 sessions. This variance
1612 in attendance and completed questionnaires can be attributed to either couples or
1613 groups filling in one questionnaire between them, it was also noted that a small number
1614 of attendees at the sessions were not comfortable with either reading or writing. A total
1615 of 158 individuals registered for the various workshop sessions, with the biggest
1616 difference in the number of people registered for the session and present at the
1617 session occurring in Brandvlei. The attendance in Upington was also less than
1618 registered. In Kenhardt, Prieska and Williston the number of people present was
1619 higher than the number of registrations. Overall, the 'roadshow' can be considered as
1620 successful with most individuals present expressing their satisfaction with the
1621 speakers present in the town they attended (Fig. 3.3 (A-F)). 3.3% of respondents from
1622 Williston considered it likely that they were unsatisfied with the session they attended.
1623 This could be because of their expectations not being met, having attended the
1624 sessions with the purpose of receiving aid, or confusion on completing the form.



1625 **Figure 3.3.** Likelihood of satisfaction with the speakers at the session attended in A)
 1626 Brandvlei; B) Kenhardt; C) Upington; D) Prieska; E) Williston.

1627 Included in the questionnaire was a question requesting if there were any other
 1628 subjects the respondents would have liked to have discussed during the session they
 1629 attended. The majority of respondents indicated that they were satisfied with the
 1630 speakers and that they consider the session to have been relatively informative. Some
 1631 other comments were that more time should be spent on the topics discussed by the
 1632 speakers, as well as practical solutions for herbicide application and physical removal
 1633 of *Prosopis* and more information in general. The sustainability of projects and
 1634 *Prosopis* control was also noted for further discussion. At both Prieska and Upington
 1635 the use of biomass in construction and the offset of finished products was also added
 1636 for further consideration, whereas the development and implementation of biological

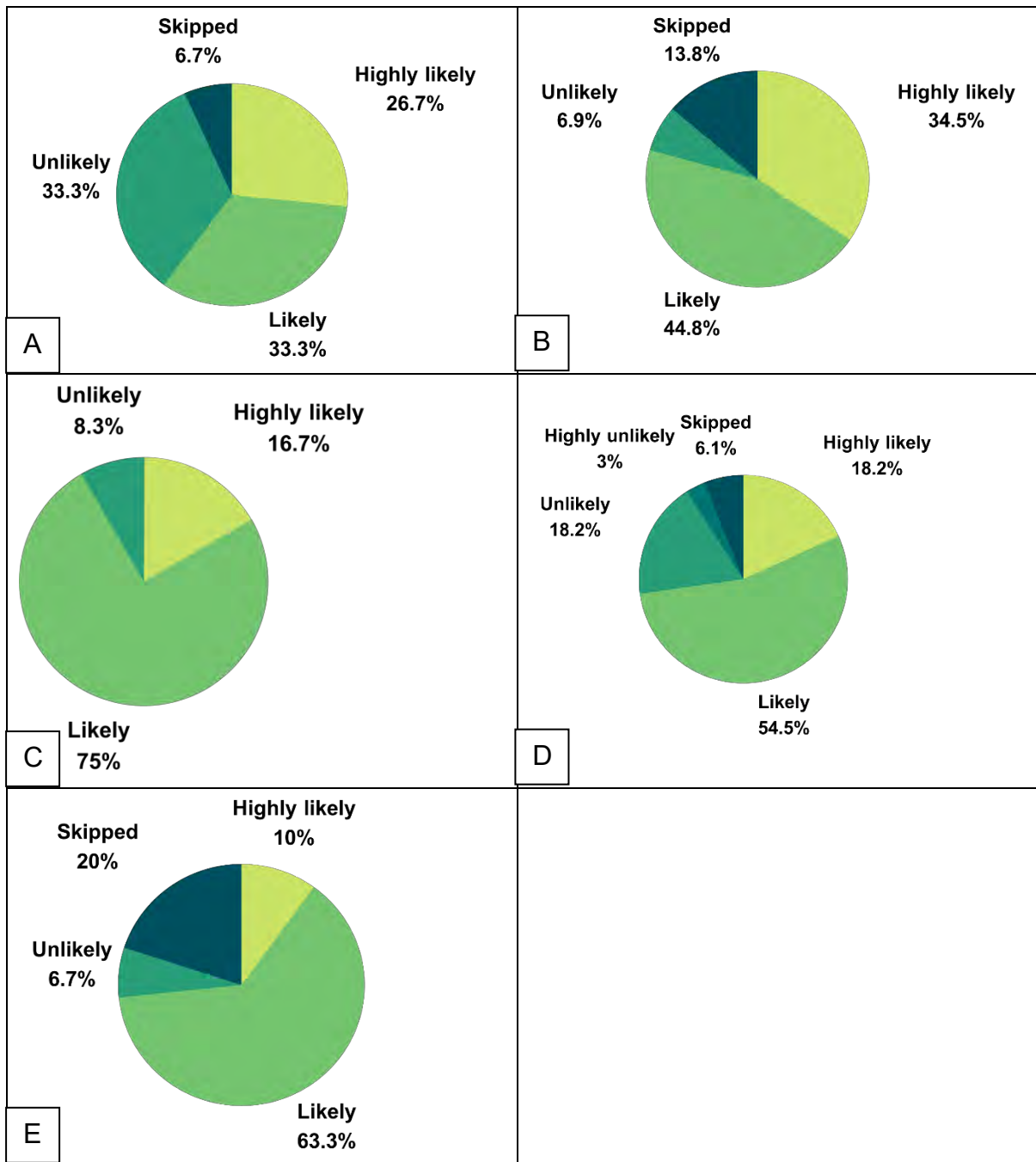
1637 control agents was also noted. This question was also skipped by quite a few of the
1638 respondents over the five sessions.

1639 An introductory presentation was used to detail the reasoning behind the
1640 implementation of biological control and the main goal of the workshop series. At each
1641 town the first question asked was to the safety of biological control and the research
1642 pertaining to it. Respondents were asked if they were aware of the implemented
1643 biological control agents, with 74 of respondents indicating yes, 37 indicating no. Nine
1644 respondents skipped the question. When asked to provide an example of biological
1645 control agents used for *Prosopis* invasion, 75 respondents skipped the question. The
1646 remaining respondents indicated varieties of 'insect,' 'kewer' and 'mot' with two
1647 respondents noting *Evippe sp. #1* by name. While interest in the release of biological
1648 control agents in the area is marked, less attention is paid to the actual functioning of
1649 the different species.

1650 Respondents were asked how likely they thought it that biological control agents would
1651 be successful in the control of *Prosopis* (Fig. 3.4 (A-E)). There was no distinction made
1652 that this would be part of an integrated farm-level approach to *Prosopis* as 'pest' on
1653 properties, which should be rectified in future surveys of this kind. Of the 119
1654 respondents who answered the question, 25 respondents consider it highly likely, and
1655 64 of respondents consider it likely that biological control agents will be successful in
1656 controlling *Prosopis*, with the majority of respondents indicating likelihood of success
1657 attending the Prieska session. Twelve respondents consider the successful control of
1658 *Prosopis* through biological control unlikely. Over the five sessions 13 respondents
1659 skipped the question.

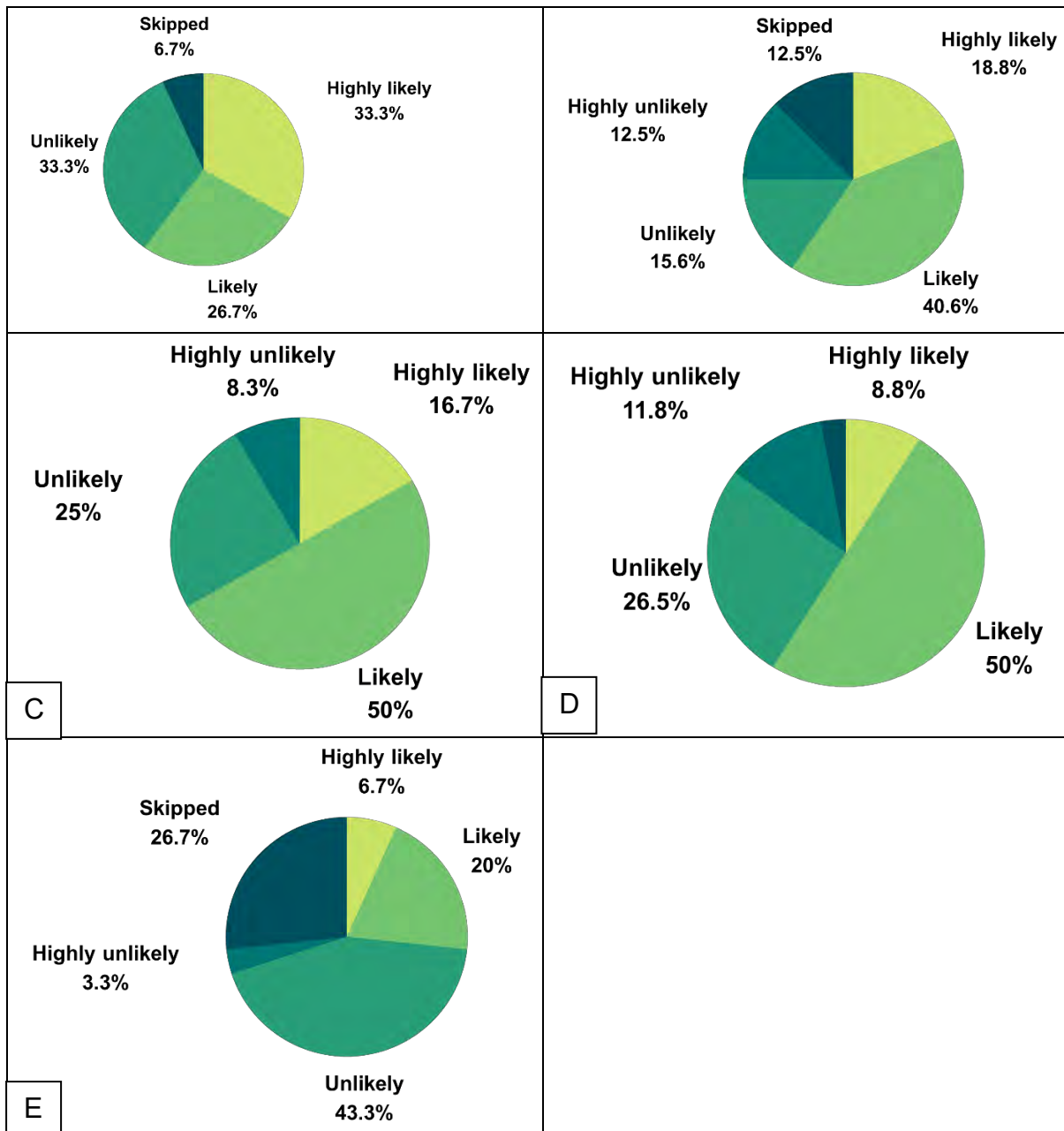
1660

1661



1662 **Figure 3.4.** Likelihood that biological control agents would be considered successful
 1663 for *Prosopis* management in session attended at A) Brandvlei; B) Kenhardt; C)
 1664 Upington; D) Prieska; E) Williston.

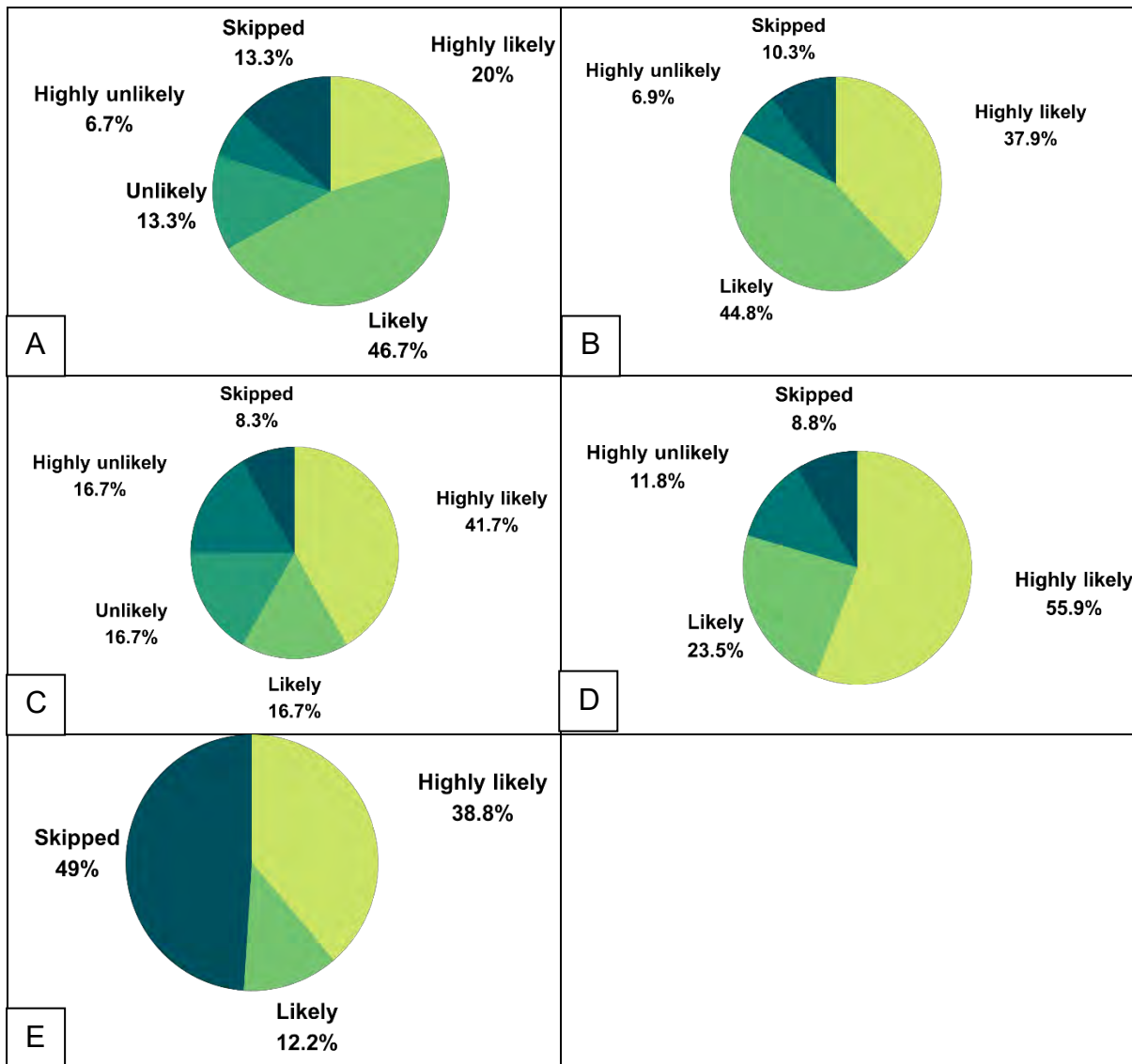
1665 Included in the questionnaire was the question “What is the likelihood that *Prosopis*
 1666 biological control agents will have a negative impact on native trees?” (Fig. 3.5 (A-E)).
 1667 Overall, eighteen respondents indicated that it was highly likely and 46 respondents
 1668 indicated that it was likely that *Prosopis* biological agents will have a negative impact
 1669 on native trees. 35 respondents consider it unlikely and 7 respondents consider it
 1670 highly unlikely that *Prosopis* biological control agents will have a negative impact on
 1671 native trees. This question was skipped by 14 respondents.



1672 **Figure 3.5.** Likelihood that biological control agents will have a negative on
 1673 indigenous plant growth in session attended in A) Brandvlei; B) Kenhardt, C)
 1674 Upington; D) Prieska; E) Williston.

1675 When asked what the likelihood of *Prosopis* control is on their property (Fig. 3.6 (A-
 1676 E)), over the five workshop sessions 57 respondents indicated that it was highly likely
 1677 they were presently busy with control of *Prosopis*. Of these respondents, 19 individuals
 1678 attended Prieska and Williston, respectively. 35 respondents indicated it likely that
 1679 they were presently busy with control of *Prosopis* on their property. 4 respondents
 1680 indicated it to be unlikely, and 9 respondents indicated it to be highly unlikely that they
 1681 were controlling *Prosopis* on their property. 15 respondents skipped the question.
 1682 Brandvlei is presently still experiencing the effects of the drought, as is Kenhardt, with

1683 many landowners abandoning their farms to work in the nearest town. This could be
 1684 contributing to both the attitude of the attendees of the sessions hosted in Kenhardt
 1685 and Brandvlei, as well as their present outlook on invasive species and *Prosopis*
 1686 control. The overall financial position of these towns is different to that of Prieska,
 1687 where there is a high presence of large irrigation farms as well as specialist farming
 1688 industries.



1689 **Figure 3.6.** The likelihood that respondents were busy with *Prosopis* management
 1690 on their properties in A) Brandvlei; B) Kenhardt; C) Upington; D) Prieska; E) Williston.
 1691 An open text question relating to factors that hinder the control of *Prosopis* on the
 1692 property of the various respondents who attended the workshop series was included
 1693 in the questionnaire (Fig. 3.7 (A-E)). 49 respondents indicated that the main
 1694 hinderance to the sustained control of *Prosopis* the overall cost of control (50% of the
 1695 question respondents in Brandvlei, 34.5% of respondents in Kenhardt, 38.5% of

1696 respondents in Upington, 39.5% of respondents in Prieska and 28.2% of respondents
1697 in Williston. Respondents from Kenhardt (13.8%), Prieska (7%) and Williston (2.6%)
1698 also indicated that they were farming on community property surrounding the town,
1699 with little to no control over animal movement nor an organised approach to the control
1700 of invasive plants. Over the four sessions, 14 respondents also expressed concern
1701 towards the labour intensity of *Prosopis* control and the dependability of the labour
1702 force, resulting in higher costs because of the required manpower for sustained
1703 *Prosopis* control, with. Four respondents from Williston indicated that they were
1704 situated next to the Sakriver, and that the *Prosopis* stands were simply too dense to
1705 start with control on their properties. The availability of resources was also noted to be
1706 a hindrance, especially in conjunction with the use of a management plan. Time
1707 constraints were also considered a factor influencing the control of *Prosopis* by 1
1708 respondent from Kenhardt and three respondents from Williston. Overall, 21
1709 respondents indicated that there are no factors hindering the control of *Prosopis* on
1710 their property, while 27 respondents skipped the question.

1711

1712

1713

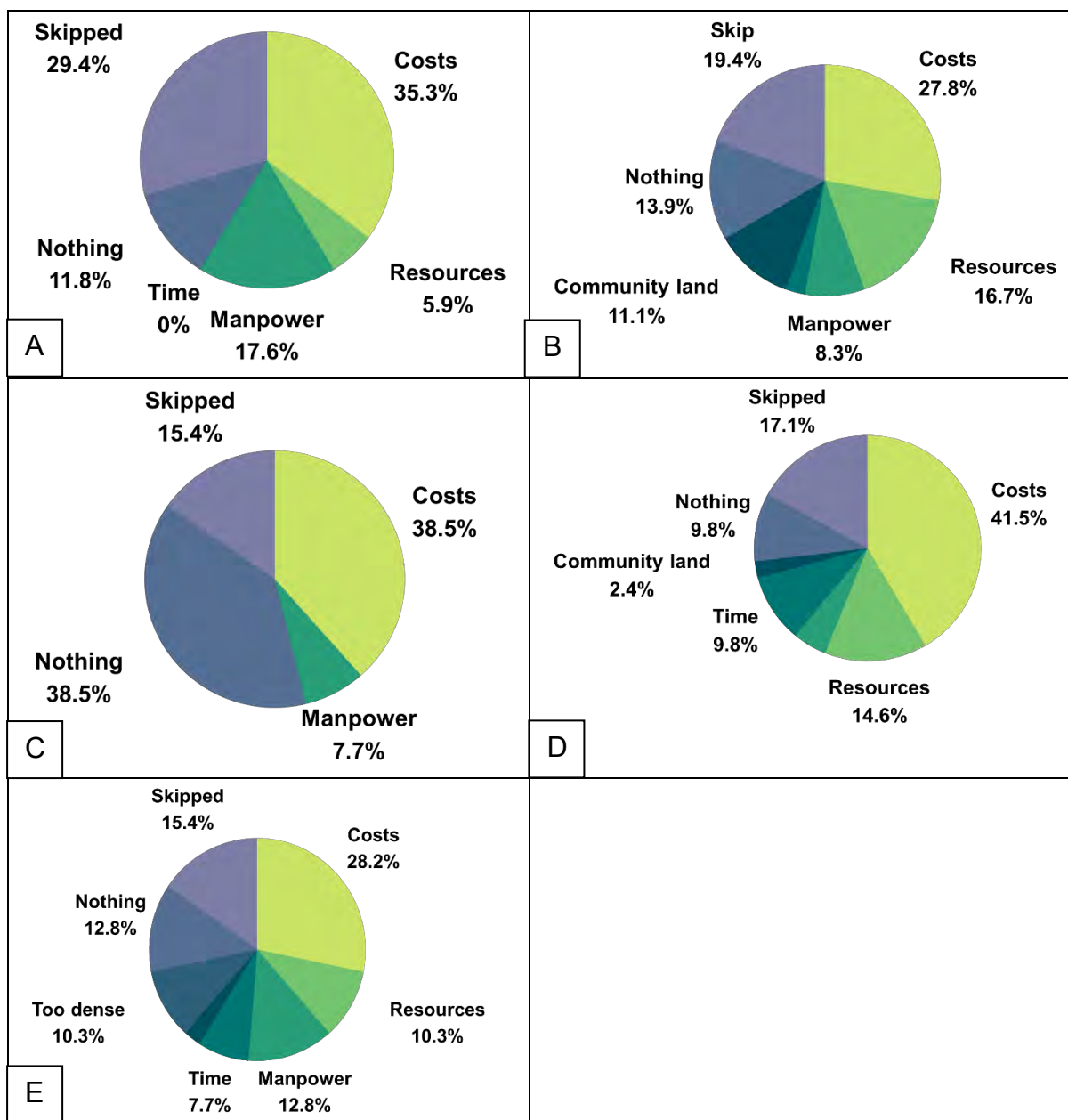
1714

1715

1716

1717

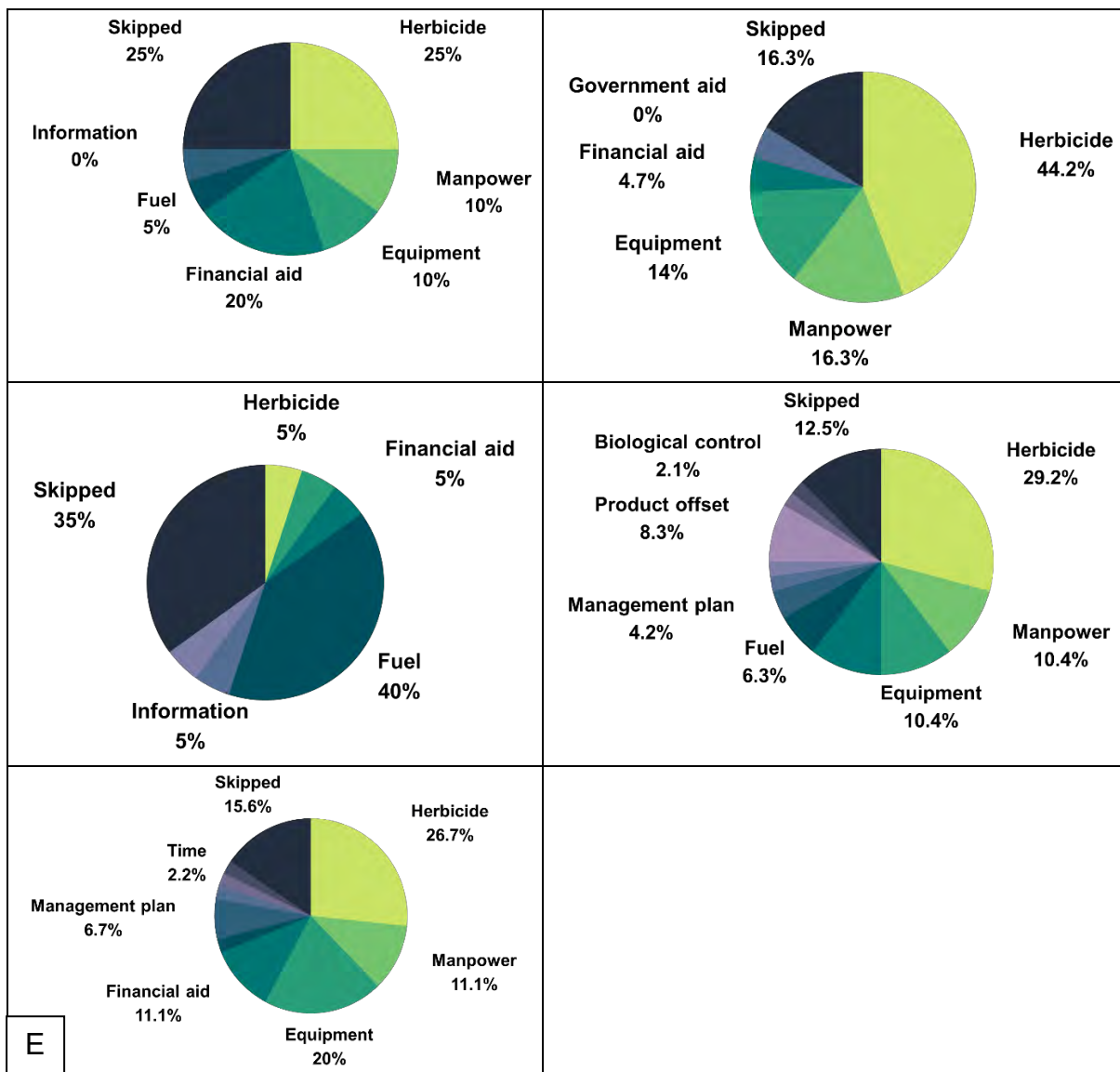
1718



1719 **Figure 3.7.** General factors that hinder the control of *Prosopis* on respondents' property in A) Brandvlei; B) Kenhardt; C) Upington; D) Prieska; E) Williston.

1720
 1721 When asked what other resources the respondents would consider to support their
 1722 efforts of controlling *Prosopis* on their property (Fig. 3.8 (A-E)), 51 respondents
 1723 indicated that herbicide aid, more affordable herbicide and more information on
 1724 herbicide use will assist them in controlling *Prosopis*. Manpower and labour were also
 1725 indicated as additional resources that would support *Prosopis* control by 19
 1726 respondents, as well as fuel (13 respondents), improved machinery and other
 1727 mechanical tools such as chainsaws (23 respondents). Financial aid was also added
 1728 as consideration, either privately funded (17 respondents) or through increased
 1729 cooperation with government departments (2 respondents). The possible need of a

1730 management plan was indicated by respondents from Brandvlei (1 respondent),
 1731 Prieska (2 respondents) and Williston (3 respondents). Four respondents from Prieska
 1732 also indicated that having an offset for various biomass products will support their
 1733 efforts in controlling *Prosopis* (8.5%). Being able to have biological control agents on
 1734 their property was also noted to be a supplementary resource by one respondent in
 1735 Prieska and Williston, respectively. Two respondents also indicated having more time
 1736 available for *Prosopis* control will enable them to more successfully control *Prosopis*.
 1737 This question was skipped by 32 respondents.



1738 **Figure 3.8.** Resources that respondents would consider to aid the management of
 1739 *Prosopis* on their properties in A) Brandvlei; B) Kenhardt; C) Upington; D) Prieska; E)
 1740 Williston.

1741 **3.4 Discussion**

1742 After the workshop series it was decided to move to using a Telegram channel as the
1743 platform to engage with interested parties on *Prosopis* research in the Northern Cape.
1744 The Telegram channel was launched the day after the conclusion of the workshop
1745 series, gaining seven subscribers in the first day and currently standing at 17
1746 subscribers. The suggestion of Telegram was relatively well received, with the hope
1747 that this results in improved communication and sharing of information. This is in part
1748 because of the cloud-based nature of Telegram, allowing new subscribers to have
1749 access to previous messages.

1750 Upon receiving several messages from individuals who were unable to attend,
1751 indicating their interest in the workshop series, a second newsletter had been compiled
1752 (Appendix H). The newsletter was designed using Canva (Name: Canva Pty Ltd,
1753 Location: Sydney, Australia Main website: canva.com). It was distributed via email to
1754 all respondents who have completed the first survey in 2021 and the registration
1755 survey for the Groblershoop workshop. It was also shared on the *Prosopis* WhatsApp-
1756 group and via WhatsApp message to the individuals who were in contact to indicate
1757 their presence at the workshop sessions. As well as on the newly established
1758 Telegram channel. The newsletter focuses more on the use of *Prosopis* biomass in a
1759 whole-farm approach as part of the integrated management of *Prosopis*. Included in
1760 the newsletter are two pages detailing the concept of Integrated Pest Management
1761 (IPM), usually applied to agricultural pest insects, but still applicable to pest species in
1762 general. The pillars that IPM is based on was also included, although in future it would
1763 be helpful to include examples of actions that could be used in an integrated manner
1764 to address *Prosopis* invasion in the Northern Cape. Three threshold values were also
1765 included and described using *Prosopis* as an example, detailing the economic
1766 threshold value (the level where the impact of invasion justifies the cost of control),
1767 economic injury level (the level where the population density will cause economic
1768 damage) and the action threshold (the level where control is needed to prevent the
1769 pest population from reaching the economic injury level).

1770 The implementation of biological control is still a concern, with the question “how are
1771 you sure that it will not impact native trees after killing all the *Prosopis*?” asked at every
1772 session. Communication efforts in this regard needs improvement. The use of biomass
1773 in construction garnered a lot of attention over the five sessions, respondents asking

1774 where they can offset the finished products or provide the company with biomass.
1775 Several conversations on this were also had during the various lunches. A carpenter
1776 from Brandvlei indicated that he already has moulds to use for owl- and bat houses,
1777 he just needs the biomass based 'cement' with which to make the products. He also
1778 already has a client base, and can use the biomass from invasive *Prosopis* on his
1779 property.

1780 Respondents were concerned with how to move forward in respect to the topics
1781 covered in the workshop sessions. After discussing the use of an invasive
1782 management plan on their properties, respondents in Kenhardt indicated that while
1783 they would be interested, they have too much experience with NRM (Natural Resource
1784 Management) issuing directives the moment they are made aware of the property
1785 owner. The director of ORLU (*Oranje Rivier Landbou Unie*) confirmed this, saying their
1786 organisation has been working for three years to get directives issued to farmers
1787 during the drought, withdrawn. The practice of issuing directives to farmers is not only
1788 damaging to trust between private landowners and the government, but also to
1789 biodiversity because of the continued invasion of *Prosopis* where landowners across
1790 the board are punished rather than supported.

1791 The offset for finished biomass products was also raised, with the speakers focusing
1792 on property owners either working independently, forming a cooperative agreement or
1793 as part of a business. The onus is on the landowner to identify a demand they want to
1794 supply and, with the needed support in terms of knowledge and qualifications, start.
1795 Parties concerned with the utilization of *Prosopis* in their successful companies and a
1796 farming enterprise that is successfully controlling *Prosopis* on their property (as well
1797 as researching uses of biomass for alternative energy and soil enrichment), have
1798 combined their knowledge to further biodiversity and environmentally friendly farming
1799 practices with carbon sequestration and sustainable biomass use. The use of a
1800 conservancy was suggested, to consolidate both control efforts and transport of
1801 removed biomass from secluded properties.

1802 Addressing IAS is a complex relationship, and the integration of both ecological and
1803 social processes with equal consideration in invasion science is trying. Integrating
1804 local socio-economic knowledge can both assist and hinder the process, but ultimately
1805 help in showing how different views can be maintained (while making use of the same

1806 information sources). Addressing barriers for the control of IAS, as well as developing
1807 outreach tools for translating scientific benchmarks into layman's terms and
1808 communicating measurable progress, are factors that are imperative in gaining and
1809 holding stakeholder attention and support. The control of *Prosopis* invasions in South
1810 Africa is impacted by different views on its costs and benefits, as well as the
1811 consideration that *Prosopis* is naturalised and part of the ecosystems they have
1812 invaded. Controlling *Prosopis* is still contentious among community stakeholders.
1813 Some projects also have a way of approaching stakeholders as victims who do not
1814 understand their own problems.

1815 The invasion of *Caulerpa taxifolia* in Croatia was addressed relatively quickly on,
1816 although insufficient follow-up planning has resulted in secondary invasions occurring
1817 along the coast. Compared with the rapid response towards the invasion of *Caulerpa*
1818 *taxifolia* in the Agua Hedionda Lagoon in California, USA, *Prosopis* invasions in South
1819 Africa can only be addressed in this manner in smaller areas, with little to no previous
1820 *Prosopis* presence and with massive initial effort. In the USA case study, barriers that
1821 would hinder successful control of *C. taxifolia* were identified swiftly and thoroughly,
1822 enabling the working group to address them accordingly, allowing for quick decision
1823 turn around. With *C. taxifolia* considered as an accidental introduction in California and
1824 the invaded area considered as recreational area, there are fewer conflicts of interest
1825 compared with IAS present in more diverse areas with a different history of
1826 introduction. Even if a CoP was not explicitly formed, private and public stakeholders
1827 were involved from inception through funding and scouting, resulting in successfully
1828 controlling the invasive alga.

1829 The presence of *Tithonia diversifolia* in Zambia is comparable to *Prosopis* in South
1830 Africa, in the sense that although both species have large impacts on agricultural
1831 holdings, pastures and rangelands, the management thereof is either too expensive,
1832 too labour intensive, or not worth the effort because of the considered costs and
1833 benefits. Both species were also introduced deliberately, with the benefits of the
1834 species experienced for a limited time after introduction. Where *T. diversifolia* has
1835 invaded in the Afar region, less than 20% of the provincial population is considered to
1836 be small-scale farmers. Of the respondents' part of the study, 70% own livestock and
1837 99% grew crops. In the study, 84% of respondents also indicated that management of
1838 *T. diversifolia* made no difference to their livelihoods. This contrasts with the control of

1839 *Prosopis* in South Africa, where the majority of the stakeholders are landowners and
1840 farmers with direct interest in controlling the species. The control of *Prosopis* is also
1841 proven to improve grazing, animal health and water provision, supporting the overall
1842 endeavour to raise awareness of the impact of *Prosopis* on farming in the Northern
1843 Cape. The costs of both *Prosopis* and *T. diversifolia* show some intersection,
1844 impacting movement, reduced grass cover, water availability, livestock health and
1845 causing the extinction of local plants.

1846 In most studies of invasion science, it is assumed that native biodiversity will follow the
1847 removal of the target species, in this case *Prosopis*. Unfortunately, in some cases the
1848 native seed bank is too depleted to fully recover the previous level of growth, resulting
1849 in dominant native weedy species. Some landowners and farmers have concerns on
1850 the increased presence of three-thorn bushes and black thorn trees. In the case of
1851 successful *Prosopis* control, contingency plans must take the presence of these and
1852 other species into account, to adequately restore native biodiversity and resume the
1853 provision of ecosystem services, improving the resilience of the area.

1854 Invasive *Prosopis* in India is threatening livestock-based economies, because of
1855 dense infestations in livestock pastures. This is the same in South Africa, although
1856 South African farmers use *Prosopis* as livestock feed whereas Indian farmers consider
1857 the pods of invasive *Prosopis* indigestible to cattle and buffalo, even resulting in
1858 livestock losses. The researchers emphasised the importance of reporting research
1859 findings to stakeholders, they used a final workshop where the majority of stakeholders
1860 were present. They also suggested to maximise the use of *Prosopis*, and eradicated
1861 and control the invasion in protected and vulnerable areas.

1862 *Prosopis* in Argentina has a rich history of use, and the utilization of *Prosopis* has been
1863 investigated in India, Kenya and Somalia. In South Africa the commercially viable
1864 utilization of *Prosopis* is hampered by the cost of removing the trees from the invaded
1865 areas, and transporting them to where they can be used to form part of either
1866 construction, furniture, or foodstuffs. The aim with the workshop series was to provide
1867 stakeholders with ideas on what they could do with 'their' *Prosopis* on their properties,
1868 reducing the need for transporting the raw biomass and localising the economic
1869 benefits of a successful product. The present spread of the *Prosopis* invasion in the
1870 Northern Cape is too large a problem to be tackled by a single entity and with a single

1871 purpose. Supporting the provision of herbicide and information, investigating the
1872 various possible uses for *Prosopis* biomass are some of the supporting factors which
1873 could aid landowners clear their property. If 40 neighbouring landowners have
1874 sufficiently cleared their properties, making use of follow-up treatments, there is a
1875 chance of not only restoring biodiversity, but also support local rural economies.

1876

CHAPTER FOUR

GENERAL DISCUSSION AND CONCLUSION

1877

1878

1879 4. Introduction

1880 The *Prosopis* invasion in South Africa and the Northern Cape poses a direct threat to
1881 biodiversity, the delivery of ecosystem services and farmers and indirect threat to
1882 consumers, and thus there is an increased interest in the integrated control of *Prosopis*
1883 and utilising its biomass. The aims of this thesis were to 1) improve the understanding
1884 of the implementation of biological control as part of an integrated management
1885 approach for *Prosopis* in the Northern Cape; 2) identify the most appropriate approach
1886 to a community of practice; and 3) assess the role and impact of a coordinator
1887 (champion) to promote an engaged community of practice.

1888 The research aims were approached in a manner that would allow for flexibility,
1889 because neither the problem of *Prosopis* invasion nor the stakeholders can be
1890 confined or defined by a single approach. To try and achieve these aims it was decided
1891 to focus on open communication to interested affected parties and stakeholders. Due
1892 to the vast distances of the Northern Cape, and differing views and interests of
1893 possible stakeholders, it was decided the primary communication channels would be
1894 a *Prosopis* WhatsApp group and email list as well as establishment of a Telegram
1895 channel rather than try and arrange to see individual stakeholders.

1896 This approach was taken to improve on previous situations where researchers only
1897 communicated with stakeholders with the purpose of completing their research, with
1898 little to no concern with the effect this may have on future research projects or
1899 livelihoods. The hosted workshops served as short-term 'microcosms' where like-
1900 minded people could have discussions guided by the topics of the workshop, as well
1901 as having easy access to experts in the field. The inclusion of 'experts in their field' to
1902 present at the workshops gave the workshops a credibility on which to improve the
1903 implementation of biological control projects, and contribute to a community of practice
1904 and a more engaged community through the actions of a coordinator as champion,
1905 which proved to be key to the success of this programme.

1906 4.1. The role of a Champion

1907 Schön (1963) defines champions as "individuals who informally emerge to promote
1908 the idea with conviction, persistence and energy, and willingly risk their position and

1909 reputation to ensure the success of the innovation” (Gallagher, 2009). According to
1910 Anderson *et al.* (2000), champions bring about widespread support for innovative
1911 products, methods and processes (Gallagher, 2009), since champions have a long-
1912 term interest in a project, and are able to bring stakeholders together to effectively
1913 work towards a common goal (Turner *et al.*, 2016; Shackleton *et al.*, 2018).

1914 Maidique (1980) also suggests that champions are personally committed to innovative
1915 ideas, and to ensure success use personal activism and informal networks (Gallagher,
1916 2009). The construct of the champion behaviour includes three facets: enthusiasm
1917 and confidence about the success of the innovation, persistence in the face of
1918 adversity and involvement of key actors (Howell, 2005; Gallagher, 2009). During this
1919 project it was initially considered that the student was the champion, and although she
1920 did take on much of the role, there were other individuals identified who had a more
1921 invested interest and the ability to motivate their local communities. These individuals
1922 were responsible for getting stakeholders to the workshops. In future, identifying a
1923 champion should come from within in the local community. These champions should
1924 then be coordinated by a person such as the student, who acts as a liaison agent
1925 between organisations and the champions.

1926 **4.2. Stakeholder engagement in invasion science**

1927 Complex and dynamic challenges require engagement with diverse and conflicting
1928 stakeholder and public priorities (Reed, 2008; Reed *et al.*, 2018). Engagement is
1929 important for understanding perceptions and practices, promoting awareness and
1930 social learning. This builds collaborative research and improves the possibility of
1931 reaching consensus and agreements as well as solving conflicts and aiding in
1932 prioritisation and planning (Stokes *et al.*, 2006; García-Llorente *et al.*, 2008; Reed,
1933 2008; Dehnen-Schmutz *et al.*, 2010; Liu *et al.*, 2010; Bryce *et al.*, 2011; Fischer *et al.*,
1934 2014; Touza *et al.*, 2014; Adriaens *et al.*, 2015; Novoa *et al.*, 2016; Gaertner *et al.*,
1935 2017; Cockburn *et al.*, 2018; Bravo-Vargas *et al.*, 2019). Widespread species,
1936 traditionally, require the greatest amount of engagement for research and
1937 management since they are the most likely to have effects on a wider cross-section of
1938 the community and the environment (Shackleton *et al.*, 2018). For instance, the
1939 *Acacia* and *Prosopis* genera have been commonly studied because they are globally
1940 two of the most widespread invasive tree taxa (Rejmánek *et al.*, 2013), providing
1941 substantial economic benefits and costs (Shackleton *et al.*, 2018).

1942 The role and importance of stakeholder engagement has received increased attention
1943 in the context of environmental decision-making, including the formulation of national
1944 and international policies (Reed, 2008; Novoa *et al.*, 2015; Sterling *et al.*, 2017;
1945 Shackleton *et al.*, 2018) as well as in academic research, with the number of
1946 publications concerned with invasion science and addressing stakeholder importance
1947 markedly increasing over the past decade (Shackleton *et al.*, 2018).

1948 The research into stakeholder engagement in invasion science is dispersed across
1949 multiple countries and island states around the world, representing different social-
1950 ecological contexts and developmental states (Shackleton *et al.*, 2018). The majority
1951 of this research has been concentrated in a few countries (primarily the USA and South
1952 Africa, also including Australia, Canada, India, Spain and the UK). These countries
1953 contribute nearly three quarters of the existing work, which coincides with global
1954 invasion hotspots (Dawson *et al.*, 2017; Shackleton *et al.*, 2018). A great number of
1955 studies undertaken in invasion science have also included multiple land-tenure types,
1956 followed by those concerned with only private rangelands and protected/conservation
1957 areas, agricultural fields and urban areas and communal lands (Shackleton *et al.*,
1958 2018).

1959 In the Northern Cape, many farms have been in family-ownership for multiple
1960 generations, within multiple properties not uncommon. Stakeholders who attended the
1961 workshops were mainly family farmers, but community farmers were also in
1962 attendance as well as NRM managers. The concern of *Prosopis* invasion is much less
1963 dependent on property size than previously considered as well as stock type and
1964 interest in conversation. One of the main concerns for all stakeholders who attended
1965 the workshops were the question of property ownership rights and expropriation (with
1966 or without compensation). Property use and size influences the stakeholder that would
1967 be in attendance, as stakeholders with bigger farms are considered to have more
1968 resources available to them. The study area needs to be taken into consideration, as
1969 in the case of the Northern Cape property sizes are generally much larger than
1970 elsewhere due to the nature of the rangelands and availability of water. This also
1971 influences the farming practice and financial position of the farmer (commercial or
1972 community), which influences their capacity for study participation.

1973 **4.3. Social learning and stakeholder engagement**

1974 Social learning has increasingly become a normative goal for environmental
1975 management and policy making (Reed *et al.*, 2010; Shackleton *et al.*, 2018). Social
1976 learning should result in changes in the knowledge and perceptions of individuals in
1977 the engagement process. Building on stakeholders' social capital, this information
1978 should then reach the broader public or other less involved stakeholders through social
1979 interaction and processes (Shackleton *et al.*, 2018). In the case of invasive species,
1980 social learning can lead to increased awareness and literacy of issues in regards to
1981 biological invasions. This is crucial in tackling such complex environmental issues
1982 (Mascia *et al.*, 2003; Lucy *et al.*, 2016; Shackleton *et al.*, 2018), especially as
1983 knowledge is often lacking where the lowest level of management normally occurs
1984 (i.e., the purchasing of native plants and removal of invasive plants in an ornamental
1985 garden) (Shackleton *et al.*, 2016; Shackleton *et al.*, 2018). The promotion of social
1986 learning can therefore promote management and beneficial decision making at the
1987 smallest scale (Shackleton *et al.*, 2018).

1988 It is important to note that the users of biological control are not the subject of the
1989 research, much as the researchers are not the causation of their research. All parties
1990 are partners in how to make the best use of biological control and implement it in the
1991 most efficient way (Ivey *et al.*, 2019). The goal is to have an equal minded partnership,
1992 which ensures the cyclic flow of information between stakeholders, researchers and
1993 implementers of biological control to maximise the benefits of using biological control
1994 methods (Ivey *et al.*, 2019). Providing feedback from the research findings is
1995 imperative, especially to both stakeholders and the larger public, as this will aid in
1996 improving social learning, local awareness and keep stakeholders interested in the
1997 topic and further developments (Shackleton *et al.*, 2018).

1998 Shackleton *et al.* (2018) found it justifiably concerning that several studies they
1999 included in their paper findings gave little to no background information on the invasive
2000 species or on the stakeholder groups they engaged. A crucial part of stakeholder
2001 engagement, which is often glossed over, is to report-back findings to the participating
2002 stakeholders and to promote social learning amongst them (Shackleton *et al.*, 2018).
2003 The lack of reporting is primarily because of the fact that most studies are concerned
2004 with conducting one-way consultations extracting information from participants without
2005 providing learning or feedback (Shackleton *et al.*, 2018). Manetti (2011) emphasised

2006 that the majority of stakeholder engagement studies were undertaken as a way to
2007 learn from and control stakeholders rather than to improve collaboration. In some
2008 biodiversity conservation literature, it appears that stakeholder engagement was
2009 included as an afterthought, instead of being an integral part of the project from onset
2010 (Shackleton *et al.*, 2018).

2011 Insights into the human aspects of IAS are essential for effective decision making as,
2012 in many cases, there are complex social issues at play which delineate the full suite
2013 of benefits and costs associated with invasions (García-Llorente *et al.*, 2008;
2014 Shackleton *et al.*, 2015). It is particularly important for researchers and stakeholders
2015 to evaluate their knowledge, perceptions, practices, awareness and wants and needs
2016 in regards to biological invasions to accurately address the complex conflicts of
2017 interest that might arise from managing invasive species, such as *Prosopis*, which
2018 were introduced for specific reasons and still provide valuable services to some
2019 community members (Shackleton *et al.*, 2007; Low, 2012; Dickie *et al.*, 2014; Van
2020 Wilgen *et al.*, 2014; Shackleton *et al.*, 2015).

2021 Implementing a national strategy for control of the present *Prosopis* invasion in South
2022 Africa is hampered by the fact that vested parties do not have a concrete grasp on the
2023 social dimensions of the problem (Shackleton *et al.*, 2015). Recurrently, management
2024 strategies have been implemented without proper consultation with stakeholders and
2025 those directly influenced by the implemented strategies, especially regarding their
2026 perceptions and needs (Shackleton *et al.*, 2015). Regarding *Prosopis* in South Africa,
2027 improved knowledge of the human dimension could most certainly contribute in
2028 highlighting benefits versus costs, exploring new opportunities for effective
2029 management and justifying contentious interventions (Shackleton *et al.*, 2015). The
2030 social situation in the Northern Cape needs to be taken into account when conducting
2031 research in the province, irrespective of the financial capacity of the stakeholders
2032 being engaged with. Property size, for instance, is not indicative of wealth, neither is
2033 degrees an indicator of intellect. For a researcher to assume they understand the plight
2034 of each individual stakeholder from inception is detrimental to the project, especially
2035 due to the general differences in living experience between the farmers and other
2036 stakeholders and researchers (who normally come from large cities).

2037 **4.4. Public perception of invasion**

2038 Many IAS have been introduced to South Africa as ornamentals or beneficial plants
2039 (for example forestry). This has resulted in the perception that not only are IAS a
2040 problem for another day and another person, but that distribution of these plants for a
2041 nicer garden is acceptable. In the case of *Prosopis*, many farmers consider the use of
2042 *Prosopis* biomass as a fodder during the drought as one of the reasons that they were
2043 able to continue farming. The spread of *Prosopis* seed through livestock is also
2044 considered something that does not directly or presently affect them, so it is
2045 acceptable. The effects of *Prosopis* on farms are not conceptualised in some cases,
2046 because of the perception that 'at least there is something'. Not realising that the
2047 presence of the invasive species is the cause of the disruption, and with removal
2048 comes increased biodiversity, improved soil health and resilience of both the grazing
2049 and the farming enterprise (Ndhlovu *et al.*, 2011).

2050 In many countries, including South Africa, landowners may be aware of the impacts of
2051 weeds, but grossly underestimate their impacts on yield and rangeland productivity
2052 (Day *et al.*, 2012; Shackleton *et al.*, 2017; Witt, Beale and Van Wilgen, 2018; Day *et*
2053 *al.*, 2019). This was not the case during this study. The perceived conflict between
2054 managing *Prosopis* and the benefits derived from the plant was not present during the
2055 process of stakeholder engagement. Most farmers are more than aware that, with the
2056 removal of *Prosopis*, their rangeland and carrying capacity (and therefore livestock
2057 quality) would improve. Weed management is often given a lower priority, because of
2058 other concerns such as the availability of clean water and health (Labrada, 1996),
2059 despite the presence of weeds and bush encroachment also impacting on these
2060 issues (Day *et al.*, 2019). Unfortunately, in the daily workings of farming enterprises
2061 and other agricultural businesses, weed management is not the deciding factor for
2062 success, compared with animal handling and sales, or harvesting the seasons crops
2063 before the weather becomes unfavourable. It is therefore usually relegated to a lower
2064 priority and consistently doing so in favour of other priority needs will eventually lead
2065 to a problem the landowner can no longer address.

2066 Another concern limiting weed biological control is the fact that some weeds are also
2067 considered to be beneficial. For instance, one of the reasons that biological control of
2068 *Mikania micrantha* Kunth (Asteraceae) was not implemented in some countries in the
2069 Pacific, was because the plant is used to treat cuts (Day *et al.*, 2012, 2016, 2019).

2070 Some farmers also used *M. micrantha* as a cover crop, thus biological control was not
2071 implemented, despite the occurrences of *M. micrantha* smothering crop such as
2072 bananas, papaya, and cocoa (significantly reducing yields) (Day *et al.*, 2012, 2016,
2073 2019). *Prosopis* has been used as fodder for livestock since its introduction
2074 (Zimmermann, 1991), with some farmers crediting the performance of their livestock
2075 to the use of *Prosopis* biomass (contributing to the general conflict of interest when
2076 considering the control of this species). While this perception is still present, it is much
2077 less a conflict of interest and the overall consideration is that *Prosopis* is a problem
2078 species impeding farming activities and overall biodiversity on farms.

2079 When managing invasive species, trampling by labourers or disturbance caused by
2080 the movement and operation of heavy machinery can also result in unforeseen non-
2081 target impacts. Many invasive plant species are favoured by soil disturbance (Davis *et*
2082 *al.*, 2000; Van Driesche *et al.*, 2016), and it is possible that mechanical removal of one
2083 invader facilitates their replacement by another invasive species (Van Driesche *et al.*,
2084 2016). Follow-up treatments and monitoring are important to adequately address
2085 regrowth as well as secondary invasions and native bush encroachment in vulnerable
2086 areas. Managing ecosystem services and processes, particularly maintaining them as
2087 close as possible to natural processes could possibly inhibit new invasions while
2088 assisting in the management of invasions present in the area/landscape (Van Driesche
2089 *et al.*, 2016). Louda (2000) argues that good pasture management and prevention of
2090 overgrazing can limit weed invasion (Van Driesche *et al.*, 2016).

2091 **4.5. Public perception of biological control**

2092 There are still perceptions that weed biological control is risky, with either the
2093 development of new strains or mutations, resulting in the biological control agents
2094 feeding on other plants such as crops (Day *et al.*, 2019). There is also a perception
2095 that the weed could be controlled by using native organisms in the country where the
2096 weed is a problem in. Other factors that influence biological control efforts include lack
2097 of capacity and resources, poor awareness of the impacts of invasive plants (such as
2098 weeds and other invasive plants in agricultural fields and irrigation areas), and
2099 absence of regulations and processes to support research and implementation (Day
2100 *et al.*, 2019).

2101 Stakeholders and the public are often poorly informed about biological control, with
2102 some even dismissing it as both an unfeasible and undesirable method of invasive
2103 species management (Barratt *et al.*, 2018). In conservation areas, biological control
2104 has historically not been adequately integrated into management practice, although
2105 increasingly successful projects have been undertaken (Van Driesche *et al.*, 2017;
2106 Barratt *et al.*, 2018). Negative public views are usually supported by historic examples
2107 that have had negative impacts, such as generalist vertebrates that have been used
2108 for biological control (Barratt *et al.*, 2018). These examples of 'failed' biological control
2109 implementation are often widely and repeatedly publicised, eroding public support for
2110 biocontrol. This, despite the relatively large number of successes with which they can
2111 be countered (Barratt *et al.*, 2018). The possible non-target impacts of classical
2112 biological control are increasingly researched, because established biological control
2113 agents cannot be removed and may spread autonomously, are increasingly
2114 researched (Van Driesche *et al.*, 2016).

2115 Common concerns expressed include that weed biological agents may attack other
2116 species once the weed is controlled, biological control agents could mutate and start
2117 attacking other plant species (Day *et al.*, 2019). Both concerns were raised at every
2118 workshop session, and at every consequent discussion on the use of biological control
2119 agents for *Prosopis* invasions. These concerns are often based on the assumption
2120 that the biological control agent will eradicate the weed, where after the agent may
2121 then attack other plant species (Day *et al.*, 2019). This reflects a lack of knowledge on
2122 the principles of weed biological control involving the use of co-evolved organisms
2123 collected from the target weed in its native range (Day *et al.*, 2019). Biological control
2124 agents do not have the ability to eradicate the target species, but reduces its
2125 populations to levels where the weed is no longer considered to be a problem (hence
2126 the inclusion of IPM principles in the second newsletter) (Day *et al.*, 2019). Thus, the
2127 decision to attempt to eradicate a pest population is not compatible with a decision to
2128 implement the use of biological control (Van Driesche *et al.*, 2016).

2129 The cultivation of public trust and support by biological control researchers is critically
2130 important, especially for continued funding and policy support (Van Lenteren, 2004;
2131 Warner *et al.*, 2008). With the acknowledgement that no pest-management strategy is
2132 risk free, biological control is often considered as the most cost-effective approach
2133 (Delfosse, 2004, 2005; Van Lenteren, 2004; Warner *et al.*, 2008). To improve the

2134 understanding and implementation of biological control as part of an integrated
2135 approach for *Prosopis* in the Northern Cape, it must first be understood that an
2136 integrated approach is different for every stakeholder, but that dependence on a single
2137 control method is not economically or environmentally sustainable. Through the first
2138 survey and subsequent workshops, information on the released biocontrol agents
2139 have been more attainable, although the perception of non-target effects has not been
2140 adequately shifted. Continuing with endeavours such as these, and others, over time
2141 will address the concerns about biological control agents having a negative impact on
2142 native plants. Another common perception is that, with the use of biological control
2143 agents, the responsibility of *Prosopis* control is shifted away from landowners.

2144 While non-target impacts are a valid concern, and need to remain as such, since the
2145 1980's many biological control scientists and groups affected by invasive species have
2146 become relatively aware of avoiding non-target impacts (Pemperton, 2000; Simberloff,
2147 2012; Van Driesche *et al.*, 2016). The knowledge on how to do so has been greatly
2148 expanded by research and implementing the necessary changes to promote overall
2149 safety of biological control science (Van Driesche *et al.*, 2016). With the increase of
2150 additional high-impact invasive plants in the future relatively likely, the need for
2151 biological control programmes will be sustained. To make such programmes safer,
2152 they should be integrated into restoration ecology and conservation biology. This could
2153 ensure that projects have a good perspective on the biodiversity of the communities
2154 affected by the invasive species (Van Driesche *et al.*, 2016).

2155 **4.6. Critique of science communication**

2156 Public misconception of scientific literature, especially concerning biological control,
2157 genetically modified organisms *et. cetera*, is not always best addressed with more
2158 information (Rampton *et al.*, 2002; Warner *et al.*, 2008). Science communication is
2159 often limited to peer-reviewed scientific journals, or the research is communicated in
2160 very selective popular journals. This results in landowners, community members and
2161 the broader public being less informed on matters such as invasion science,
2162 agricultural practices and other subjects that influence them as consumers.
2163 Stakeholder may feel side-lined, because of the research not being accessible and the
2164 project progress not communicated to them appropriately. Overall, this creates a
2165 research community that is distanced from the 'real-world' and a population who
2166 mistrusts scientific fact and reason.

2167 Communication and information provided by scientists should be easily
2168 comprehended and in plain language, adapted to the needs of stakeholders and take
2169 into consideration regional differences (Barratt *et al.*, 2018). This is particularly
2170 important for the establishment of a rapport in developing countries, where language,
2171 long-standing traditions, and the need for quick returns for issues are hard to
2172 overcome (Barratt *et al.*, 2018). The introduction of a more participatory approach
2173 where researchers and consultants can assist groups of farmers and land-owners to
2174 attend training sessions, has been successfully implemented by FAO, CABI and other
2175 overseas aid agencies (Barratt *et al.*, 2018). The financial and other benefits of
2176 biological control and IPM programmes need to be demonstrated clearly (Barratt *et*
2177 *al.*, 2018).

2178 **4.7. The Role of Workshops**

2179 Members of the public who have experience with the implementation of biological
2180 control, having benefited from coordinated initiatives for weed management, are much
2181 more likely to provide support (political or financial). Once benefitted, a landowner is
2182 more likely to act in support of biological control than any number of consumers who
2183 express a favourable opinion on a mass survey (Warner *et al.*, 2008). To change or
2184 adopt management practices and benefit from biological control, farmers and land-
2185 managers need to be able to understand what they are being advised to do and why,
2186 as well as the inclusion of a long-term financial benefit (Barratt *et al.*, 2018).

2187 Although it was not explicit during the survey analysis, the concern of expropriation
2188 without compensation leaves some landowners unwilling to do improvements on their
2189 farm, including infrastructure control of invasive- and bush encroachment. This was
2190 confirmed at the Kenhardt workshop. The defence they offer is 'if the government
2191 wants my property, they'll have to take it as it is'. The difficulty of the matter is that,
2192 because of invasion legislation according to NEM: BA, not controlling the invasion of
2193 *Prosopis* on owned properties increases the possibility of expropriation. This is
2194 especially frustrating as indicated by many respondents raising the concern that the
2195 government does not control *Prosopis* on state-owned properties, with little to no
2196 repercussions.

2197 Regarding post-workshop actions, both newsletters were received quite well, and
2198 served as comprehensive reference documents for both respondents and

2199 researchers. In future, it is suggested to include summaries of the relevant
2200 organisations as well as pertinent researchers and their work, while also providing
2201 updates on progress of projects previously highlighted in the newsletters. Attendance
2202 at the workshops were also much better than expected, and most of the respondents
2203 were satisfied with both the presenters and the topics discussed. While the MSc
2204 student was the driver and compiler of the two newsletters, in future it would be a
2205 valuable addition to include some of the work farmers have done (and are continuing)
2206 to address invasion of non-indigenous species on rangelands, as well as highlighting
2207 institutional research and interest.

2208 **4.8. Future work**

2209 It is suggested that any future work regarding *Prosopis* in the Northern Cape needs to
2210 take into account the large dependency on medium-scale agricultural enterprises, and
2211 the impact agricultural challenges has on the greater functioning of the Northern Cape
2212 community. This is especially true for projects that require investment in either time or
2213 financially. Agricultural challenges, such as droughts, livestock movement and selling
2214 bans (were the trade in live animals and animal products are restricted because of
2215 health or quality concerns) as well as the recognition of property ownership rights
2216 influence the livelihoods of a great number of landowners in the province, for a number
2217 of years, not just the time of crisis. For researchers there may be a distinction between
2218 their legacy, work, livelihood and family, for farmers and landowners there are no
2219 distinctions. This influences public interest and the implementation of projects.

2220 The cooperation of researchers in the agricultural field, including animal nutritionists
2221 and pasture experts, may allow for a more transdisciplinary approach towards invasive
2222 management in South Africa, *Prosopis*- and bush encroachment management in the
2223 Northern Cape. Attending to the gaps in knowledge that resulted in environmental
2224 conditions that have contributed to the increased presence of IAS, such as
2225 overgrazing, livestock choices and pressure on native wildlife, may enable landowners
2226 and farmers to make more informed choices in the future. This reduces the prevalence
2227 of either native bush encroachment or secondary invasions, resulting in a more
2228 sustainable farming practice for future generations.

2229 **4.9. Conclusion**

2230 The public's lack of trust in both academic institutions and governmental departments
2231 needs to be addressed in a sustainable manner, with collaboration from respected
2232 companies and institutions. One of the aims of the newsletters was to introduce
2233 stakeholders to the various companies and institutions with a vested interest in the
2234 management of *Prosopis*. The use of credible institutions and knowledgeable
2235 speakers also improves the image of the CoP, making it more desirable for interested
2236 parties to form part of the initiative. The aim of this should not be about convincing nor
2237 educating the public, but improving public perceptions on projects through increased
2238 transparency, risk-management efforts and peer review, as well as emphasising public
2239 good features, through increased farm productivity and improved animal health. This
2240 supports the project aim of identifying the most appropriate approach to a CoP, as well
2241 as assessing the role and impact of a coordinator/champion to promote an engaged
2242 community of practice.

2243 Through the interventions of the researcher as a champion of the CoP, we were able
2244 to begin the process of building trust between academic institutions and stakeholders,
2245 including both commercial- and subsistence farmers. However, this is only the first
2246 step towards community understanding and acceptance of management plans, as well
2247 as the inclusion of biological control as part of an integrated approach to the
2248 management of *Prosopis* in the Northern Cape. There is a danger that if this initial
2249 CoP does not continue then mistrust would return. Biological control researchers are
2250 continuing to work on this target weed and must continue to participate in the CoP,
2251 with the goal of sustained transparency and trust. With increased transparency and
2252 trust comes increased awareness and willingness to evaluate the merits of biological
2253 control for *Prosopis* management. Thus, addressing stakeholder perceptions as one
2254 of the barriers to the successful implementation and monitoring of biological control,
2255 stated as the third aim of this project, is supported by continued communication on the
2256 project progress by the local champion, possibly driving interested parties to want to
2257 form part of the established community of practice.

2258 *Prosopis* as an invasive weed is a species of conflict, and will likely remain as such.
2259 Endeavouring to eradicate the species is neither sustainable nor plausible, and the
2260 cost of managing the species is likely to continue increasing. Establishing a CoP with
2261 the aid of a local champion to both coordinate the flow of information and initiatives

2262 (such as the initial release of biological control agents) sustains the interest in
2263 integrated *Prosopis* management, as well as fostering trust and cooperation between
2264 diverse stakeholders and interdisciplinary researchers. A local champion not only
2265 provides the project with a recognisable figurehead, but also increases stakeholders'
2266 will and ability to communicate concerns and ideas. These concerns and ideas can be
2267 addressed in a constructive manner, without alienating stakeholders, funders or
2268 governmental officials. The champion also ensures communication from the project
2269 and researchers reaches the stakeholders and broader community. Continuing with
2270 projects such as this will not only improve the implementation of biological control
2271 science, but also improve agricultural practices and food security. Addressing
2272 *Prosopis* in the Northern Cape is an action in support of future generations, in
2273 accordance with stewardship and practices that support biodiversity in natural
2274 rangelands.

2275

2276

REFERENCES

2277 **References**

- 2278 Abdulahi, M.M., Ute, J.A. and Regasa, T. (2017) 'Prosopis juliflora L: distribution, impacts
2279 and available control methods in Ethiopia', *Tropical and Subtropical Agroecosystems*, 20(1),
2280 pp. 75–89.
- 2281 Admasu, D. (2008) 'Invasive plants and food security: the case of *Prosopis juliflora* in the
2282 Afar region of Ethiopia', *FARM-Africa*, IUCN, pp. 1–13.
- 2283 Adriaens, T. *et al.* (2015) 'Trying to engage the crowd in recording invasive alien species in
2284 Europe: experiences from two smartphone applications in northwest Europe', *Management
2285 of Biological Invasions*, 6(2), p. 215.
- 2286 Ali, A. and Labrada, R. (2006) 'Problems posed by *Prosopis*', in *Problems posed by the
2287 introduction of Prosopis spp. in selected countries*. Rome, Italy: FAO.
- 2288 Alston, G. (1914) 'The screw-bean: a useful shrub', *Agricultural Journal of the Union of
2289 South Africa* [Preprint].
- 2290 Alston, J.M. and Pardey, P.G. (2014) 'Agriculture in the global economy', *Journal of
2291 Economic Perspectives*, 28(1), pp. 121–146.
- 2292 Anagae, A. *et al.* (2004) *Policy and stakeholder analysis for invasive plants management in
2293 Ethiopia: Report submitted to CAB International under the PDF-B Phase of the UNEP/GEF-
2294 Funded Project: Removing Barriers to Invasive plants Management in Africa, Ethiopia*. Addis
2295 Ababa, Ethiopia: Ethiopian Agricultural Research Organization (EARO).
- 2296 Anderson, L.M. and Bateman, T.S. (2000) 'Individual environmental initiative: Championing
2297 natural environmental issues in US business organizations', *Academy of Management
2298 journal*, 43(4), pp. 548–570.
- 2299 Anderson, L.W.J. (2005) 'California's reaction to *Caulerpa taxifolia*: a model for invasive
2300 species rapid response', *Biological Invasions*, pp. 1003–1016.
- 2301 Angassa, A. and Oba, G. (2008) 'Herder perceptions on impacts of range enclosures, crop
2302 farming, fire ban and bush encroachment on the rangelands of Borana, southern Ethiopia',
2303 *Human Ecology*, 36(2), pp. 201–215.
- 2304 Angelstam, P. *et al.* (2013) 'Solving problems in social–ecological systems: Definition,
2305 practice and barriers of transdisciplinary research', *Ambio*, 42(2), pp. 254–265.
- 2306 Aplin, P. (2005) 'Remote sensing: ecology', *Progress in Physical Geography*, 29(1), pp. 104–
2307 113.
- 2308 Babiker, A.G.T. (2006) 'Mesquite (*Prosopis* spp) in Sudan: history, distribution and control',
2309 *Problems posed by the introduction of Prosopis spp. in selected countries*, pp. 11–20.
- 2310 Barratt, B.I.P. *et al.* (2018) 'The status of biological control and recommendations for
2311 improving uptake for the future', *BioControl*, 63(1), pp. 155–167. Available at:
2312 <https://doi.org/10.1007/s10526-017-9831-y>.
- 2313 Berkes, F., Colding, J. and Folke, C. (2000) 'Rediscovery of traditional ecological knowledge
2314 as adaptive management.', *Ecological Applications*, 10(5), pp. 1251–1262. Available at:
2315 <https://doi.org/10.2307/2641280>.

- 2316 Berkes, F. and Folke, C. (1998) *Linking social and ecological systems: management*
 2317 *practices and social mechanisms for building resilience*. Cambridge, UK: Cambridge
 2318 University Press.
- 2319 Bieling, C. and Plieninger, T. (2017) *The science and practice of landscape stewardship*.
 2320 Cambridge University Press.
- 2321 Binder, C.R. *et al.* (2013) 'Comparison of frameworks for analyzing social-ecological
 2322 systems', *Ecology and Society*, 18(4), p. art26. Available at: [https://doi.org/10.5751/ES-](https://doi.org/10.5751/ES-05551-180426)
 2323 05551-180426.
- 2324 Blanchard, R. and Holmes, P.M. (2008) 'Riparian vegetation recovery after invasive alien
 2325 tree clearance in the Fynbos Biome', *South African Journal of Botany*, 74(3), pp. 421–431.
 2326 Available at: <https://doi.org/10.1016/J.SAJB.2008.01.178>.
- 2327 Bravo-Vargas, V. *et al.* (2019) 'Do people care about pine invasions? Visitor perceptions and
 2328 willingness to pay for pine control in a protected area', *Journal of Environmental*
 2329 *Management*, 229, pp. 57–66.
- 2330 Bromilow, C. (2010) *Problem plants and alien weeds of South Africa*. Pretoria: Briza
 2331 Publications.
- 2332 Brown, J.H. and Sax, D.F. (2004) 'An essay on some topics concerning invasive species',
 2333 *Austral ecology*, 29(5), pp. 530–536.
- 2334 Bryce, R. *et al.* (2011) 'Turning back the tide of American mink invasion at an unprecedented
 2335 scale through community participation and adaptive management', *Biological conservation*,
 2336 144(1), pp. 575–583.
- 2337 Burkart, A.E. (1976) 'A monograph of the genus *Prosopis* (Leguminosae Subfam.
 2338 Mimosoideae)', *Journal of the Arnold Arboretum*, 57(3), pp. 219–249. Available at:
 2339 <https://doi.org/10.5962/p.185864>.
- 2340 Byers, J.E. *et al.* (2002) 'Directing research to reduce the impacts of nonindigenous species',
 2341 *Conservation Biology*, 16(3), pp. 630–640.
- 2342 Cadman, M. *et al.* (2010) 'Biodiversity for development: South Africa's landscape approach
 2343 to conserving biodiversity and promoting ecosystem resilience.'
- 2344 Catalano, S.A. *et al.* (2008) 'Molecular phylogeny and diversification history of *Prosopis*
 2345 (Fabaceae: Mimosoideae)', *Biological Journal of the Linnean Society*, 93(3), pp. 621–640.
- 2346 Chapin, F. Stuart *et al.* (2009) 'Resilience-based stewardship: strategies for navigating
 2347 sustainable pathways in a changing world', in F. S Chapin, G. P Kofinas, and C Folke (eds)
 2348 *Principles of Ecosystem Stewardship: Resilience-based natural resource management in a*
 2349 *changing world*. New York, NY: Springer New York, pp. 319–337. Available at:
 2350 https://doi.org/10.1007/978-0-387-73033-2_15.
- 2351 Chapin, F.S. *et al.* (2010) 'Ecosystem stewardship: sustainability strategies for a rapidly
 2352 changing planet', *Trends in Ecology & Evolution*, 25(4), pp. 241–249. Available at:
 2353 <https://doi.org/10.1016/j.tree.2009.10.008>.
- 2354 Choge, S.K. and Ngujiri, F.D. (2006) 'The Status and impact of *Prosopis* spp in Kenya',
 2355 *Problems Posed by the Introduction of*, pp. 29–35.

- 2356 Clewley, G.D. *et al.* (2012) 'The effectiveness of classical biological control of invasive
2357 plants', *Journal of Applied Ecology*, 49, pp. 1287–1295. Available at:
2358 <https://doi.org/10.1111/j.1365-2664.2012.02209.x>.
- 2359 Cockburn, J. *et al.* (2018) 'Towards place-based research to support social–ecological
2360 stewardship', *Sustainability*, 10(5), p. 1434.
- 2361 Cockburn, J.J. (2018) *Stewardship and collaboration in multifunctional landscapes: a
2362 transdisciplinary enquiry*. Rhodes University.
- 2363 Coetzer, W. and Hoffmann, J.H. (1997) 'Establishment of *Neltumius arizonensis*
2364 (Coleoptera: Bruchidae) on mesquite (prosopis species: Mimosaceae) in South Africa',
2365 *Biological Control*, 10(3), pp. 187–192.
- 2366 Davis, M.A., Grime, J.P. and Thompson, K. (2000) 'Fluctuating resources in plant
2367 communities: a general theory of invasibility', *Journal of Ecology*, 88, pp. 528–534.
- 2368 Dawson, W. *et al.* (2017) 'Global hotspots and correlates of alien species richness across
2369 taxonomic groups', *Nature Ecology & Evolution*, 1(7), pp. 1–7.
- 2370 Day, M.D. *et al.* (2012) '*Mikania micrantha* Kunth (Asteraceae) (mile-a-minute): Its
2371 distribution and physical and socio economic impacts in Papua New Guinea', *Pacific
2372 Science*, 66, pp. 213–223.
- 2373 Day, M.D. and Winston, R.L. (2016) 'Biological control of weeds in the 22 Pacific islands and
2374 territories: current status and future prospects', *Neobiota*, 30, pp. 167–192.
- 2375 Day, M.D. and Witt, A.B.R. (2019) 'Weed biological control: challenges and opportunities',
2376 *Journal of Asian-Pacific Weed Science Society*, 1(2), pp. 34–44.
- 2377 De Groot, R.S., Wilson, M.A. and Boumans, R.M.J. (2002) 'A typology for the classification,
2378 description and valuation of ecosystem functions, goods and services', *Ecological
2379 Economics*, 41(3), pp. 393–408. Available at: [https://doi.org/10.1016/S0921-8009\(02\)00089-
2380 7](https://doi.org/10.1016/S0921-8009(02)00089-7).
- 2381 DEA (2014) 'National environmental management: Biodiversity act 2004 (Act no. 10 of
2382 2004): Alien and invasive species lists, 2014', *Department of Environmental Affairs
2383 [Preprint]*.
- 2384 Dean, W.R.J. *et al.* (2002) 'Avian assemblages in native *Acacia* and alien *Prosopis* drainage
2385 line woodland in the Kalahari, South Africa', *Journal of Arid Environments*, 51(1), pp. 1–19.
- 2386 Dehnen-Schmutz, K., Chas-Amil, M.L. and Touza, J. (2010) 'Stakeholders' perceptions of
2387 plant invasions in Galicia, Spain', *Aspects of Applied Biology*, 104, pp. 13–18.
- 2388 Delfosse, E.S. (2004) 'Introduction', in E.M. Coombs *et al.* (eds) *Biological Control of
2389 Invasive Plants in the United States*. Corvallis, USA: Oregon State University Press, pp. 1–
2390 11.
- 2391 Delfosse, E.S. (2005) 'Risk and ethics in biological control', *Biological Control*, 35, pp. 319–
2392 329.
- 2393 Denier, L. *et al.* (2015) *The little sustainable landscapes book*. Oxford, UK: Global Canopy
2394 Programme.

- 2395 Denney, J.M. *et al.* (2018) 'Power in participatory processes: Reflections from multi-
2396 stakeholder workshops in the Horn of Africa', *Sustainability Science*, 13(3), pp. 879–893.
- 2397 Denslow, J.S. (2007) 'Managing dominance of invasive plants in wildlands', *Current Science*,
2398 pp. 1579–1586.
- 2399 Dickie, I. *et al.* (2014) 'Conflicting values: Ecosystem services and invasive tree
2400 management', *Biological Invasions*, 16. Available at: [https://doi.org/10.1007/s10530-013-](https://doi.org/10.1007/s10530-013-0609-6)
2401 0609-6.
- 2402 Direba Balcha, L. (2022) '*Prosopis juliflora* distribution, impacts, and control methods
2403 available in Ethiopia', *International Journal of Natural Resource Ecology and Management*
2404 [Preprint]. Available at: <https://doi.org/10.11648/j.ijnrem.20220703.12>.
- 2405 Doody, T.M. *et al.* (2011) 'Potential for water salvage by removal of non-native woody
2406 vegetation from dryland river systems', *Hydrological Processes*, 25(26), pp. 4117–4131.
2407 Available at: <https://doi.org/10.1002/hyp.8395>.
- 2408 Dzikiti, S. *et al.* (2013) 'Water relations and the effects of clearing invasive *Prosopis* trees on
2409 groundwater in an arid environment in the Northern Cape, South Africa', *Journal of Arid*
2410 *Environments*, 90, pp. 103–113.
- 2411 Dzikiti, S. *et al.* (2016) 'Quantifying potential water savings from clearing invasive alien
2412 *Eucalyptus camaldulensis* using in situ and high resolution remote sensing data in the Berg
2413 River Catchment, Western Cape, South Africa', *Forest Ecology and Management*, 361, pp.
2414 69–80.
- 2415 Dzikiti, S. *et al.* (2017) 'Assessing water use by *Prosopis* invasions and *Vachellia karroo*
2416 trees: Implications for groundwater recovery following alien plant removal in an arid
2417 catchment in South Africa', *Forest Ecology and Management*, 398, pp. 153–163.
- 2418 Easterly, W. (2006) *The white man's burden: why the West's efforts to aid the rest have*
2419 *done so much ill and so little good*. New York, USA: Penguin Press.
- 2420 Elfadl, M.A. and Luukkanen, O. (2006) 'Field studies on the ecological strategies of *Prosopis*
2421 *juliflora* in a dryland ecosystem: 1. A leaf gas exchange approach', *Journal of Arid*
2422 *Environments*, 66(1), pp. 1–15.
- 2423 Evans, J.M., Wilkie, A.C. and Burkhardt, J. (2008) 'Adaptive management of nonnative
2424 species: moving beyond the "either-or" through experimental pluralism', *Journal of*
2425 *Agricultural and Environmental Ethics*, 21(6), pp. 521–539. Available at:
2426 <https://doi.org/10.1007/s10806-008-9118-5>.
- 2427 Felker, P. (2019) 'Mesquite: an all-purpose leguminous arid land tree', in *New agricultural*
2428 *crops*. CRC Press, pp. 89–132.
- 2429 Fischer, A. *et al.* (2014) 'The public and professionals reason similarly about the
2430 management of non-native invasive species: a quantitative investigation of the relationship
2431 between beliefs and attitudes', *PloS one*, 9(8), p. e105495.
- 2432 Folke, C. *et al.* (2005) 'Adaptive governance of social-ecological systems', *Annual Review of*
2433 *Environment and Resources*, 30(1), pp. 441–473. Available at:
2434 <https://doi.org/10.1146/annurev.energy.30.050504.144511>.

- 2435 Folke, C. *et al.* (2016) 'Social-ecological resilience and biosphere-based sustainability
2436 science', *Ecology and Society*, 21(3), p. art41. Available at: [https://doi.org/10.5751/ES-](https://doi.org/10.5751/ES-08748-210341)
2437 08748-210341.
- 2438 Forsyth, G.G. *et al.* (2012) 'The prioritisation of invasive alien plant control projects using a
2439 multi-criteria decision model informed by stakeholder input and spatial data', *Journal of*
2440 *Environmental Management*, 103, pp. 51–57.
- 2441 Fourie, F. *et al.* (2007) *The effect of vegetation (Prosopis sp.) on groundwater levels in*
2442 *Rugseer River, Kenhardt, South Africa, Groundwater and Ecosystems, XXXV IAH Congress.*
2443 *Poster paper presented at Groundwater and Ecosystems, XXXV IAH Congress.* Department
2444 of Water Affairs, South Africa, pp. 17–21.
- 2445 Frost, P. *et al.* (2006) 'Landscape-scale approaches for integrated natural resource
2446 management in tropical forest landscapes', *Ecology & Society*, 11.
- 2447 Gaertner, M. *et al.* (2017) 'Managing invasive species in cities: a decision support framework
2448 applied to Cape Town', *Biological Invasions*, 19(12), pp. 3707–3723.
- 2449 Gallagher, D.R. (2009) 'Advocates for environmental justice: the role of the champion in
2450 public participation implementation', <http://dx.doi.org/10.1080/13549830903244417>, 14(10),
2451 pp. 905–916. Available at: <https://doi.org/10.1080/13549830903244417>.
- 2452 García-Llorente, M. *et al.* (2008) 'Social perceptions of the impacts and benefits of invasive
2453 alien species: implications for management', *Biological Conservation*, 141(12), pp. 2969–
2454 2983.
- 2455 Geesing, D., Al-Khawlani, A. and Abba, M.L. (2004) 'Management of introduced *Prosopis*
2456 species: can economic exploitation control an invasive species?', *Unasylva*, 55(217), pp.
2457 289–299.
- 2458 Glicken, J. (2000) 'Getting stakeholder participation "right": a discussion of participatory
2459 processes and possible pitfalls', *Environmental Science & Policy*, 3(6), pp. 305–310.
- 2460 Goldman, R.L., Thompson, B.H. and Daily, G.C. (2007) 'Institutional incentives for managing
2461 the landscape: Inducing cooperation for the production of ecosystem services', *Ecological*
2462 *Economics*, 64(2), pp. 333–343. Available at:
2463 <https://doi.org/10.1016/J.ECOLECON.2007.01.012>.
- 2464 Gordon, L.J., Finlayson, C.M. and Falkenmark, M. (2010) 'Managing water in agriculture for
2465 food production and other ecosystem services', *Agricultural Water Management*, 97(4), pp.
2466 512–519. Available at: <https://doi.org/10.1016/J.AGWAT.2009.03.017>.
- 2467 Hara, K. *et al.* (2016) 'Participatory approach in vision setting: emerging initiatives in local
2468 municipalities in Japan', *Sustainability Science* [Preprint].
- 2469 Harding, G.B. (1987) 'Status of *Prosopis* as a weed', *Applied Plant Science*, 1(1), pp. 43–48.
- 2470 Haregeweyn, N. *et al.* (2013) 'Analysis of the invasion rate, impacts and control measures of
2471 *Prosopis juliflora*: a case study of Amibara District, Eastern Ethiopia', *Environmental*
2472 *Monitoring and Assessments*, pp. 7527–7542.
- 2473 Hellmann, J.J. *et al.* (2008) 'Five potential consequences of climate change for invasive
2474 species', *Conservation Biology*, 22(3), pp. 534–543.

- 2475 Henderson, L. (2007) 'Invasive, naturalized and casual alien plants in southern Africa: a
2476 summary based on the Southern African Plant Invaders Atlas (SAPIA)', *Bothalia*, 37(2), pp.
2477 215–248. Available at: <https://doi.org/10.4102/abc.v37i2.322>.
- 2478 Heras, M. and Tàbara, J.D. (2014) 'Let's play transformations! Performative methods for
2479 sustainability', *Sustainability Science*, 9(3), pp. 379–398. Available at:
2480 <https://doi.org/10.1007/s11625-014-0245-9>.
- 2481 Hoffman, T.M. and Todd, S. (2000) 'A national review of land degradation in South Africa:
2482 The influence of biophysical and socio-economic factors', *Journal of Southern African
2483 Studies*, 26(4), pp. 743–758. Available at: <https://doi.org/10.1080/713683611>.
- 2484 Hoffmann, J.H., Impson, F.A.C. and Moran, V.C. (1993) 'Competitive interactions between
2485 two bruchid species (*Algarobius* spp) introduced into South Africa for biological control of
2486 mesquite weeds (*Prosopis* spp)', *Biological Control*, 3(3), pp. 215–220.
- 2487 Holling, C.S. (1973) 'Resilience and stability of ecological systems', *Annual Review of
2488 Ecology and Systematics*, 4(1), pp. 1–23. Available at:
2489 <https://doi.org/10.1146/annurev.es.04.110173.000245>.
- 2490 Howell, J.M. (2005) 'The right stuff: Identifying and developing effective champions of
2491 innovation', *Academy of Management Perspectives*, 19(2), pp. 108–119.
- 2492 Huang, C. and Asner, G.P. (2009) 'Applications of remote sensing to alien invasive plant
2493 studies', *Sensors*, 9(6), pp. 4869–4889.
- 2494 Hulme, P.E. (2006) 'Beyond control: wider implications for the management of biological
2495 invasions', *Journal of Applied Ecology*, 43(5), pp. 835–847. Available at:
2496 <https://doi.org/10.1111/j.1365-2664.2006.01227.x>.
- 2497 Impson, F.A.C., Moran, V.C. and Hoffmann, J.H. (1999) 'A review of the effectiveness of
2498 seed-feeding bruchid beetles in the biological control of mesquite, *Prosopis* species
2499 (Fabaceae), in South Africa', *Biological Control of Weeds in South Africa*, (1), pp. 81–88.
- 2500 Institute of Biodiversity Conservation (IBC) (2005) 'National Biodiversity Strategy and Action
2501 Plan'. Addis Ababa, Ethiopia: Government of the Federal Democratic Republic of Ethiopia.
- 2502 ISSC IDS; UNESCO (2016) *World Social Science Report 2016, Challenging Inequalities:
2503 Pathways to a Just World*. Paris, France: UNESCO Publishing.
- 2504 Ivey, P., Weaver, K. and de Bruno Austin, E. (2019) 'Landowners and researchers in
2505 partnership to ensure the success of biological control in South Africa', in H.L. Hinz (ed.)
2506 *Proceedings of the XV International Symposium on Biological Control of Weeds*. Engelberg,
2507 Switzerland, pp. 235–238. Available at: <https://www.ibiocontrol.org/proceedings/>.
- 2508 Jordaan, A.J., Sakulski, D. and Jordaan, A.D. (2013) 'Interdisciplinary drought risk
2509 assessment for agriculture: The case of communal farmers in the Northern Cape Province,
2510 South Africa.', *South African Journal of Agricultural Extension*, 41, pp. 44–58.
- 2511 Kariuki, P.M. (1993) *A social forestry project in Baringo, Kenya: A critical analysis*. University
2512 of Queensland.
- 2513 Kissinger, D.G. (2005) 'A new species of *Coelocephalapion wagner* (Coleoptera:
2514 Curculionidea: Apionidae: Apioninae) from Argentina and Chile associated with the genus
2515 *Prosopis* L.(Fabaceae)', *The Coleopterists Bulletin*, 59(4), pp. 493–500.

- 2516 Kleinjan, C.A. *et al.* (2021) 'Developments and prospects for biological control of *Prosopis*
 2517 (Leguminosae) in South Africa', *African Entomology*, 29(3), pp. 859–874. Available at:
 2518 <https://doi.org/10.4001/003.029.0859>.
- 2519 Kogan, M. (1998) 'Integrated pest management: historical perspectives and contemporary
 2520 developments', *Annual Review of Entomology*, 43, pp. 243–270. Available at:
 2521 <https://doi.org/10.1146/annurev.ento.43.1.243>.
- 2522 Kull, C.A. *et al.* (2011) 'Adoption, use and perception of Australian acacias around the world',
 2523 *Diversity and Distributions*, 17(5), pp. 822–836.
- 2524 Labrada, R. (1996) 'The importance of biological control for the reduction of the incidence of
 2525 major weeds in developing countries', in V.C. Moran and J.H. Hoffmann (eds) *Proceedings*
 2526 *of the IX International Symposium on Biological Control of Weeds*. Stellenbosch, South
 2527 Africa: University of Cape Town, South Africa, pp. 287–290.
- 2528 Lang, D.J. *et al.* (2012) 'Transdisciplinary research in sustainability science: practice,
 2529 principles, and challenges', *Sustainability Science*, 7(S1), pp. 25–43. Available at:
 2530 <https://doi.org/10.1007/s11625-011-0149-x>.
- 2531 Larson, D.L. *et al.* (2011) 'A framework for sustainable invasive species management:
 2532 Environmental, social, and economic objectives', *Journal of Environmental Management*,
 2533 92(1), pp. 14–22.
- 2534 Le Maitre, D.C. (1999) 'Prosopis and groundwater: a literature review and bibliography.
 2535 Report Number ENV-SC 99077', *Natural Resources and the Environment, CSIR, prepared*
 2536 *for the Working for Water Programme, Department of Water Affairs and Forestry* [Preprint].
- 2537 Le Maitre, D.C. *et al.* (2011) 'Impacts of invasive Australian acacias: implications for
 2538 management and restoration', *Diversity and Distributions*, 17(5), pp. 1015–1029. Available
 2539 at: <https://doi.org/10.1111/j.1472-4642.2011.00816.x>.
- 2540 Le Maitre, D.C., Versfeld, D.B. and Chapman, R.A. (2000) 'Impact of invading alien plants on
 2541 surface water resources in South Africa: A preliminary assessment', *Water South Africa*,
 2542 26(3).
- 2543 Leach, M., Raworth, K. and Rockström, J. (2013) 'Between social and planetary boundaries:
 2544 Navigating pathways in the safe and just space for humanity', in OECD Publishing (ed.)
 2545 *World Social Science Report 2013, Changing Global Environments*. Paris, France: UNESCO
 2546 Publishing.
- 2547 Lenachuru, C. (2003) 'Impacts of *Prosopis* species in Baringo district', in *Proceedings of*
 2548 *workshop on integrated management of Prosopis species in Kenya, Workshop held at Soi*
 2549 *Safari Club, Lake Baringo*, pp. 1–2.
- 2550 Lescouret, F. *et al.* (2015) 'A social–ecological approach to managing multiple agro-
 2551 ecosystem services', *Current Opinion in Environmental Sustainability*, 14, pp. 68–75.
 2552 Available at: <https://doi.org/10.1016/j.cosust.2015.04.001>.
- 2553 Leventon, J. *et al.* (2016) 'An applied methodology for stakeholder identification in
 2554 transdisciplinary research', *Sustainability Science*, 11(5), pp. 763–775. Available at:
 2555 <https://doi.org/10.1007/s11625-016-0385-1>.

- 2556 Liu, S., Proctor, W. and Cook, D. (2010) 'Using an integrated fuzzy set and deliberative
2557 multi-criteria evaluation approach to facilitate decision-making in invasive species
2558 management', *Ecological Economics*, 69(12), pp. 2374–2382.
- 2559 Lodge, D.M. *et al.* (2006) 'Biological invasions: recommendations for US policy and
2560 management', *Ecological Applications*, 16(6), pp. 2035–2054.
- 2561 Lodge, D.M. and Shrader-Frechette, K. (2003) 'Nonindigenous species: ecological
2562 explanation, environmental ethics and public policy', *Conservation Biology*, 17, pp. 31–37.
- 2563 Louda, S.M. (2000) 'Negative ecological effects of the musk thistle biological control agent,
2564 *Rhinocyllus conicus*', in P.A. Follett and J.J. Duan (eds) *Non-target effects of Biological
2565 Control*. Boston, Massachusetts, USA: Kluwer, pp. 215–243.
- 2566 Low, T. (2012) 'Australian acacias: Weeds or useful trees?', *Biological Invasions*, 14.
2567 Available at: <https://doi.org/10.1007/s10530-012-0243-8>.
- 2568 Lowe, S. *et al.* (2000) *100 of the world's worst invasive alien species: a selection from the
2569 global invasive species database*. Invasive Species Specialist Group Auckland.
- 2570 Lucy, F. *et al.* (2016) 'INVASIVESNET towards an international association for open
2571 knowledge on invasive alien species', *Management of Biological Invasions*, 7(2), pp. 131–
2572 139. Available at: <https://doi.org/10.3391/mbi.2016.7.2.01>.
- 2573 Lym, R.G. and Carlson, R.B. (2002) 'Effect of leafy spurge (*Euphorbia esula*) genotype on
2574 feeding damage and reproduction of *Apthona* spp.: implications for biological weed control',
2575 *Biological Control*, 23(2), pp. 127–133.
- 2576 Maathai, W. (2011) 'Challenge for Africa', *Sustainability Science*, 6(1), pp. 1–2. Available at:
2577 <https://doi.org/10.1007/s11625-010-0120-2>.
- 2578 Macdonald, I.A.W. (2004) 'Recent research on alien plant invasions and their management
2579 in South Africa: a review of the inaugural research symposium of the Working for Water
2580 programme: working for water', *South African Journal of Science*, 100(1), pp. 21–26.
- 2581 Maguire, L.A. (2004) 'What can decision analysis do for invasive species management?',
2582 *Risk Analysis*, 24, pp. 859–868.
- 2583 Maidique, M.A. (1980) 'Entrepreneurs, champions, and technological innovation', *Sloan
2584 Management Review*, 21(2), pp. 59–76.
- 2585 Manetti, G. (2011) 'The quality of stakeholder engagement in sustainability reporting:
2586 empirical evidence and critical points', *Corporate Social Responsibility and Environmental
2587 Management*, 18(2), pp. 110–122.
- 2588 Mangachena, J.R. and Geerts, S. (2017) 'Invasive alien trees reduce bird species richness
2589 and abundance of mutualistic frugivores and nectarivores; a bird's eye view on a conflict-of-
2590 interest species in riparian habitats', *Ecological Research*, 32(5), pp. 667–676. Available at:
2591 <https://doi.org/10.1007/s11284-017-1481-0>.
- 2592 Mangachena, J.R. and Geerts, S. (2019) 'The absence of keystone indigenous trees inhibits
2593 bird recovery up to a decade after invasive tree removal from riparian habitats', *Acta
2594 Oecologica*, 101, p. 103483. Available at: <https://doi.org/10.1016/J.ACTAO.2019.103483>.

- 2595 Manrique, V. *et al.* (2008) 'Effect of host-plant genotypes on the performance of three
2596 candidate biological control agents of *Schinus terebinthifolius* in Florida', *Biological Control*,
2597 47(2), pp. 167–171.
- 2598 Martin, S.C. (1970) 'Longevity of velvet mesquite seed in the soil', *Journal of Range*
2599 *Management*, 23(1), p. 69. Available at: <https://doi.org/10.2307/3896014>.
- 2600 Martín-Retortillo, M. *et al.* (2021) 'Is there a Latin American agricultural growth pattern?
2601 Factor endowments and productivity in the second half of the 20th century', *Revista de*
2602 *Historia Económica / Journal of Iberian and Latin American Economic History*, pp. 1–36.
2603 Available at: <https://doi.org/10.1017/S0212610920000294>.
- 2604 Mascia, M.B. *et al.* (2003) 'Conservation and the social sciences', *Conservation Biology*, 17.
- 2605 Mathenge, C.W. *et al.* (2010) 'Determination of biotypes of *Dactylopius tomentosus*
2606 (Hemiptera: Dactylopiidae) and insights into the taxonomic relationships of their hosts,
2607 *Cylindropuntia* spp.', *Bulletin of Entomological Research*, 100(3), pp. 347–358. Available at:
2608 <https://doi.org/10.1017/S0007485309990496>.
- 2609 Mathevet, R., Bousquet, F. and Raymond, C.M. (2018) 'The concept of stewardship in
2610 sustainability science and conservation biology', *Biological Conservation*, 217, pp. 363–370.
- 2611 Maundu, P. *et al.* (2009) 'Impact of *Prosopis juliflora* on Kenya's semi-arid and arid
2612 ecosystems and local livelihoods', *Biodiversity*, 10, pp. 33–50.
- 2613 Mbaabu, P.R. *et al.* (2019) 'Spatial evolution of *Prosopis* invasion and its effects on LULC
2614 and livelihoods in Baringo, Kenya', *Remote Sensing*, 11, p. 1217.
- 2615 McArthur, M. (2012) *The Meaning and Practice of Stewardship*. University of Calgary.
- 2616 McKay, F. and Gandolfo, D. (2007) 'Phytophagous insects associated with the reproductive
2617 structures of mesquite (*Prosopis* spp.) in Argentina and their potential as biocontrol agents in
2618 South Africa', *African Entomology*, 15(1), pp. 121–131.
- 2619 Meroni, M. *et al.* (2017) 'Mapping *Prosopis juliflora* in west Somaliland with Landsat 8
2620 satellite imagery and ground information', *Land Degradation & Development*, 28(2), pp. 494–
2621 506.
- 2622 Millennium Assessment (2005) 'Millennium Ecosystem Assessment: Ecosystems and Human
2623 Well-Being: Current State and Trends';
- 2624 Miller, T.R. *et al.* (2014) 'The future of sustainability science: a solutions-oriented research
2625 agenda', *Sustainability Science*, 9(2), pp. 239–246. Available at:
2626 <https://doi.org/10.1007/s11625-013-0224-6>.
- 2627 Milton, S.J., Dean, W.R.J. and Richardson, D.M. (2003) 'Economic incentives for restoring
2628 natural capital in southern African rangelands', *Frontiers in Ecology and the Environment*,
2629 1(5), pp. 247–254.
- 2630 Minang, P.A. *et al.* (2014) *Climate-smart landscapes: multifunctionality in practice*. ASB
2631 Partnership for The Tropical Forest margins.
- 2632 Mohan, G. and Stokke, K. (2000) 'Participatory development and empowerment: The
2633 dangers of localism', *Third World Quarterly*, 21(2), pp. 247–268. Available at:
2634 <https://doi.org/10.1080/01436590050004346>.

- 2635 Moran, V.C., Hoffmann, J.H. and Zimmermann, H.G. (1993) 'Objectives, constraints, and
2636 tactics in the biological control of mesquite weeds (*Prosopis*) in South Africa', *Biological*
2637 *Control*, 3(1), pp. 80–83.
- 2638 Mucina, L. and Rutherford, M.C. (2006) *The vegetation of South Africa, Lesotho and*
2639 *Swaziland*. Pretoria: South African National Biodiversity Institute.
- 2640 Musvoto, C. *et al.* (2015) 'Imperatives for an agricultural green economy in South Africa',
2641 *South African Journal of Science*, 111(1–2). Available at:
2642 <https://doi.org/10.17159/SAJS.2015/20140026>.
- 2643 Mwangi, E. and Swallow, B. (2005) 'Invasion of *Prosopis juliflora* and local livelihoods: Case
2644 study from the lake Baringo area of Kenya', *Nairobi, Kenya: World Agroforestry Centre*, 22,
2645 pp. 1–68.
- 2646 Ndhlovu, T., Milton-Dean, S.J. and Esler, K.J. (2011) 'Impact of *Prosopis* (mesquite) invasion
2647 and clearing on the grazing capacity of semiarid Nama Karoo rangeland, South Africa',
2648 *African Journal of Range & Forage Science*, 28(3), pp. 129–137.
- 2649 Nel, J.L. *et al.* (2004) 'A proposed classification of invasive alien plant species in South
2650 Africa: towards prioritizing species and areas for management action: working for water',
2651 *South African Journal of Science*, 100(1), pp. 53–64.
- 2652 Ng, W.-T. *et al.* (2017) 'Assessing the potential of Sentinel-2 and Pléiades data for the
2653 detection of *Prosopis* and *Vachellia* spp. in Kenya', *Remote sensing*, 9(1), p. 74.
- 2654 Nilsen, E.T. *et al.* (1983) 'Diurnal and seasonal water relations of the desert phreatophyte
2655 *Prosopis glandulosa* (honey mesquite) in the Sonoran Desert of California', *Ecology*, 64(6),
2656 pp. 1381–1393.
- 2657 Nkonya, E. *et al.* (2011) *Economics of land degradation - the costs of action versus inaction*.
- 2658 Northern Cape Municipalities (2022) *Northern Cape municipalities, Municipalities of South*
2659 *Africa*. Available at: <https://municipalities.co.za/provinces/view/7/northern-cape> (Accessed:
2660 16 September 2022).
- 2661 Novoa, A. *et al.* (2015) 'Soft touch or heavy hand? Legislative approaches for preventing
2662 invasions: Insights from cacti in South Africa', *Invasive Plant Science and Management*,
2663 8(3), pp. 307–316.
- 2664 Novoa, A. *et al.* (2016) 'Resolving a prickly situation: involving stakeholders in invasive
2665 cactus management in South Africa', *Environmental Management*, 57(5), pp. 998–1008.
- 2666 Nqobizitha, D. (2009) *Economic evaluation of possible loss of Prosopis pods as a result of*
2667 *biological control in the Northern Cape Province, South Africa*. University of Fort Hare.
- 2668 Nsikani, M.M. *et al.* (2019) 'Secondary invasion after clearing invasive *Acacia saligna* in the
2669 South African fynbos', *South African Journal of Botany*, 125, pp. 280–289. Available at:
2670 <https://doi.org/10.1016/J.SAJB.2019.07.034>.
- 2671 Nsikani, M.M. *et al.* (2020) 'Secondary invasion and weedy native species dominance after
2672 clearing invasive alien plants in South Africa: Status quo and prognosis', *South African*
2673 *Journal of Botany*, 132, pp. 338–345. Available at:
2674 <https://doi.org/10.1016/J.SAJB.2020.05.009>.

- 2675 Nsikani, M.M., van Wilgen, B.W. and Gaertner, M. (2018) 'Barriers to ecosystem restoration
2676 presented by soil legacy effects of invasive alien N₂-fixing woody species: implications for
2677 ecological restoration', *Restoration Ecology*, 26(2), pp. 235–244. Available at:
2678 <https://doi.org/10.1111/rec.12669>.
- 2679 Ntshidi, Z. (2015) *A comparative assessment of the quantity and sources of water used by*
2680 *alien invasive Prosopis spp and indigenous Acacia karroo in the Northern Cape Province.*
2681 University of the Western Cape.
- 2682 Nuijten, M. (2004) 'Peasant "participation", rural property and the state in western Mexico',
2683 *Journal of Peasant Studies*, 31(2), pp. 181–209. Available at:
2684 <https://doi.org/10.1080/0306615042000224276>.
- 2685 O'Farrell, P.J. and Anderson, P.M. (2010) 'Sustainable multifunctional landscapes: a review
2686 to implementation', *Current Opinion in Environmental Sustainability*, 2(1–2), pp. 59–65.
2687 Available at: <https://doi.org/10.1016/j.cosust.2010.02.005>.
- 2688 Ogden, J.A.E. and Rejmánek, M. (2005) 'Recovery of native plant communities after the
2689 control of a dominant invasive plant species, *Foeniculum vulgare*: implications for
2690 management', *Biological Conservation*, 125(4), pp. 427–439.
- 2691 Palmer, A.R. and Hoffman, M.T. (1997) 'Nama-karoo', in D.M. Pierce and S.M. Pierce (eds)
2692 *Vegetation of Southern Africa*. Cambridge University Press, Cambridge. pp167-188.
- 2693 Pasiecznik, N.M. *et al.* (2001) *The Prosopis juliflora-Prosopis pallida complex: a monograph.*
2694 HDRA Coventry.
- 2695 Pasiecznik, N.M. *et al.* (2006) 'Implications of uncertain *Prosopis* taxonomy for biocontrol',
2696 *Biocontrol News and Information*, 27(1), pp. 1–2.
- 2697 Peacock, D. and Abbott, I. (2010) 'The mongoose in Australia: failed introduction of a
2698 biological control agent', *Australian Journal of Zoology*, 58(4), p. 205. Available at:
2699 <https://doi.org/10.1071/ZO10043>.
- 2700 Pearson, D.E. *et al.* (2016) 'Secondary invasion: The bane of weed management', *Biological*
2701 *Conservation*, 197, pp. 8–17. Available at: <https://doi.org/10.1016/J.BIOCON.2016.02.029>.
- 2702 Pemperton, R.W. (2000) 'Predictable risk to native plants in weed biological control',
2703 *Oecologia*, 125, pp. 489–494.
- 2704 Penker, M. *et al.* (2013) 'Understanding landscape stewardship – lessons to be learned from
2705 public service economics', *Journal of Agricultural Economics*, 64(1), pp. 54–72. Available at:
2706 <https://doi.org/10.1111/j.1477-9552.2012.00363.x>.
- 2707 Peterson, M.N. *et al.* (2010) 'Views of Private-Land Stewardship among Latinos on the
2708 Texas–Tamaulipas Border', *Environmental Communication*, 4(4), pp. 406–421. Available at:
2709 <https://doi.org/10.1080/17524032.2010.520723>.
- 2710 Polk, M. (2014) 'Achieving the promise of transdisciplinarity: a critical exploration of the
2711 relationship between transdisciplinary research and societal problem solving', *Sustainability*
2712 *Science*, 9(4), pp. 439–451. Available at: <https://doi.org/10.1007/s11625-014-0247-7>.
- 2713 Pope, J., Annandale, D. and Morrison-Saunders, A. (2004) 'Conceptualising sustainability
2714 assessment', *Environmental Impact Assessment Review*, 24(6), pp. 595–616. Available at:
2715 <https://doi.org/10.1016/j.eiar.2004.03.001>.

- 2716 Poteete, A. (2012) 'Levels, scales, linkages, and other' multiples' affecting natural
2717 resources', *International Journal of the Commons*, 6(2).
- 2718 Poynton, R.J. (1990) 'The Genus *Prosopis* in Southern Africa', *South African Forestry*
2719 *Journal*, 152(1), pp. 62–66.
- 2720 Prager, K., Reed, M. and Scott, A. (2012) 'Encouraging collaboration for the provision of
2721 ecosystem services at a landscape scale—Rethinking agri-environmental payments', *Land*
2722 *Use Policy*, 29(1), pp. 244–249. Available at:
2723 <https://doi.org/10.1016/j.landusepol.2011.06.012>.
- 2724 Pyšek, P. and Richardson, D.M. (2010) 'Invasive species, environmental change and
2725 management, and health', *Annual Review of Environment and Resources*, 35(1), pp. 25–55.
2726 Available at: <https://doi.org/10.1146/annurev-environ-033009-095548>.
- 2727 Rampton, S. and Stauber, J. (2002) *Trust Us We're Experts: How Industry Manipulates*
2728 *Science and Gambles with Your Future*. Tarther, New York.
- 2729 Raudsepp-Hearne, C., Peterson, G.D. and Bennett, E.M. (2010) 'Ecosystem service bundles
2730 for analyzing tradeoffs in diverse landscapes', *Proceedings of the National Academy of*
2731 *Sciences*, 107(11), pp. 5242–5247. Available at: <https://doi.org/10.1073/pnas.0907284107>.
- 2732 Raworth, K. (2012) *A safe and just space for humanity: can we live within the doughnut?*
2733 Oxfam.
- 2734 Raymond, C.M. *et al.* (2013) 'Ecosystem services and beyond: Using multiple metaphors to
2735 understand human–environment relationships', *BioScience*, 63(7), pp. 536–546.
- 2736 Reed, M.S. (2008) 'Stakeholder participation for environmental management: a literature
2737 review', *Biological Conservation*, 141(10), pp. 2417–2431.
- 2738 Reed, M.S. *et al.* (2010) 'What is social learning?', *Ecology and Society*, 15.
- 2739 Reed, M.S. *et al.* (2018) 'A theory of participation: what makes stakeholder and public
2740 engagement in environmental management work?', *Restoration Ecology*, 26, pp. S7–S17.
2741 Available at: <https://doi.org/10.1111/rec.12541>.
- 2742 Rejmánek, M. and Richardson, D.M. (2013) 'Trees and shrubs as invasive alien species—
2743 2013 update of the global database', *Diversity and Distributions*, 19(8), pp. 1093–1094.
- 2744 Richardson, D.M. *et al.* (2000) 'Naturalization and invasion of alien plants: concepts and
2745 definitions', *Diversity and Distributions*, 6(2), pp. 93–107. Available at:
2746 <https://doi.org/10.1046/j.1472-4642.2000.00083.x>.
- 2747 Richardson, D.M. and Kluge, R.L. (2008) 'Seed banks of invasive Australian *Acacia* species
2748 in South Africa: Role in invasiveness and options for management', *Perspectives in Plant*
2749 *Ecology, Evolution and Systematics*, 10(3), pp. 161–177. Available at:
2750 <https://doi.org/10.1016/J.PPEES.2008.03.001>.
- 2751 Richardson, D.M. and Rejmánek, M. (2011) 'Trees and shrubs as invasive alien species—a
2752 global review', *Diversity and Distributions*, 17(5), pp. 788–809.
- 2753 Richardson, D.M. and Van Wilgen, B.W. (2004) 'Invasive alien plants in South Africa: how
2754 well do we understand the ecological impacts?: working for water', *South African Journal of*
2755 *Science*, 100(1), pp. 45–52.

- 2756 Ridings, P. (2018) 'Redefining environmental stewardship to deliver governance frameworks
2757 for marine biodiversity beyond national jurisdiction', *ICES Journal of Marine Science*, 75(1),
2758 pp. 435–443.
- 2759 Roberts, A.P. (2006) *Biological control of alien invasive mesquite species (Prosopis) in*
2760 *South Africa: the role of introduced seed-feeding bruchids*. University of Cape Town.
- 2761 Robertson, I. and Woodborne, S. (2002) *Carbon isotopes confirm the competitive*
2762 *advantages of Prosopis over Acacia erioloba*. International Atomic Energy Agency (IAEA),
2763 pp. 433–434.
- 2764 Robinson, L.W. *et al.* (2017) 'Transcending landscapes: working across scales and levels in
2765 pastoralist rangeland governance', *Environmental Management*, 60, pp. 185–199. Available
2766 at: <https://doi.org/10.1007/s00267-017-0870-z>.
- 2767 Sachs, J. (2006) *The end of poverty*. New York, USA: Penguin.
- 2768 Santha, C.R. *et al.* (1991) 'Biological control of aquatic vegetation using grass carp:
2769 simulation of alternative strategies', *Ecological Modelling*, 59(3–4), pp. 229–245. Available
2770 at: [https://doi.org/10.1016/0304-3800\(91\)90179-5](https://doi.org/10.1016/0304-3800(91)90179-5).
- 2771 Schachtschneider, K. (2010) *Water sourcing by riparian tree species in ephemeral rivers*.
2772 University of Cape Town. Available at: <http://hdl.handle.net/11427/6182>.
- 2773 Schachtschneider, K. and February, E.C. (2013) 'Impact of *Prosopis* invasion on a keystone
2774 tree species in the Kalahari Desert', *Plant Ecology*, 214(4), pp. 597–605.
- 2775 Scherr, S.J. and McNeely, J.A. (2008) 'Biodiversity conservation and agricultural
2776 sustainability: towards a new paradigm of "ecoagriculture" landscapes', *Philosophical*
2777 *Transactions of the Royal Society B: Biological Sciences*, 363(1491), pp. 477–494. Available
2778 at: <https://doi.org/10.1098/rstb.2007.2165>.
- 2779 Schön, D.A. (1963) 'Champions for radical new inventions', *Harvard Business Review*, 41,
2780 pp. 77–86.
- 2781 Schwarzländer, M. *et al.* (2018) 'Biological control of weeds: an analysis of introductions,
2782 rates of establishment and estimates of success, worldwide', *BioControl*, 63, pp. 319–331.
2783 Available at: <https://doi.org/10.1007/s10526-018-9890-8>.
- 2784 Scotcher, J.S.B. (2009) *The green choice living farms reference 2009/2010*. Green Choice
2785 Alliance (A World Wide Fund for Nature and Conservation International partnership).
- 2786 Shackleton, C.M. *et al.* (2007) 'Assessing the effects of invasive alien species on rural
2787 livelihoods: case examples and a framework from South Africa', *Human Ecology*, 35(1), pp.
2788 113–127.
- 2789 Shackleton, C.M. and Shackleton, R.T. (2016) 'Knowledge, perceptions and willingness to
2790 control designated invasive tree species in urban household gardens in South Africa',
2791 *Biological Invasions*, 18(6), pp. 1599–1609.
- 2792 Shackleton, R.T. *et al.* (2014) '*Prosopis*: a global assessment of the biogeography, benefits,
2793 impacts and management of one of the world's worst woody invasive plant taxa', *AoB plants*,
2794 6(6).

- 2795 Shackleton, R.T. *et al.* (2015) 'The impact of invasive alien *Prosopis* species (mesquite) on
2796 native plants in different environments in South Africa', *South African Journal of Botany*, 97,
2797 pp. 25–31.
- 2798 Shackleton, R.T. *et al.* (2016) 'Identifying barriers to effective management of widespread
2799 invasive alien trees: *Prosopis* species (mesquite) in South Africa as a case study', *Global*
2800 *Environmental Change*, 38, pp. 183–194.
- 2801 Shackleton, R.T. *et al.* (2017) 'Towards a national strategy to optimise the management of a
2802 widespread invasive tree (*Prosopis* species; mesquite) in South Africa', *Ecosystem Services*,
2803 27, pp. 242–252.
- 2804 Shackleton, R.T. *et al.* (2018) 'Stakeholder engagement in the study and management of
2805 invasive alien species', *Journal of Environmental Management*, 229, pp. 88–101.
- 2806 Shackleton, R.T., Le Maitre, D.C. and Richardson, D.M. (2015) 'Stakeholder perceptions and
2807 practices regarding *Prosopis* (mesquite) invasions and management in South Africa', *Ambio*,
2808 44(6), pp. 569–581.
- 2809 Sheppard, A.W. *et al.* (2003) 'A global review of risk-benefit-cost analysis for the introduction
2810 of classical biological control agents against weeds: a crisis in the making?', *Biocontrol News*
2811 *and Information*, (2003), pp. 18-pp.
- 2812 Shiferaw, H. *et al.* (2004) 'Some biological characteristics that foster the invasion of *Prosopis*
2813 *juliflora* (Sw.) DC. at Middle Awash Rift Valley Area, north-eastern Ethiopia', *Journal of Arid*
2814 *environments*, 58(2), pp. 135–154.
- 2815 Simberloff, D. (2012) 'Risks of biological control for conservation purposes', *Biological*
2816 *Control*, 57, pp. 263–276.
- 2817 Sintayehu, D.W., Dalle, G. and Bobasa, A.F. (2020) 'Impacts of climate change on current
2818 and future invasion of *Prosopis juliflora* in Ethiopia: environmental and socio-economic
2819 implications', *Heliyon*, 6.
- 2820 Stallman, H.R. (2011) 'Ecosystem services in agriculture: Determining suitability for provision
2821 by collective management', *Ecological Economics*, 71(1), pp. 131–139. Available at:
2822 <https://doi.org/10.1016/J.ECOLECON.2011.08.016>.
- 2823 Steele, P., Breithaupt, J. and Labrada, R. (2007) 'Increased food security: control and
2824 management of *Prosopis juliflora*', in *Proceedings of an expert consultation*. Awash,
2825 Ethiopia: FAO.
- 2826 Steelman, T. *et al.* (2015) 'Practicing the science of sustainability: the challenges of
2827 transdisciplinarity in a developing world context', *Sustainability Science*, 10(4), pp. 581–599.
2828 Available at: <https://doi.org/10.1007/s11625-015-0334-4>.
- 2829 Steffen, W. *et al.* (2011) 'The anthropocene: From global change to planetary stewardship',
2830 *AMBIO*, 40(7), pp. 739–761. Available at: <https://doi.org/10.1007/s13280-011-0185-x>.
- 2831 Stem, C. *et al.* (2005) 'Monitoring and evaluation in conservation: a review of trends and
2832 approaches', *Conservation Biology*, 19(2). Available at: <https://doi.org/10.1111/j.1523-1739.2005.00594.x>.
- 2834 Sterling, E.J. *et al.* (2017) 'Assessing the evidence for stakeholder engagement in
2835 biodiversity conservation', *Biological Conservation*, 209, pp. 159–171.

- 2836 Stokes, K.E. *et al.* (2006) 'The importance of stakeholder engagement in invasive species
2837 management: a cross-jurisdictional perspective in Ireland', *Biodiversity & Conservation*,
2838 15(8), pp. 2829–2852.
- 2839 Suckling, D.M., François, R. and Sforza, H. (2014) 'What magnitude are observed non-target
2840 impacts from weed biocontrol?', *PLoS ONE*, 9(1), p. 84847. Available at:
2841 <https://doi.org/10.1371/journal.pone.0084847>.
- 2842 Tchoundjeu, Z., Weber, J. and Guarino, L. (1997) 'Germplasm collections of endangered
2843 agroforestry tree species: the case of *Prosopis africana* in the semi-arid lowlands of West
2844 Africa', *Agroforestry Systems*, 39, pp. 91–100. Available at:
2845 <https://doi.org/10.1023/A:1005887706700>.
- 2846 Terblanche, C. *et al.* (2016) 'An approach to the development of a national strategy for
2847 controlling invasive alien plant species: The case of *Parthenium hysterophorus* in South
2848 Africa', *Bothalia*, 46. Available at: <https://doi.org/10.4102/abc.v46i1.2053>.
- 2849 Tessema, Y.A. (2012) 'Ecological and economic dimensions of the paradoxical invasive
2850 species - *Prosopis juliflora* and policy challenges in Ethiopia', *Journal of Economics and
2851 Sustainable Development*, 3(8), pp. 62–70.
- 2852 Thorp, J.R. and Lynch, R. (2000) 'The Determination of weeds of national significance', in:
2853 Launceston, Tas: National Weeds Strategy Executive Committee. Available at:
2854 <http://www.weeds.org.au/docs/WONS/>.
- 2855 Touza, J. *et al.* (2014) 'Explaining the rank order of invasive plants by stakeholder groups',
2856 *Ecological Economics*, 105, pp. 330–341.
- 2857 Turner, R.K., Palmieri, M.G. and Luisetti, T. (2016) 'Lessons from the construction of a
2858 climate change adaptation plan: A broads wetland case study', *Integrated Environmental
2859 Assessment and Management*, 12(4), pp. 719–725. Available at:
2860 <https://doi.org/10.1002/IEAM.1774>.
- 2861 Turpie, J. (2004) 'The role of resource economics in the control of invasive alien plants in
2862 South Africa: Working for water', *South African Journal of Science*, 100(1), pp. 87–93.
- 2863 Van den Berg, E.C., Kotze, I. and Beukes, H. (2013) 'Detection, quantification and
2864 monitoring of *Prosopis* in the Northern Cape Province of South Africa using remote sensing
2865 and GIS', *South African Journal of Geomatics*, 2(2), pp. 68–81.
- 2866 Van der Laan, M. *et al.* (2017) 'Towards ecologically sustainable crop production: A South
2867 African perspective', *Agriculture, Ecosystems & Environment*, 236, pp. 108–119. Available
2868 at: <https://doi.org/10.1016/J.AGEE.2016.11.014>.
- 2869 Van Driesche, J. and Van Driesche, R. (2004) 'From endemic to generic', in *Nature Out of
2870 Place: Biological Invasion in the Global Age*. Washington, D.C: Island Press, pp. 7–32.
- 2871 Van Driesche, R.G. and Rearden, R.C. (2017) 'Suppressing over-abundant invasive plants
2872 and insects in natural areas by use of their specialized natural enemies', in *Forest Health
2873 Technology Enterprise Team FHET-2017-02*.
- 2874 Van Driesche, R.G. and Simberloff, D. (2016) 'Benefit-risk assessment of biological control
2875 in wildlands', in R.G. Van Driesche *et al.* (eds) *Integrating Biological Control into
2876 Conservation Practice*. Chichester, West Sussex, UK: John Wiley & Sons Ltd.

- 2877 Van Klinken, R. *et al.* (2009) 'Prosopis species (Leguminosae)', *Biological Control of Tropical*
 2878 *Weeds Using Arthropods*, pp. 353–377. Available at:
 2879 <https://doi.org/10.1017/CBO9780511576348.018>.
- 2880 Van Klinken, R.D. *et al.* (2002) 'Challenges facing the successful management of widely
 2881 distributed weeds: biological control of mesquite (*Prosopis* species', in H.J. Spafford, J.
 2882 Dodd, and J.H. Moore (eds) *Weeds: Threats Now and Forever? Thirteenth Australian*
 2883 *Weeds Conference*. Plant Protection Society of WA Inc.
- 2884 Van Klinken, R.D. (2012) '*Prosopis* spp. Mesquite', in M. Julien, R.E. McFayden, and J.
 2885 Cullen (eds) *Biological Control of Weeds in Australia*. CSIRO Publishing, pp. 477–485.
- 2886 Van Klinken, R.D., Fichera, G. and Cordo, H. (2003) 'Targeting biological control agents
 2887 across diverse landscapes: the release, establishment and early success of two mesquite
 2888 (*Prosopis* spp.) insects in Australian rangelands', *Biological Control*, 26, pp. 8–20.
- 2889 Van Lenteren, J. (2004) 'Biological control: sound, safe and sustainable', in *Presidential*
 2890 *Address at the General Assembly of the International Organization of Biological Control*.
 2891 Brisbane, Australia.
- 2892 Van Wilgen, B. and Wannenburgh, A. (2016) 'Co-facilitating invasive species control, water
 2893 conservation and poverty relief: Achievements and challenges in South Africa's Working for
 2894 Water programme', *Current Opinion in Environmental Sustainability*, 19, pp. 7–17. Available
 2895 at: <https://doi.org/10.1016/j.cosust.2015.08.012>.
- 2896 Van Wilgen, B.W. *et al.* (2008) 'A biome-scale assessment of the impact of invasive alien
 2897 plants on ecosystem services in South Africa', *Journal of Environmental Management*, 89(4),
 2898 pp. 336–349.
- 2899 Van Wilgen, B.W. *et al.* (2011) 'National-scale strategic approaches for managing introduced
 2900 plants: insights from Australian acacias in South Africa', *Diversity and Distributions*, 17(5),
 2901 pp. 1060–1075.
- 2902 Van Wilgen, B.W., Forsyth, G.G., *et al.* (2012) 'An assessment of the effectiveness of a
 2903 large, national-scale invasive alien plant control strategy in South Africa', *Biological*
 2904 *Conservation*, 148(1), pp. 28–38.
- 2905 Van Wilgen, B.W., Cowling, R.M., *et al.* (2012) 'Challenges in invasive alien plant control in
 2906 South Africa: news and views', *South African Journal of Science*, 108(11), pp. 1–3.
- 2907 Van Wilgen, B.W. *et al.* (2020) 'Quantifying the social and economic benefits of the biological
 2908 control of invasive alien plants in natural ecosystems', *Current Opinion in Insect Science*, 38,
 2909 pp. 1–5. Available at: <https://doi.org/10.1016/J.COIS.2019.12.004>.
- 2910 Van Wilgen, B.W. and Richardson, D.M. (2014) 'Challenges and trade-offs in the
 2911 management of invasive alien trees', *Biological Invasions*, 16(3), pp. 721–734.
- 2912 Van Wyk, B. and Van Wyk, P. (1997) *Field Guide to Trees of Southern Africa*. Edited by P.
 2913 Joyce. Cape Town: Struik Publishers.
- 2914 Versfeld, D.B., Le Maitre, D.C. and Chapman, R.A. (1998) *Alien invading plants and water*
 2915 *resources in South Africa : a preliminary assessment*. Stellenbosch: Water Research
 2916 Commission.

- 2917 Visser, N. (2009) 'Potensiële beheermaatreëls vir *Prosopis* in die ariede en semi-ariëde dele
2918 van die Karoo- 'n literatuuroorsig', *Eisenberg Journal* [Preprint].
- 2919 Vitousek, P.M. (1990) 'Biological invasions and ecosystem processes: towards an
2920 integration of population biology and ecosystem studies', *Oikos*, 57(1), pp. 7–13. Available
2921 at: <https://doi.org/10.2307/3565731>.
- 2922 Vitousek, P.M. *et al.* (1997) 'Introduced species: a significant component of human-caused
2923 global change', *New Zealand Journal of Ecology*, pp. 1–16.
- 2924 Volchansky, C.R., Hoffmann, J.H. and Zimmermann, H.G. (1999) 'Host-plant affinities of two
2925 biotypes of *Dactylopius opuntiae* (Homoptera: Dactylopiidae): enhanced prospects for
2926 biological control of *Opuntia stricta* (Cactaceae) in South Africa', *Journal of Applied Ecology*,
2927 36(1), pp. 85–91.
- 2928 Wakie, T., Evangelista, P. and Laituri, M. (2012) 'Utilization assessment of *Prosopis juliflora*
2929 in Afar Region, Ethiopia', in. US Forest Service, USDA Office of International Programs,
2930 USAID Pastoral Livelihoods Initiative II Project (PLI II).
- 2931 Wakie, T.T. *et al.* (2014) 'Mapping current and potential distribution of non-native *Prosopis*
2932 *juliflora* in the Afar region of Ethiopia', *PloS one*, 9(11), p. e112854.
- 2933 Wakie, T.T., Laituri, M. and Evangelista, P.H. (2016) 'Assessing the distribution and impacts
2934 of *Prosopis juliflora* through participatory approaches', *Applied Geography*, 66.
- 2935 Walker, B. *et al.* (2002) 'Resilience management in social-ecological systems: a working
2936 hypothesis for a participatory approach', *Conservation Ecology*, 6(1), p. art14. Available at:
2937 <https://doi.org/10.5751/ES-00356-060114>.
- 2938 Walker, B.H., Steffen, W.L. and Langridge, J. (1999) 'Interactive and integrated effects of
2939 global change on terrestrial ecosystems', in B. Walker *et al.* (eds) *The Terrestrial Biosphere*
2940 *and Global Change Implications for Natural and Managed Ecosystems*. Cambridge
2941 University Press, pp. 329–375.
- 2942 Ward, C.R. *et al.* (1977) 'Annotated checklist of New World insects associated with *Prosopis*
2943 (mesquite)', in. Agricultural research Service, United States Department of Agriculture.
- 2944 Warner, K.D., McNiel, J.N. and Getz, C. (2008) 'What every biocontrol researcher should
2945 know about the public', in *Proceedings of the XII International Symposium on Biological*
2946 *Control of Weeds*. Wallingford, UK: CAB International, pp. 390–394.
- 2947 Welchman, J. (2012) 'A defence of environmental stewardship', *Environmental Values*,
2948 21(3), pp. 297–316.
- 2949 Wenger, E. (2011) 'Communities of practice: A brief introduction'.
- 2950 Wheeler, D. and Sillanpää, M. (1998) 'Including the stakeholders: The business case', *Long*
2951 *Range Planning*, 31(2), pp. 201–210. Available at: [https://doi.org/10.1016/S0024-](https://doi.org/10.1016/S0024-6301(98)00004-1)
2952 [6301\(98\)00004-1](https://doi.org/10.1016/S0024-6301(98)00004-1).
- 2953 Wilcove, D.S. *et al.* (1998) 'Quantifying threats to imperiled species in the United States',
2954 *BioScience*, 48(8), pp. 607–615.

- 2955 Wise, R.M., Van Wilgen, B.W. and Le Maitre, D.C. (2012) 'Costs, benefits and management
2956 options for an invasive alien tree species: The case of mesquite in the Northern Cape, South
2957 Africa', *Journal of Arid Environments*, 84, pp. 80–90.
- 2958 Witt, A. and Boy, G. (2013) *Invasive alien plants and their management in Africa*. Nairobi,
2959 Kenya: CABI Africa.
- 2960 Witt, A.B.R. *et al.* (2019) 'Distribution of invasive alien *Tithonia* (Asteraceae) species in
2961 eastern and southern Africa and the socioecological impacts of *T. diversifolia* in Zambia',
2962 *Bothalia-African Biodiversity & Conservation*, 49(1), pp. 1–11.
- 2963 Witt, A.B.R., Beale, T. and Van Wilgen, B.W. (2018) 'An assessment of the distribution and
2964 potential ecological impacts of invasive alien plant species in eastern Africa', *Transactions of*
2965 *the Royal Society of South Africa*, 73, pp. 217–236.
- 2966 Wittenberg, R. and Cock, M.J.W. (2005) 'Best practices for the prevention and management
2967 of invasive alien species', *Scope-Scientific Committee on Problems of the Environment*
2968 *International Council of Scientific Unions*, 63, p. 209.
- 2969 Wittmayer, J.M. and Schöpke, N. (2014) 'Action, research and participation: roles of
2970 researchers in sustainability transitions', *Sustainability Science*, 9(4), pp. 483–496. Available
2971 at: <https://doi.org/10.1007/s11625-014-0258-4>.
- 2972 World Bank (2012) *World Development Indicators Online*, World Bank.
- 2973 Worrell, R. and Appleby, M.C. (2000) 'Stewardship of natural resources: definition, ethical
2974 and practical aspects', *Journal of agricultural and environmental ethics*, 12(3), pp. 263–277.
- 2975 Wynberg, R. (2002) 'A decade of biodiversity conservation and use in South Africa: tracking
2976 progress from the Rio Earth Summit to the Johannesburg World Summit on Sustainable
2977 Development', *South African Journal of Science*, 98, pp. 233–243.
- 2978 Zachariades, C., Hoffmann, J.H. and Roberts, A.P. (2011) 'Biological control of mesquite
2979 (*Prosopis* species)(Fabaceae) in South Africa', *African Entomology*, 19(2), pp. 402–415.
- 2980 Zavaleta, E.S., Hobbs, R.J. and Mooney, H.A. (2001) 'Viewing invasive species removal in a
2981 whole-ecosystem context', *Trends in Ecology and Evolution* [Preprint].
- 2982 Zhang, W. *et al.* (2007) 'Ecosystem services and dis-services to agriculture', *Ecological*
2983 *Economics*, 64(2), pp. 253–260. Available at:
2984 <https://doi.org/10.1016/J.ECOLECON.2007.02.024>.
- 2985 Zimmermann, H.G. (1991) 'Biological control of mesquite, *Prosopis* spp.(Fabaceae), in
2986 South Africa', *Agriculture, Ecosystems & Environment*, 37(1–3), pp. 175–186.
- 2987 Zimmermann, H.G., Hoffmann, J.H. and Witt, A.B.R. (2006) 'A South African perspective on
2988 prosopis', *Biocontrol News and Information*, 27, pp. 6–9.
- 2989 Zwölfer, H. and Harris, P. (1971) 'Host specificity determination of insects for biological
2990 control of weeds', *Annual Review of Entomology*, 16(1), pp. 159–178.
- 2991
- 2992

2993

APPENDICES

2994 Appendix A: Advertisement poster

**Prosopis bestuur
in die
Noord-Kaap**

'n MSc Navorsingsprojek

DOEL

Die ontwikkeling van 'n gemeenskapsgedrewe inisiatief om *Prosopis* sp. te beheer.

TEN EINDE

- Persepsies te verander
- Effektiewe geïntegreerde beheer op *Prosopis* sp. toe te pas
- Bewaring van inheemse veld te bevorder

DEUR MIDDEL VAN

- Vraelyste
- Werkswinkels
- Professionele bystand en ondersteuning

Skandeer

Kontak: Gretha van Staden - grethavs5@gmail.com

IN SAMEWERKING MET

<https://www.surveymonkey.com/r/RVJQRN5>

2995

2996

Prosopis in die Noord-Kaap: 'n MSc Studie

Prosopis in die Noord-Kaap

Die doel van hierdie vraelys is om inligting vanaf die landelike omgewing te verkry rakende persepsies oor *Prosopis* boom indringing. Hierdie inligting gaan dan gebruik word in 'n navorsingsprojek om gemeenskap inisiatiewe te ontwikkel om *Prosopis* bome te beheer.

Die inligting deurgegee in hierdie vraelys word veilig bewaar en is slegs beskikbaar vir die navorsers betrokke in die projek. Die inligting word ook slegs gebruik vir die projek en word geensins gekommunikeer aan ander partye nie. Deelname aan hierdie vraelys is vrywillig. Deelnemers kan enige tyd onttrek van die navorsing sonder nagevolge. Die inligting verkry uit hierdie vraelys sal op so wyse gebruik en bewaar word dat die deelnemers anoniem bly. Deelnemers aan hierdie vraelys moet kennis neem dat die inligting wat hul deurgee deel gaan vorm van 'n akademiese MSc proefskrif by Rhodes Universiteit en moontlik in akademiese artikels gepubliseer word.

Rakende die vrae: by die ronde kolletjies (bv by vraag 1) kan slegs een antwoord gegee word, die grys strepe (bv by vraag 2) vereis 'n geskrewe antwoord en die vierkantige blokkies kan verskeie opsies gekies word.

Etiese klaring nommer: SCI2018/033 (uitgereik deur die hoof van die RUESC).

* 1. Vrywaring: Ek, as anonieme deelnemer, neem kennis dat resultate verkry in hierdie vraelys deel vorm van 'n MSc proefskrif.

Ja

Nee

2. Kontak inligting

Naam en Van

Epos adres

Selfoon nommer

3. Ouderdom

Jonger as 20

20-29

30-39

40-49

50-59

60-69

70-79

80 of ouer

4. Munisipale distrik waarin woonagtig

- | | |
|---|---------------------------------------|
| <input type="checkbox"/> Dawid Kruiper | <input type="checkbox"/> Ubuntu |
| <input type="checkbox"/> Tsantsabane | <input type="checkbox"/> Emathanjeni |
| <input type="checkbox"/> !Kheis | <input type="checkbox"/> Umsobomvu |
| <input type="checkbox"/> Kai !Garib | <input type="checkbox"/> Renosterberg |
| <input type="checkbox"/> Khai-Ma | <input type="checkbox"/> Thembelihie |
| <input type="checkbox"/> Nama Khoi | <input type="checkbox"/> Kgatelopele |
| <input type="checkbox"/> Richtersveld | <input type="checkbox"/> Sol Plaatjie |
| <input type="checkbox"/> Kamiesberg | <input type="checkbox"/> Magareng |
| <input type="checkbox"/> Hantam | <input type="checkbox"/> Phokwane |
| <input type="checkbox"/> Karoo Hoogland | <input type="checkbox"/> Dikgatlong |
| <input type="checkbox"/> Siyancuma | <input type="checkbox"/> Ga-Segonyana |
| <input type="checkbox"/> Siyatamba | <input type="checkbox"/> Gamagara |
| <input type="checkbox"/> Kareeberg | <input type="checkbox"/> Joe Morolong |

5. Munisipale distrikte waarin grond besit word

- | | |
|---|---------------------------------------|
| <input type="checkbox"/> Dawid Kruiper | <input type="checkbox"/> Ubuntu |
| <input type="checkbox"/> Tsantsabane | <input type="checkbox"/> Emathanjeni |
| <input type="checkbox"/> !Kheis | <input type="checkbox"/> Umsobomvu |
| <input type="checkbox"/> Kai !Garib | <input type="checkbox"/> Renosterberg |
| <input type="checkbox"/> Khai-Ma | <input type="checkbox"/> Thembelihie |
| <input type="checkbox"/> Nama Khoi | <input type="checkbox"/> Kgatelopele |
| <input type="checkbox"/> Richtersveld | <input type="checkbox"/> Sol Plaatjie |
| <input type="checkbox"/> Kamiesberg | <input type="checkbox"/> Magareng |
| <input type="checkbox"/> Hantam | <input type="checkbox"/> Phokwane |
| <input type="checkbox"/> Karoo Hoogland | <input type="checkbox"/> Dikgatlong |
| <input type="checkbox"/> Siyancuma | <input type="checkbox"/> Ga-Segonyana |
| <input type="checkbox"/> Siyatamba | <input type="checkbox"/> Gamagara |
| <input type="checkbox"/> Kareeberg | <input type="checkbox"/> Joe Morolong |

6. Beraamde plaas grootte van plaas waarop woongtig

- <100 ha
- 100ha - 1 999ha
- 2 000ha - 3 999ha
- 4 000ha - 5 999ha
- 6 000ha - 7 999ha
- 8 000ha - 9 999ha
- >10 000ha

7. Beraamde grootte van total grond besit

- <1 000ha
- 1 000ha-4 999ha
- 5 000ha-9 999ha
- 10 000ha-14 999ha
- 15 000ha-19 999ha
- >20 000ha

8. Primêre boerdery tipe

- Skape
- Bokke
- Beeste
- Wild
- Besproeiing
- Kombinasie (spesifiseer)

9. Water gebruik op plaas

- Boorgat
- Pyplyn

10. Wat is die waarskynlikheid dat u die verwydering van *Prosopis* boom materiaal uit rivierlope, droë-lope, gronddamme ens. sal aanmoedig by jou bure, mede-boere en/of kollegas?

- Hoogs waarskynlik
- Waarskynlik
- Onwaarskynlik
- Geensins

11. Wat is die primêre gebruik van *Prosopis* boom materiaal op u grond?

12. Hoe gereeld word *Prosopis* materiaal op u grond gebruik?

- Glad nie
- Net in tye van droogte
- Soms
- Gereeld
- Daaglik

13. Indien daar nie *Prosopis* bome op jou grond was nie, sou u iets anders kon gebruik vir bogenoemde behoeftes?

- Definitief Onwaarskynlik
 Hoogs waarskynlik Geensins
 Waarskynlik

14. Met watter plant sou u *Prosopis* materiaal kon vervang indien dit nie meer beskikbaar was nie?

15. Beraamde digtheid van *Prosopis* bome op u grond?

- Geen 30-59 bome p/ha
 1-9 bome p/ha 60-100 bome p/ha
 10-29 bome p/ha >100 bome p/ha

16. Ervaar u die teenwoordigheid van *Prosopis* bome op u grond as 'n probleem?

- Hoogs waarskynlik
 Waarskynlik
 Onwaarskynlik
 Geensins

17. Indien nie, wat is die waarskynlikheid dat u dit in die toekoms as probleem sal ervaar?

- Hoogs waarskynlik
 Waarskynlik
 Onwaarskynlik
 Geensins

18. Indien die teenwoordigheid van *Prosopis* wel as probleem geag word, word beheermetodes op u grond toegepas?

- Hoogs waarskynlik
 Waarskynlik
 Onwaarskynlik
 Geensins

19. Watter bestryding metodes word primêr gebruik?

- Geen
 Gif
 Span met kragssaag
 Saagtrekker
 Stootskraper

20. Hoe gereeld word *Prosopis* bestry op u grond?

- Voltyds
- Maandeliks
- Seisoenaal
- Kwartaalliks
- Jaarliks
- Geensins

21. Word opvolg behandelings toegepas?

- Voltyds
- Maandeliks
- Seisoenaal
- Kwartaalliks
- Jaarliks
- Geensins

22. Wat ag u as die ideale digtheid *Prosopis* bome per hektaar?

23. Wat is u bereid om te doen om die ideale digtheid *Prosopis* bome per hektaar te bereik, in terme van tyd besteding en inspanning?

24. Wat is u bereid om maandeliks te betaal om *Prosopis* bome te verwyder vanaf u grond?

25. Hoe dink u gaan die veld lyk indien die *Prosopis* boom digtheid verminder?

- Geen waarneembare verskil in weiding
- Toename in gras weiding
- Toename in ongewenste plante
- Toename in bossies
- Woestyn

26. Dink u die areas waar *Prosopis* bome verwyder is, moet gerehabiliteer word?

- Definitief
- Hoogswaarskynlik
- Waarskynlik
- Onwaarskynlik
- Geensins

27. Indien u dink die areas waar *Prosopis* verwyder is, gerehabiliteer moet word, watter inheemse plant/e stel u voor?

28. Wat is die waarskynlikheid dat u betrokke sal wees by die opstel van 'n kleinskaalse *Prosopis*- en bosindringing bestuursplan rakende u grond?

- Hoogs waarskynlik
- Waarskynlik
- Onwaarskynlik
- Geensins

29. Wat is die waarskynlikheid dat u betrokke sal wil wees by grond rehabilitasie inisiatiewe in u omgewing, indien dit sou nodig wees?

- Hoogs waarskynlik
- Waarskynlik
- Onwaarskynlik
- Geensins

30. Wat is die waarskynlikheid dat u die voorbereiding van kleinskaalse *Prosopis*- en bosindringing bestuursplanne sal aanraai vir u bure, mede-boere en/of kollegas?

- Hoogs waarskynlik
- Waarskynlik
- Onwaarskynlik
- Geensins

31. Wat is die waarskynlikheid dat u die gebruik van Working for Water spanne om *Prosopis* bome te verwyder sal aanraai vir jou bure, mede-boer en/of kollegas?

- Hoogs waarskynlik
- Waarskynlik
- Onwaarskynlik
- Geensins

32. Wat is die waarskynlikheid dat u die gebruik van onafhanklike spanne om *Prosopis* bome te verwyder sal aanraai vir jou bure, mede-boer en/of kollegas?

- Hoogs waarskynlik
- Waarskynlik
- Onwaarskynlik
- Geensins

33. Ag u die funksionering en reëlings van die Sprinkaan-beheer program as nuttig en relatief suksesvol?

- Hoogs waarskynlik
- Waarskynlik
- Onwaarskynlik
- Geensins

34. Wat is die waarskynlikheid dat u sou deel wees van 'n inisiatief soortgelyk aan die Sprinkaan-beheer program wat fokus op *Prosopis*- en bosindringing beheer?

- Hoogs waarskynlik
- Waarskynlik
- Onwaarskynlik
- Geensins

35. Is veiligheid 'n bekommernis op u grond?

- Nee
- Veediefstal/diefstal
- Wilddiefstal/stroppers
- Plaasaanvalle
- Plaasmoorde

36. Wat is die waarskynlikheid dat u meer geneig sal wees om geld te spandeer aan sekuriteitsinfrastruktuur eerder as aan *Prosopis* beheer?

- Hoogs waarskynlik
- Waarskynlik
- Onwaarskynlik
- Geensins

37. Waar lê *Prosopis* beheer en bosindringing op die volgende prioriteitslys, volgens u boerdery behoeftes (dui aan met 'n nommer deur op die pyltjies te klik, 1 vir mees belangrik en tot 4 vir onbelangrik)?

- Boerdery infrastruktuur (drade, pyplyne, damme, algemene onderhoud)
- Vee (gesondheid, verkope en aankope)
- Prosopis*- en bosindringing beheer
- Sekuriteit en voertuie

38. Gedurende die droogte het u gebruik gemaak van die volgende

- Amptelike Bos tot Kos metode en voer
- Eie weergawe van Bos tot Kos
- Voer mengsel/droogte voer
- Lek met ruminante lek byvoegsel (BrowsePlus of Browser)

39. Wat is die waarskynlikheid dat u in die toekoms van *Prosopis* plant materiaal as voer gebruik sal maak?

- Hoogs waarskynlik
- Waarskynlik
- Onwaarskynlik
- Geensins

40. Biologiese beheer

Het u al daarvan gehoor?

Indien ja, waar?

Hoe werk dit, breedvoerig gestel?

41. Wat is volgens u die waarskynlikheid dat biologiese beheer insekte op ander plante as *Prosopis* sal oorleef en sodoende 'n negatiewe impak op die omgewing het?

- Hoogs waarskynlik
- Waarskynlik
- Onwaarskynlik
- Geensins

42. Wat is die waarskynlikheid van suksesvolle *Prosopis* beheer deur gebruik te maak van biologiese beheer?

- Hoogs waarskynlik
- Waarskynlik
- Onwaarskynlik
- Geensins

43. Hoe sal u suksesvolle *Prosopis* beheer met die gebruik van biologiese beheer beskryf?

44. Wat is die waarskynlikheid dat u die gebruik van biologiese beheer vir die beheer van *Prosopis* aan u bure, mede-boere en/of kollegas voor te stel?

- Hoogs waarskynlik
- Waarskynlik
- Onwaarskynlik
- Geensins

45. Waar verkry u inligting rakende

Boerderypraktyke
(bewaringsboerdery,
drakrag)

Prosopis bome (plant
eienskappe, beheer,
tydsberekening van
beheer, opvolg
behandeling)

Tipes gif vir
indringerplante, die
aanwending daarvan

Biologiese beheer
(navorsing, biobeheer
metodes, insekte)

3006

3007

3008

Prosopis in die Noord-Kaap: 'n MSc projek

Werkswinkel Registrasie

Baie dankie vir u belangstelling in die Prosopis werkswinkel, in samewerking met die Rhodes Universiteit Sentrum vir Biologiese Beheer. Die werkswinkel dien as geleentheid om inligting uit te ruil en kennis te neem van die verskeie projekte en inisiatiewe rakende indringer beheer in die Noord-Kaap asook die navorsing en steun daaragter.

Die werkswinkel vind 15 Junie 2022 in Groblershoop by The Hedgehog Padstal and Orange River Cellars plaas.

* 1. Ek sal graag die werkswinkel bywoon

Ja

Nee

2. Besonderhede

Naam en Van

Organisasie/Besigheid/Boerdery

Epos address

Selfoon nommer

3. Ek sal aansit by die ete wat voorsien word

Ja, klink heerlik

Nee dankie, ek bring my eie

4. Het u enige voedsel allergieë?

1

Nuusflits Uitgawe 1 Julie 2022

NUUSFLITS

Baie Dankie

VIR U TEENWOORDIGHEID BY
DIE INDRINGER WERKSWINKEL

Baie dankie ook vir diegene wat steeds belangstel en betrokke is waar hulle kan, al kon julle nie die werkswinkel bywoon nie, jul gewilligheid gaan nie ongesiens nie.

Daar is nog baie werk wat voorlê, saam kan ons 'n groot verskil maak!

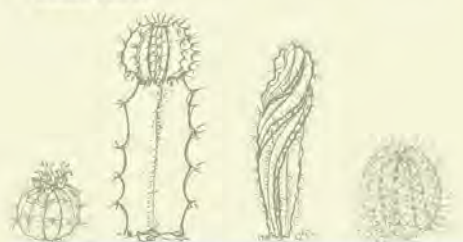
Werkswinkel

Op 15 Junie 2022 het die Indringer Werkswinkel plaas gevind op Groblershoop by die Hedgehog Padstal en Oranjerivier Wyn Kelders. Hierdie geleentheid is aangebied deur die MSc student, Gretha van Staden, in samewerking met die Rhodes Universiteit se Sentrum vir Biologiese Beheer in Grahamstad.

Mense het van sover as Kenhardt en Williston gekom om deel te neem aan die onderskeie navorsers se praatjies. Afgevaardigdes van verskeie staatsdepartemente, sowel as AgriNK en die RPO was teenwoordig gewees. Die dag word as 'n groot sukses beskou, met verskeie belangstellendes wat met woema weg gestap het.

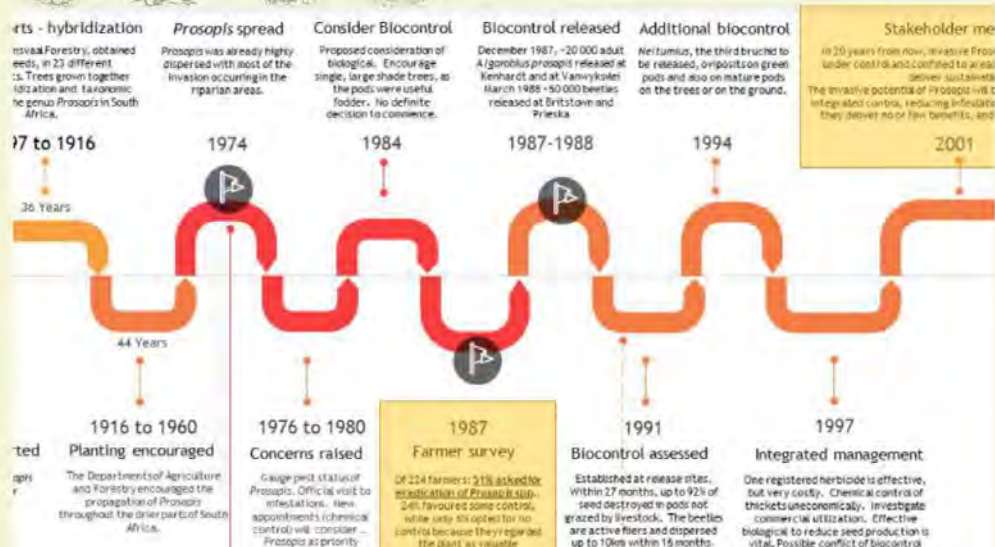
Philip Ivey: *Prosopis* vestiging & beheer geskiedenis

Philip Ivey is verbonde aan die Rhodes Universiteit se Sentrum vir Biologiese Beheer, met die fokus op *Prosopis*- en kaktus indringing en die beheer daarvan.



Philip het ook die Kimberley Indringer Forum, in Maart 2022, bygewoon. Hierdie forum is 'n deurlopende inisiatief deur Invasive Species South Africa (ISSA). Philip se praatjie van daardie dag is beskikbaar op YouTube, die skakel is beskikbaar op die eerste skakel bladsy.

Sy praatjie by die werkswinkel was gefokus op die geskiedenis van *Prosopis* indringing, en die verloop van beheer pogings tot op hede. Hy het 'n baie effektiewe tydskaal saamgestel wat die vestiging van *Prosopis* en die daaropvolgende ingrypings voorstel.



Prosopis establishment & control history

Forestry and Agricultural sectors introduced *Prosopis* from the arid South Western United States to South Africa during the 1880's. Since the 1970's, researchers began to show concern about its spread and impact and undertook much traditional research to understand the threat of *Prosopis* and possible management approaches.

From 1984, researchers at the Department of Agriculture began to consider biological control.

Due to the potential for farmers to feed *Prosopis* pods to their livestock, researchers were concerned not to compromise this source of fodder. Farmers completed a postal survey, which found that just over 50% of the farmers would like to see *Prosopis* eradicated and a further 24% were in favour of some form of control.

—Continues on next page

In order to avoid the conflict of interest, researchers focused on biological control agents that only damaged the seed. Researchers introduced three seed feeding insect species, which under certain conditions can destroy up to 90% of the seeds produced. Even with these agents released, established and damaging seeds, *Prosopis* continued to spread at an alarming rate.

Prosopis can use up to six times more water than indigenous trees, mainly due to the dense stands that it forms but also due to the extremely deep roots, which can grow up to 70 meters deep into the groundwater.

**"Towards a National Programme for
Prosopis Management in
South Africa.**

**Biological control, biomass use and
everything in between!"**

Groblershoop, 15 June 2022
Philip Ivey, Gretha van Staden,
Distinguished Professor Martin Hill
Kim Weaver

With inputs from Blair Cowie, Fritz Heystek and
Caren Kleinjan



Philip Ivey: *Prosopis* establishment and control history

In 2017, Ross Shackleton and researchers from the Council for scientific and Industrial Research (CSIR) and the Centre for Invasion Biology published a paper, "Towards a national strategy to optimise the management of a widespread invasive tree" (*Prosopis*). In this paper, they suggest four different approaches. The first would be to continue with the current approach in which both the extent of the invasion and the costs of managing the problem will increase. The second possible scenario would be to have increased mechanisation of control and more use of the biomass to offset the costs of mechanical clearing. The third approach is to research and introduce more damaging biological control agents. The fourth is a approach would be a combination of both the third and second approaches with increased use of *Prosopis* and a more damaging biological control agent acting in concert to reduce both the extent of the invasion and ultimately the costs of management of the problem.

Unfortunately, the danger of much of the research to date is that the target audience, the farmers, may end up being or feeling they are the subject of the research and not partners in the management of invasive plant species.

Therefore, it was and is important to emphasize that the users of biological control are not the subject of the research but are partners in how to make more and better use of biological control.

Ultimately, we want a partnership that ensures a virtuous cycle of information and ideas coming from farmer to researcher and implementer of biological control and back to farmer. The research is not about "studying what the farmer wants", it is about how the "researcher becomes more part of the farmer's reality" and developing a sustainable partnership between all the stakeholders with a joint mission to use biological control more effectively.

— Philip Ivey

Gretha van Staden: Die ontwikkeling van 'n gemeenskap van aksie

Doel van die projek

- Die ontwikkeling van 'n gemeenskap gedrewe inisiatief om *Prosopis spesies* te beheer
- Kleinskaalse bestuursplanne te ontwikkel saam met geïnteresseerde partye
- Die implementering van biologiese beheer metodes te ondersoek rakend belangstelling en persepsies

Gretha van Staden is 'n Noord-Kaapse inboorling, en haar familie boer al in die Hay-distrik omgewing vir meer as 100 jaar. Sy is tans besig met haar meestersgraad studies, verbonde aan die Rhodes Universiteit. Haar projek handel oor die ontwikkeling van 'n gemeenskap van aksie vir die bevordering van die biologiese beheer van *Prosopis*, asook die implementering van geïntegreerde beheer van *Prosopis* in die Noord-Kaap.

Die werkswinkel, gehou op 15 Junie, vorm deel van haar studies en is die tweede 'ingryping-gebeurtenis' in haar navorsing na 'n gemeenskap van aksie. Die eerste was 'n vraelys wat in die laaste helfte van 2021 gedeel is. Die reaksie op die onderskeie 'ingryping-gebeurtenisse' word geanaliseer om sodoende die algemene aanslag op *Prosopis* beheer aan te pas om meer volhoubaar en haalbaar te maak, gebaseer op terugvoer van die gemeenskap.

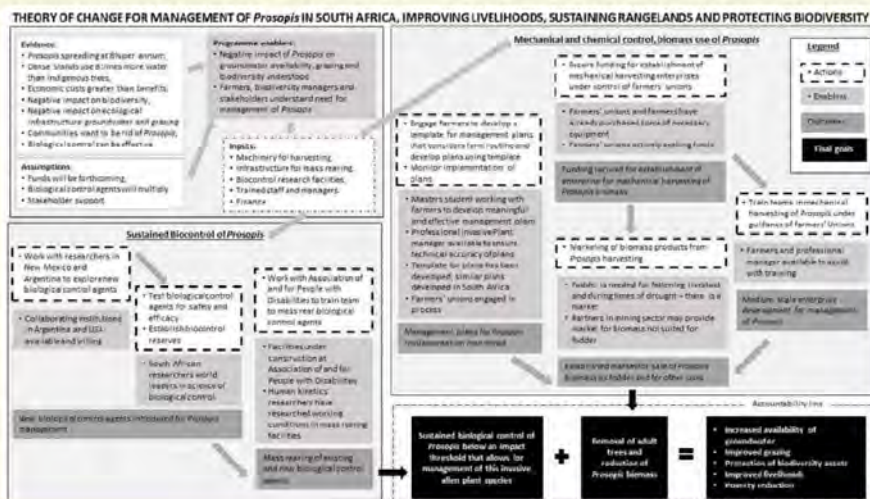
Eben Anthonissen: Van Prosopis armoede to voer fondse en biodiversiteit voordele

Eben Anthonissen is die voorsitter van Agri Noord-Kaap se Natuurlike Hulpbron Komitee. Hy is tans betrokke by 'n projek in die Hotazel omgewing. Die projek beoog om die indringing van *Prosopis* in die omringende rivierlope aan te spreek, om sodoende boerdery vooruitsigte te verbeter.

Prosopis beheer deur middel van die kombinasie van biologiese beheer en chemiese en meganiese beheer het die waarskynlike gevolg dat beide die indringing en die koste van beheer verminder word. Sodoende word *Prosopis* indringing op 'n geïntegreerde wyse bestuur.

Die Hotazel *Prosopis* projek betrek private grondeienaars, die verskeie myne wat aktief is in die omgewing, en ook die omringende landelike gemeenskap (bv. bestaansboere en restitusiegronde).

Dit is in poging om die druk vanaf Werk vir Water te neem (wat ondanks groot finansiële ondersteuning nie die indringing onder beheer kry nie), sowel as beskerming van biodiversiteit en volhoubare werkskepping.



Eben Anthonissen: Van *Prosopis* armoede to voer fondse en biodiversiteit voordele

Om die *Prosopis* indringing op 'n volhoubare manier aan te spreek, word die nodige materiaal van die *Prosopis* bome geoes, waarvan Bos tot Kos voermengsels gemaak word. Dit word dan gelewer aan koöperasies en ander belangstellendes. Sodoende word werk geskep, vind opleiding plaas, en is daar handel in die platteland wat die ekonomie stimuleer.

Die oes van die peule en blare beïnvloed die voortplantingsvermoë van die bome, wat 'n beperkende effek op die verspreiding daarvan het. Dit ondersteun ook die biologiese beheer agent bevolking, wat die impak wat hierdie insekte op *Prosopis* kan hê, verbeter.



Prosopis Biocontrol

WHY?



Natural herbivores are not present in introduced range



Biological control is used to try and reduce plant populations to similar levels as in native ranges



Cost effective method to address continued *Prosopis* invasion



Environmentally safe, compared to incorrect herbicide use



Biocontrol was originally limited to agents that reduce viable seed



Fitz Heystek: Die beheer van *Prosopis* deur die gebruik van *Evippe sp. #1*

Fritz Heystek is 'n navorser verbonde aan die Landbou Navorsing Raad (LNR) van Suid-Afrika. Sy navorsing sluit in die nuwe *Prosopis* biologiese beheer agent wat in Februarie 2021 in Suid-Afrika vrygestel is, naamlik die *Evippe sp. #1* mot. Die mot behoort aan die Gellechiidae familie, en kom oorspronklik vanaf Argentinië. In 1998 is dit in Australië as veilig vir vrylating bevind. Die *Evippe sp. #1* mot voed op die voortplantingsdele van *Prosopis*, sowel as die blare van die plant.

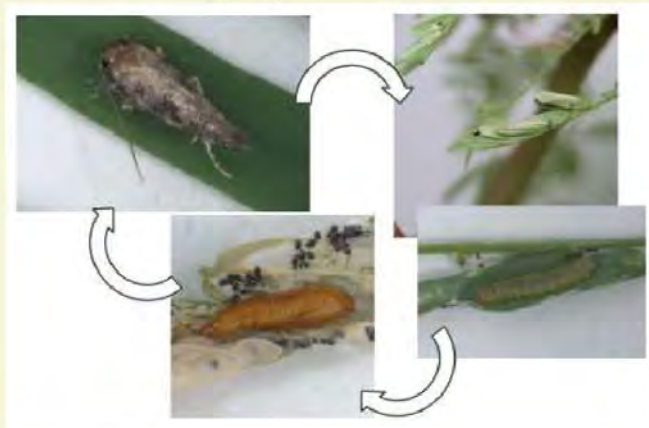
In Desember 2014 is die mot ingevoer en onder kwarantyn geplaas by die LNR navorsingsfasiliteit. Australië het reeds verskeie spesifisiteitstoetse op *Evippe sp. #1* uitgevoer, insluitend gasheer toetse op 60 verwante plante van Australiese oorsprong. Die LNR het 31 verwante spesies wat in Afrika van belang is. So ook is 86 unieke spesies en 5 oorkoppelende spesies getoets. Oorwegings voor vrylating sluit in die moontlike negatiewe effekte (konflik van belang, parasitisme, en agent interaksies) asook die potensiaal vir vestiging en effektiwiteit

Die beoogde effekte van die *Evippe* vrylating in Suid-Afrika, en moontlik verder in Afrika, sluit in die vestiging van sterk bevolkings asook verspreiding en sigbare impakte op *Prosopis* bome in dig ingedringde gebiede.

Fitz Heystek: Die beheer van *Prosopis* deur die gebruik van *Evippe sp. #1*



Evippe sp. #1 lewensiklus



Manier van vrystelling



Tekens van *Evippe sp. #1* voorlopige vestiging



History of seed feeding beetles for biological control of *Prosopis*



Algarobius prosopis

- If pods are left undisturbed on the ground, *Algarobius* can cause >90% damage to these seeds
- Even though livestock and wildlife eat pods and disperse the seed, the beetle still manages to locate and damage seeds

1987



Bruchidius submaculatus

- Indigenous
- Less than 1% seed damage

1991



Neltumius arizonensis

- Less abundant than *Algarobius prosopis*
- Only lays eggs in pods which are still in good condition
- More vulnerable to attack by parasitoids
- Prefers mature seeds above green pods

1992

Carien Kleinjan: Saad voedende kewers in die beheer van *Prosopis*

Carien Kleinjan is een van die navorsers wat betrokke is by navorsing oor die peultjie snuitkewer (*Coelocephalapion gandolfoi*). Hierdie snuitkewer val die jong, groen peule van *Prosopis* aan.

Die vrylating van *C. gandolfoi* is goedgekeur na ekstensiewe genetiese navorsing om sy gasheer plante te identifiseer, en dus inheemse skade te beperk.

Die navorsing het getoon dat Afrika en Asiatiese *Prosopis* variëteite geensins verwant is aan die indringende Amerikaanse spesies nie. Die naaste verwante plant in Suid-Afrika is die Ysterdoring (*Xerocladia viridiramis*), en dit is evolusionêr baie vêr verwyderd.

Die Argentynse navorsers betrokke by hierdie projek het in 2021 meer as 600 gesonde volwasse snuitkewers na Suid-Afrika gestuur. Na 'n kwarantyn periode is ongeveer 125 snuitkewers by 5 verskillende punte tussen Kenhardt en Prieska vrygelaat.



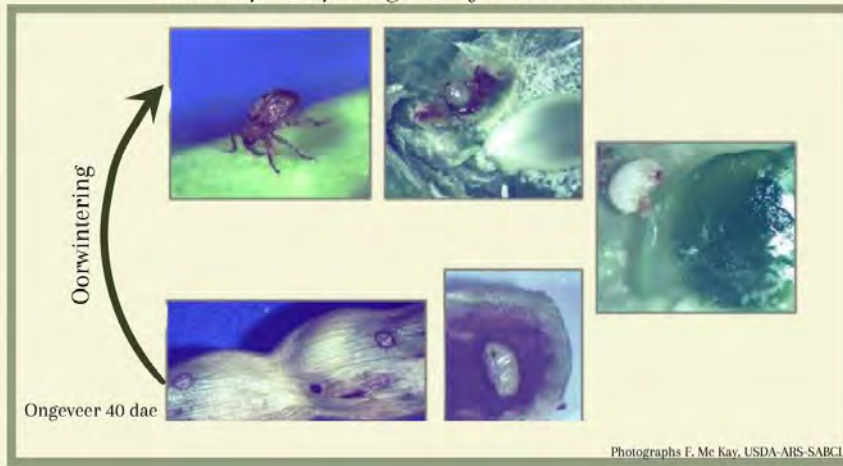
In Februarie 2022 het Carien terug gekeer na waar sy die kewers vrygelaat het, om moontlike bewyse van snuitkewer aktiwiteit waar te neem. Dit word gedoen deur te soek vir eierlegging merke op die peule, wat meer pertinent raak soos die merke verouder.

Eierlegging merke, asook merke gemaak deur die volwassenes wat uit die peule beweeg, is ook sigbaar op ouer peule.

Ondanks die uitbraak van 'n inheemse spesie plant-suier insekte, is daar definitiewe bewyse van *C. gandolfoi* (alhoewel verdere navorsing nodig is).

Carien Kleinjan: Saad voedende kewers in die beheer van *Prosopis*

Coelocephalopion gandolfoi lewensiklus



Eierlegging merke



Coelocephalopion gandolfoi vrylating areas



Graham Harding: Die bestuur van *Prosopis*, en hoekom dit belangrik is

Dr Graham Harding is al dekades betrokke by die beheer van verskeie indringer plante in Suid-Afrika. Tans is hy werksaam by sy eie maatskappy, Invader Plant Specialists (Pty) Ltd. Hy het in 1983 met *Prosopis* navorsing in die Van Wyksvlei omgewing begin. Gedurende sy tyd in die Noord-Kaap het hy gifproewe vir 'n aantal maatskappye gedoen, sowel as verskillende beheermetodes getoets (insluitende giftoediening deur die gebruik van 'n helikopter). Sy navorsing het ook die benutting van *Prosopis* materiaal ingesluit, byvoorbeeld die produksie van houtskool en die gebruik van peule vir veevoer.

Dr. Harding is van mening dat almal 'n rol te speel het in indringerbeheer, en dat die grondeienaar self 'n aktiewe rol daarin moet speel, veral siende dat hul die meeste kennis het oor hul grond en die beste geposisioneer is om effektiewe beheer toe te pas.

Hy het by die werkwinkel praktiese voorbeelde uitgewys van hoe die bestuur van *Prosopis* benader moet word, uit 'n boerdery beplanning oogpunt. Hy het klem daarop gelê dat mens nie moedeloos moet word en jou vas staar in die digte bosse nie, maar om altyd perspektief te behou.



Graham Harding: Die bestuur van *Prosopis*, en hoekom dit belangrik is

Graham raai aan om te begin deur die plaas te karteer op byvoorbeeld GoogleEarth, en al die sleutel landmerke, eienskappe en enige addisionele data by te voeg.

Daarna word die ingedringde areas gemerk in grade van digtheid (swaar, medium, lig, geen).

Soos wat mens dan ingaan op die plaas in GoogleEarth, word meer en meer detail sigbaar, wat dan geïdentifiseer en gemerk kan word.

Die neem van fotos is ook krities belangrik om perspektief te behou, en natuurlik om die vordering vas te lê.

Die kaart en fotos dien dan as 'n konkrete beginpunt, wat verhoed dat die skaal van indringing op die besitte grond oorweldigend raak (wat baie mense verhoed om 'n begin te maak).

In sy praatjie het Graham ook die gereedskap wat beskikbaar is vir indringing bestryding, bespreek.

Biobeheer is die verbeelde ideaal, siende dat dit geen insette vanaf die boer vereis nie. Ongelukkig is dit meer effektief om biobeheer met ander beheer metodes te kombineer.

Dit is krities belangrik om die regte plantdoder en die regte toediensingsmetode te kies.

By blaarbespuiting is die bedekking die bepalende faktor in of die bome gaan vrek, en of die probleem vererger. Dit is ook die geval by 'cut stump' behandelings, die hele stomp moet deeglik bedek word direk nadat die boom afgesny is, anders gaan dit onvoldoende wees om die boom te dood. Die boom moet ook verkieslik enkelhoogte afgesny word.

Indien van lugbespuiting gebruik wil word, beklemtoon Graham die belang van professionele hulpgebruik 'n geregistreerde PCO (Plant Control Officer) vlieënier wat nadink watter voertuig hul gebruik (drone, helikopter of vliegtuig).

Prosopis foliar spray times

Graham Harding het dekades se ervaring met die toediening van plantdoder op verskeie indringer plante in Suid-Afrika. Hier deel hy belangrike punte rakende die toediening van gif op Prosopis spesies.

The following is an exact from the GARLON Max label of Corteva. These points relate specifically to their product, but I see no reason why these restrictions should not apply for any foliar applied herbicide.

The herbicidal response is **strongly influenced by foliage condition, stage of growth and environmental conditions**. For optimum control, **apply when new growth foliage has turned from light to dark green**, when soil temperature is above 24° C at a depth of at least 30 cm and soil moisture is adequate for plant growth. Product performance may be adversely affected if application is **made before the plant foliage has turned from light to dark green or if foliage has been injured or removed by a late frost, insects, hail or plant diseases**.

Do not treat if plants exhibit new (light green) terminal growth in response to recent heavy rainfall during the growing season.

Do not spray target plants when drought signs are evident or showing signs of stress, such as leaf drop. After a drought some plant species remain under stress and require a recovery period following rainfall. Signs of stress may not be evident during this recovery period. Allow time for plants to fully recover after rainfall before applying foliar treatments. Should this occur, provision should be made for follow-up treatments.

Avoid spraying trees in autumn when the waxy layer on the leaves have accumulated.

Unsatisfactory control will be obtained if spraying earlier in spring, when most of the new growth present consists of recently emerged stems with immature leaves.

In this respect it is recommended that **spraying should not be undertaken before November**, by which time most of the new stems will have emerged and produced mature leaves – turned from light to dark green.

—Graham Harding

Africa Data Technologies: houtskool en biochar



Wihan Bekker en **Jean Pierre du Plessis** is mede-stigters van African Data Technologies, 'n maatskappy wat hom beywer vir meer omgewingsvriendelike praktyke. Hul werk in die gebruik van die hout verkry vanaf indringer boom beheer is 'n interessante projek, met moontlikhede in die Noord-Kaap.

African Data Technology (ADTech) is 'n maatskappy met die fokus om oplossings tot volhoubaarheid kwessies te bewerkstellig. Hulle werk tans aan 'n platform vir die ontwikkel van projekte wat klimaatsverandering aanspreek.

Wihan Bekker:
wihan@africandata.tech
071 859 6656

Die maak van "biochar" in lae koste "kilns" uit indringerhout en ander landbou materiaal wat gewoonlik gebrand word, bied 'n moontlike oplossing om koolstof te stoor, wat ook 'n aantal voordele vir grondgesondheid inhou. Daar is tans 'n groot belangstelling in die befondsing van sulke projekte internasionaal deur "carbon credits".

Video: [ADTech in die VSA](#)

ADTech is tans besig met 'n paar projekte in die Wes-Kaap, insluitend die maak van biochar met die hulp van internasionale befondsing. Hulle is ook in gesprek met Philip Ivey van Rhodes Universiteit oor die moontlikheid om soortgelyke projekte in die Noord-Kaap te loots, met *Prosopis* as die brandstof.

Video: [ADTech proses in Tulbagh](#)

Die ondersoek sal nou afhanklik wees van die insigte van boere om te bepaal of daar 'n nut aan biochar is in boerdery praktyke, die praktiese probleme en kostes wat met indringer beheer gepaardgaan, sowel as modelle en koste benodig om 'n biochar model sinvol toe te pas. —*Jean Pierre du Plessis*

Die pad voorentoe

Bekende Biologiese Beheer Agente

Die insekte wat reeds vrygestel is, moet eers vestig in die areas waar hul vrygestel is. Insekte ontwikkel stadiger in die winter, dus moet die onderskeie navorsers wag tot dit warmer word in die lente. Impakstudies op beide *Coelocephalapion gandolfi* en *Evippe sp. #1* sal hul effek op *Prosopis* kwantifiseer.

Ondersoek na ander Biologiese Beheer Agente

Daar word ondersoek ingestel na ongeveer 650 Nuwe wêreldse insek spesies (insluitend 105 Suid-Amerikaanse spp.) (Ward et al. 1977) asook meer as 300 Suid-Amerikaanse insek spesies (Cordo & DeLoach 1987).

Volgende werkswinkel

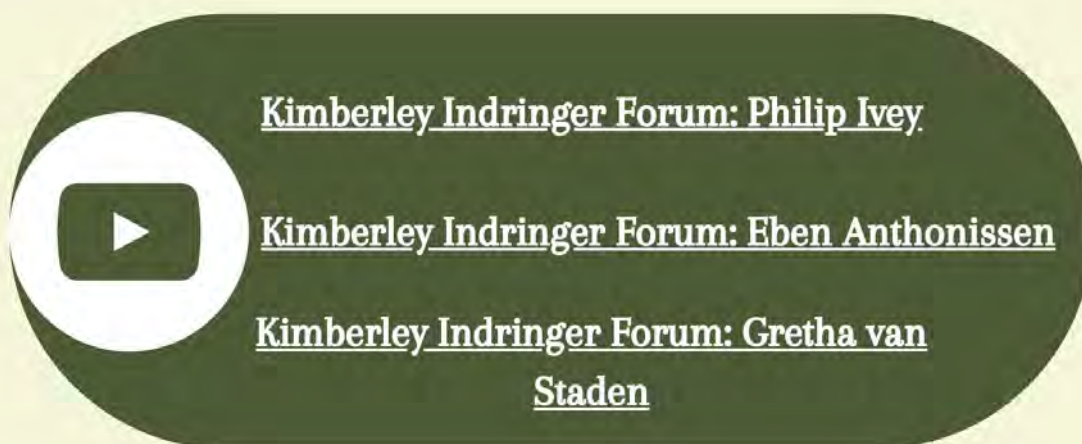
Klik [hier](#) om jou sê te sê in die besluitneming rakende waar en wanneer die volgende werkswinkel gehou word.

Vraelys versoek

Klik [hier](#) om die tweede vraelys, as deel van Gretha van Staden se MSc studies, in te vul.

YouTube Skakels

Om die skakels te gebruik, klik op die beskrywing, byvoorbeeld "Kimberley Indringer Forum", in die YouTube afdeling op hierdie bladsy.



Skakels vir artikels

Om die skakels te gebruik, klik op die beskrywing, byvoorbeeld "What is Biochar", in die afdeling op hierdie bladsy.



What is "Biochar"?

Ikhala: Biochar Kilns

Evippe sp. #1 LNR Persverklaring



Rhodes Universiteit Sentrum vir Biologiese

Beheer

Algemene kommunikasie kanale



082 443 0728



Centre for
Biological
Control-CBC



@prosopis_bestuur



Rhodes
University,
Grahamstown,
EC



@rhodesunicbc



grethavs5@gmail.
com



p.ivey@ru.ac.za

3. BIOLOGICAL CONTROL OF LEGUMES (FAMILY FABACEAE) OF AMERICAN ORIGIN

3.2 Prosopis seed beetles (*Algarobius prosopis* and *Neltumius arizonensis*)

Introduction

Both these beetle species were introduced from Arizona, USA. *Algarobius prosopis* was released in South Africa in 1987 and *Neltumius arizonensis* in 1993.

Neltumius was imported to supplement *Algarobius*, because it had been reported that *Neltumius* laid its eggs on younger pods than those utilised by *Algarobius*. It was hoped that this beetle would damage most of the seeds before the pods dropped from the trees and became available to livestock. Contrary to expectations, *Neltumius* does not lay its eggs on young pods, and it faces the same problem as *Algarobius* in that livestock normally ingest the pods before the beetle larvae have a chance to neutralise the seeds.

Life cycle of the prosopis seed beetles

The adult beetles (fig. 1a) are about 4 mm long, *Algarobius* (fig. 2) being mottled brown and *Neltumius* (fig. 3) mottled black and white.

The adult beetles of both species are active and readily fly, with the ability to cover long distances. Adult females live for several weeks. The females of *Algarobius* can each lay up to 300 eggs, while those of *Neltumius* lay about 70 eggs on average. The eggs (fig. 1b) are colourless, flattened and oval, about 1 to 2 mm long, and are laid on prosopis pods.



Figure 2. An adult of *Algarobius prosopis*.

The two beetle species differ from one another concerning their oviposition (egg-laying) behaviour. *Algarobius* deposits its eggs in clusters in cracks on mature prosopis pods or in old emergence holes of adult beetles. *Algarobius* almost invariably only oviposits on pods that are fully ripened, and the eggs are attached in place with one or

two adhesive strands. In contrast, the *Neltumius* females are meticulous about where and how they lay their eggs. Each egg is deposited on the swollen area around a seed of a mature prosopis pod, but never on a seed that is already occupied by an egg of either *Neltumius* or *Algarobius*, if free seeds are available. Unlike *Algarobius*, eggs are usually laid on undamaged pods and each egg is carefully cemented onto the surface of the pod.

After a few days tiny, cream-coloured grubs or larvae hatch from the eggs. Those of *Algarobius* have well-developed legs and crawl around on, or burrow through, the pod until they find an undamaged seed; they then chew their way into the seed. The grubs of *Neltumius* have no legs and they burrow downwards through the eggshell and pod wall, directly into the underlying seed. While chewing through the plant material, the grubs of both species push the discarded material (frass) back into the empty eggshell, which then changes its appearance from almost transparent to white as it is filled up with frass. Once inside a seed, the larva (figs. 1c and 4) feeds on the contents of the seed, including the embryo, while it matures over a period of a few weeks. The larva moults (sheds its skin) three times during its

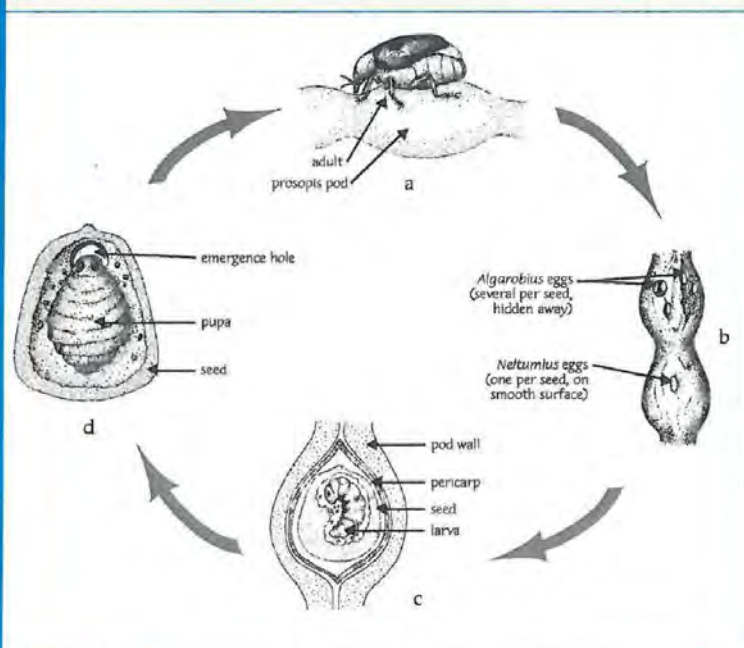


Figure 1. Life cycle of the prosopis seed beetles.

3.2 Prosopis seed beetles (*Algarobius prosopis* and *Neltumius arizonensis*)

development. If more than one larva enters the same seed, one larva will kill the others, and normally only one larva develops per seed.

After several weeks, when the larva has reached maturity, it tunnels up to the surface of the pod where it leaves a circular, weakened "trapdoor", which can be pushed out by the newly emerged adult. The larva then returns to the hollowed-out seed and pupates (fig. 1d). After a few days, an adult beetle emerges from the pupa and escapes through the trapdoor.

The beetles continue breeding throughout the year, and complete several generations per year. The larvae of *Algarobius* develop slightly faster than those of *Neltumius*. Growth rates of both species are dependent on ambient temperatures so the development times are most rapid in summer.

How to tell whether the prosopis seed beetles are present

Round exit holes are visible on the pods (fig. 5), indicating where adult beetles have emerged. It is impossible to distinguish the two beetle species by the exit holes alone. Usually white eggshells are easily distinguishable on the surface of the pods when *Neltumius* is active in an area, whereas the eggs of *Algarobius* are sheltered and therefore not easy to find.

Seed beetle damage to prosopis

The larvae of both species destroy the seed embryos and prevent the seeds from germinating. The pods remain nutritious to livestock in spite of the beetle damage and can still be used to provide stock feed. The seed beetles will not control the standing infestations of prosopis, but only reduce the number of seeds that are added to the seed bank in the soil. The seeds in the existing soil seed bank are very long-lived, however, and the effectiveness of the seed beetles will not be noticeable until this seed bank is exhausted.

The seed beetle species have dispersed widely and rapidly and at least one of the species is found in abundance wherever prosopis occurs in Southern Africa. There should therefore be no more need for redistribution of seed beetles within South Africa.

Despite this, levels of damage are often minimal because livestock and game ingest most seeds soon after the pods fall to the ground (in January/February) and before the larvae are able to fully colonise the pods. The larvae cannot survive in the digestive system of livestock. As a result, most seeds escape beetle damage unless infestations of the weed are fenced off to exclude livestock while the beetles are active. In fenced areas, beetles destroy up to 90 % of seed embryos within 8 months of the pods dropping to the ground.

Neltumius can account for more than half of the damaged seeds but usually destroys a smaller proportion of seeds than *Algarobius*. When both beetle species are present, *Algarobius* seems to compete more successfully than *Neltumius*, because the former species lays more eggs and its larvae develop faster. *Neltumius* avoids competition, however, by ensuring that its eggs are not laid near other eggs of its own species or those of *Algarobius*.

Algarobius attacks the seeds of all the invasive species and hybrids of prosopis in South Africa. *Prosopis chilensis*, which is the least invasive species in South Africa, seems to be the least suitable host plant for *Algarobius*.



Figure 3. An adult of *Neltumius arizonensis*.



Figure 4. Larvae of the seed beetles developing inside prosopis seeds.



Figure 5. Undamaged prosopis pods (bottom) and pods with escape holes, indicating where adult beetles have emerged (top).

3.2 Prosopis seed beetles (*Algarobius prosopis* and *Neltumius arizonensis*)

A few parasitic wasp species that normally parasitise native seed-feeding bruchids on our indigenous *Acacia* species have adopted *Algarobius* as a host, but, so far, levels of parasitism are low and there has not been a noticeable reduction in the population levels of the beetles. In certain areas, *Neltumius* is more severely parasitised by indigenous wasps than *Algarobius*, especially in the egg stage, which is more vulnerable on the surface of the pod.

CONTACT PERSONS

Consult leaflet 1.4 in this series for the most updated contact details.

- Biocontrol research: Weeds Research Division, ARC-PPRI (Rietondale), Private Bag X134, Pretoria 0001; Tel (012) 329 3269; Fax (012) 329 3278; e-mail weeds@plant2.agric.za. Alternatively: UCT.
- Supply of biocontrol agents: National Department of Agriculture, Directorate of Agricultural Land Resource Management (D:LRM), North-West Province.

FURTHER READING

IMPSON, F.A.C. & HOFFMANN, J.H. 1998. Competitive interactions between larvae of three bruchid species (Coleoptera) in mesquite seeds (*Prosopis* spp.) under laboratory conditions. *African Entomology* 6: 376-378.

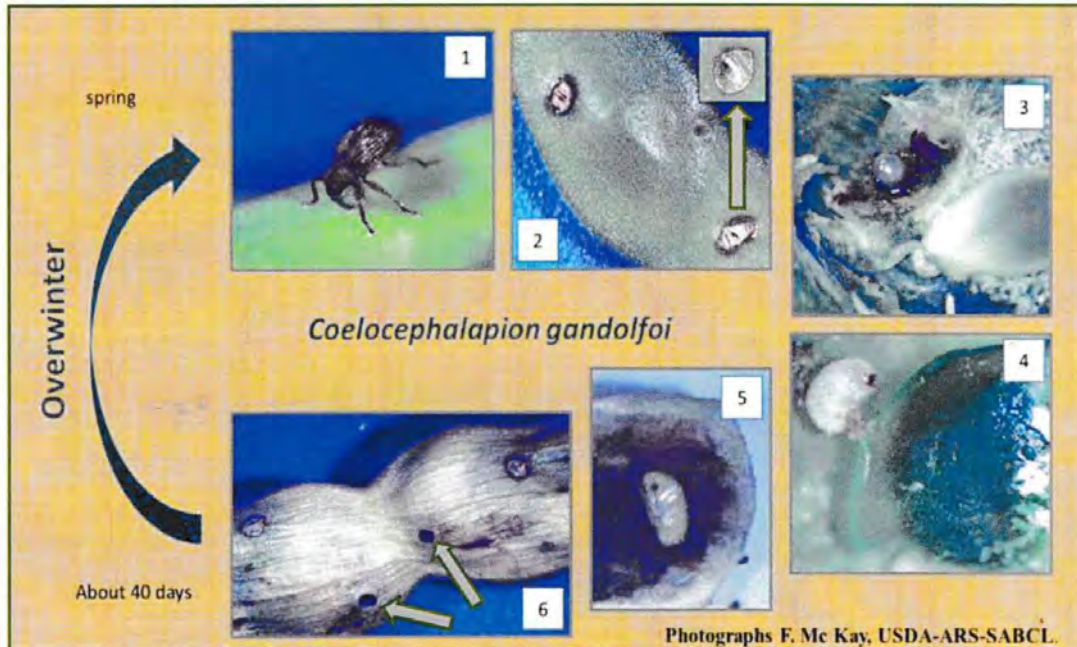
IMPSON, F.A.C., MORAN, V.C. & HOFFMANN, J.H. 1999. A review of the effectiveness of seed-feeding bruchid beetles in the biological control of mesquite, *Prosopis* species (Fabaceae), in South Africa. *African Entomology Memoir No 1*: 81-88.

ISBN 1-86849-182-X

© 2002 ARC-Plant Protection Research Institute (<http://www.arc-ppri.agric.za>)
Application for permission to reproduce or translate all or part of this publication should be made to: The Director, ARC-Plant Protection Research Institute, Private Bag X134, Pretoria 0001.

Page design: Sanet du Plessis. This leaflet was printed by United Litho, with financial assistance from the Working for Water Programme of the Department of Water Affairs and Forestry and the National Department of Agriculture.
Copies can be obtained from the librarian, ARC-PPRI at the above address.

**Die lewensiklus van *Coelocephalapion gandolfoi* (Coleoptera:Brentidae)
– 'n potensiële agent vir prosopis in Suid Afrika**



- 1) volwassenes vreet en lê eiers op jong groen peule in die lente
- 2) eiers word binne die peul gelê en die ingangslitteken bedek
- 3) elke eier word langs 'n jong saadjie gelê
- 4) nadat dit uitgebroei het, eet die larwe die ontwikkelende saad
- 5) die larwes word papies binne die saadhul
- 6) volwassenes ontluik deur 'n klein ronde gatjie in die peulwand te maak (pyle)

Ontwikkeling van eier tot volwassene duur ongeveer 40 dae, maar eiers sal eers volgende lente gelê word (wanneer jong groen peule weer beskikbaar is)



Vir meer inligting kontak: Carien Kleinjan: Catharina.kleinjan@uct.ac.za of Philip Ivey: p.ivey@ru.ac.za

Bron: McKay F, Gandolfo D (2007). Phytophagous insects associated with the reproductive structures of mesquite (*Prosopis* spp.) in Argentina and their potential as biocontrol agents in South Africa. *African Entomology* 15: 121-131

SEED-FEEDING MESQUITE BEETLES

(*Algarobius prosopis* and *Neltumius arizonensis*)

A natural enemy of

MESQUITE (*Prosopis* species)

in South Africa

11

DOSSIERS ON BIOLOGICAL CONTROL AGENTS AVAILABLE TO AID ALIEN PLANT CONTROL

DESCRIPTION

These are small beetles (up to 5 mm in length). *Algarobius* is a uniform fawn colour with elytra (hardened fore wings) that are darker than the rest of the body. *Neltumius* has a mottled black and white patchwork pattern over its entire body. The beetles are distinctive because the abdomen extends beyond the elytra. Their presence is easily noticeable by the occurrence of neat round holes in the mature seed pods of prosopis, both on the trees and on the ground.

LIFE CYCLE

Grubs of both species develop in mature seeds within mesquite seed pods. Eggs of *Neltumius* are glued singly on the surface of the pods and shells may remain in place for several months after the eggs have hatched. *Algarobius* eggs are laid in cracks and blemishes on the seed pods. Each grub enters and entirely destroys a single mesquite seed during its development. Pupation occurs within the hollowed out seed and adults emerge through distinctive holes on the surface of the pods.

FEEDING DAMAGE

Only the seeds of mesquite within the seed pods are damaged by the beetles. The seed pods and vegetative parts of the plants are not affected.

IMPACT ON MESQUITE

Although up to 95% of seeds produced by mesquite can be destroyed by these seed-beetles, they are probably having very little impact on the dynamics of mesquite invasions because seed pods are eaten by livestock and game before the beetles can utilise and destroy many of the seeds. As a result seed destruction by the beetles seldom reaches very high levels. Most seeds are ingested and pass through the gut of animals undamaged. Once dispersed in the veld, seeds are no longer suitable as a food source for the beetles.



Algarobius prosopis



Symptoms of beetle damage: adult emergence holes in pods



Neltumius arizonensis

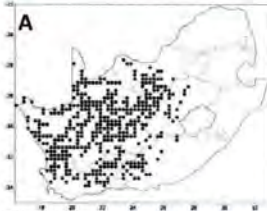


Author: J.H. HOFFMANN, Zoology Department, University of Cape Town, Rondebosch 7701

ADDITIONAL INFORMATION IS AVAILABLE. PHONE: Weedbuster Toll-free Helpline: 0800 005 376
WEBSITE: PPRI website is located via links from the Agricultural Research Council website: www.arc.agric.za



EVIPPE SP. #1
Prosopis leaf tying moth



Evippe sp. #1 as biocontrol agent

The 'Prosopis leaf tying moth', *Evippe* sp. #1, is originally from Argentina and first employed as biocontrol agent in Australia in 1998. Following rigorous host-specificity testing against African related species, this moth was released in South Africa in February 2021. It was then introduced into the field in the Northern Cape and North West Provinces of South Africa. Establishment is anticipated throughout the range of invasive *Prosopis* in South Africa (A) and Africa.

Description

The moth *Evippe* sp. #1 is an undescribed species, but moths from the genus *Evippe* belong to the family Gelechiidae. This moth has unique characters that distinguish it from other *Evippe* species already described. The mottled pale brown adults are around 4mm long, (B) and will take flight readily if disturbed. Despite their size, populations can be easily detectable in the field due to damage caused by the larvae.

Life cycle

The adult female lays eggs from a day after emergence and continues to do so throughout her life. Hatched larvae appear around eight days later; each then tunnels into a mature leaf pinnule. The mine is visible as a tiny pale blister. Within 3 ± 5 days the larva will moult into the second instar, continue to feed, and then exit to build leaf ties by webbing pinnules together and feeding and moulting within. This is repeated, and each time the larger-instar larva (C— large larva) will construct a larger leaf tie (E— Leaf ties), that incorporates more pinnules. Pupation of the fourth-instar larva takes place within the leaf tie (D— pupa), from where the adults later emerge. Development from egg to adult takes between 34 and 48 days. Adults usually survive more than a week, and may live up to three weeks.

Feeding damage and potential impact on invasive *Prosopis*

In Australia *Evippe* sp. #1 performs best in hot regions, where high levels of continuous defoliation have been observed. Substantial reductions in plant growth rates and seed production were documented, and some plant mortality was recorded. Subsequent population modelling suggested long-term declines in plant population density to result, even in the absence of significant mortality. We therefore anticipate *Evippe* sp. #1 to have a substantial impact on invasive *Prosopis* species in Africa, and likely to make the greatest biocontrol contribution of all established biocontrol agents on mesquite in Africa.

For more information contact:

ARC-Plant Health and Protection
infoweeds@arc.agric.za
Tel: 012-808-8000
www.arc.agric.za

Post-werkswinkel vraelys

Prosopis in die Noord-Kaap: n' MSc projek

Die doel van hierdie vraelys is om inligting vanaf die landelike omgewing te verkry rakende persepsies oor *Prosopis* boom indringing en die rol van werksinkels as deel van die algemene aanslag op *Prosopis* beheer.

Hierdie inligting gaan dan gebruik word in 'n navorsingsprojek om gemeenskap inisiatiewe te ontwikkel om *Prosopis* home te beheer.

Die inligting deurgegee in hierdie vraelys word veilig bewaar en is slegs beskikbaar vir die navorsers betrokke in die projek. Die inligting word ook slegs gebruik vir die projek en word geensins gekommunikeer aan ander partye nie. Deelname aan hierdie vraelys is vrywillig. Deelnemers kan enige tyd onttrek van die navorsing sonder nagevolge. Die inligting verkry uit hierdie vraelys sal op so wyse gebruik en bewaar word dat die deelnemers anoniem bly. Deelnemers aan hierdie vraelys moet kennis neem dat die inligting wat hul deurgee deel gaan vorm van 'n akademiese MSc proefskrif by Rhodes Universiteit en moontlik in akademiese artikels gepubliseer word.

Rakende die vrae: by die ronde kolletjies (bv by vraag 1) kan slegs een antwoord gegee word, die grys strepe (bv by vraag 2) vereis 'n geskrewe antwoord en die vierkantige blokkies kan verskeie opsies gekies word.

Etiese klaring nommer: SCI2018/033 (uitgereik deur die hoof van die RUESC).

* 1. Vrywaring: U, as anonieme deelnemer, neem kennis dat resultate verkry in hierdie vraelys deel vorm van 'n MSc proefskrif.

- Ja
- Nee

2. Kontak inligting

Naam en Van

Epos adres

Selfoon nommer

3. Ouderdom

- Jonger as 20
- 20-29
- 30-39
- 40-49
- 50-59
- 60-69
- 70-79
- 80 of ouer

4. Munisipale distrik waarin woonagtig

- | | |
|---|---------------------------------------|
| <input type="checkbox"/> Dawid Kruiper | <input type="checkbox"/> Ubuntu |
| <input type="checkbox"/> Tsantsabane | <input type="checkbox"/> Emathanjeni |
| <input type="checkbox"/> !Kheis | <input type="checkbox"/> Umsobomvu |
| <input type="checkbox"/> Kai !Garib | <input type="checkbox"/> Renosterberg |
| <input type="checkbox"/> Khai-Ma | <input type="checkbox"/> Thembelihie |
| <input type="checkbox"/> Nama Khoi | <input type="checkbox"/> Kgatelopele |
| <input type="checkbox"/> Richtersveld | <input type="checkbox"/> Sol Plaatjie |
| <input type="checkbox"/> Kamiesberg | <input type="checkbox"/> Magareng |
| <input type="checkbox"/> Hantam | <input type="checkbox"/> Phokwane |
| <input type="checkbox"/> Karoo Hoogland | <input type="checkbox"/> Dikgatlong |
| <input type="checkbox"/> Siyancuma | <input type="checkbox"/> Ga-Segonyana |
| <input type="checkbox"/> Siyatamba | <input type="checkbox"/> Gamagara |
| <input type="checkbox"/> Kareeberg | <input type="checkbox"/> Joe Morolong |

5. Was u by die 2019 werkswinkel in Kimberley, gereël deur AgriNK en Rhodes Universiteit?

- Ja
 Nee

6. Indien u by die Kimberley werkswinkel was, hoe suksesvol ag u die dag?

- Onsuksesvol
 Aanvaarbaar
 Redelik suksesvol
 Suksesvol
 Hoogs suksesvol

7. Indien u nie by die Kimberley werkswinkel was nie, wat het u verhoed om dit by te woon?

- Besikbaarheid van inligting
 Afstand
 Koste
 Tekort aan belangstelling
 Veels te besig
 Persoonlike redes

8. Hoe waarskynlik is dit dat die Kimberley werkswinkel 'n impak op u gehad het?

- Geensins
 Onwaarskynlik
 Waarskynlik
 Hoog waarskynlik

9. Wat is die waarskynlikheid dat u inligting verkry het by die Kimberley werkswinkel wat u voorheen nie gehad het nie?

- Hoogs waarskynlik
- Waarskynlik
- Onwaarskynlik
- Geensins

10. Was u by die werkswinkel gehou in Groblershoop op 16 Junie 2022?

- Ja
- Nee

11. Indien u by die werkswinkel was

- Was u tevrede
- Wou u meer inligting gehad het
- Was u teleurgesteld
- Sou u ander sprekers verkies het

Voorstelle vir die volgende werkswinkel:

12. Indien u nie by die Groblershoop werkswinkel was nie, wat het u verhoed om dit by te woon?

- Besikbaarheid van inligting
- Afstand
- Koste
- Tekort aan belangstelling
- Veels te besig
- Persoonlike redes

13. Wat is die waarskynlikheid dat die werkswinkel gehou in Groblershoop in 2022 'n impak op u gehad het?

- Hoogs waarskynlik
- Waarskynlik
- Onwaarskynlik
- Geensins

14. Indien u by die Groblershoop werkswinkel was, hoe suksesvol ag u die dag?

- Onsuksesvol
- Aanvaarbaar
- Redelik suksesvol
- Suksesvol
- Hoogs suksesvol

15. Wat is die waarskynlikheid dat u 'n tweede werkswinkel, gehou in 2022, sal bywoon?

- Hoogs waarskynlik
- Waarskynlik
- Onwaarskynlik
- Geensins

16. Wat is die waarskynlikheid dat u, u bure en kollegas sou aanraai om 'n werkswinkel by te woon?

- Hoogs waarskynlik
- Waarskynlik
- Onwaarskynlik
- Geensins

17. Na die Groblershoop werkswinkel: Wat is die waarskynlikheid dat u die gebruik van biologiese beheer vir die beheer van *Prosopis* aan u bure, mede-boere en/of kollegas sal voor stel?

- Hoogs waarskynlik
- Waarskynlik
- Onwaarskynlik
- Geensins

18. Na die Groblershoop werkswinkel: Wat is die waarskynlikheid dat u die gebruik van kleinskaalse bestuursplanne vir die beheer van *Prosopis* aan u bure, mede-boere en/of kollegas sal voor stel?

- Hoogs waarskynlik
- Waarskynlik
- Onwaarskynlik
- Geensins

19. Waar verkry u inligting rakende

Boerderypraktyke (bv. bewaringsboerdery en drakrag)

Prosopis bome (bv. plant eienskappe, beheer, tydsberekening van beheer en opvolg behandeling)

Tipes gif vir indringerplante en die aanwending daarvan

Biologiese beheer (bv. navorsing, biobeheer metodes en insekte)

20. Wat is die waarskynlikheid dat u die gebruik van werkswinkels aan u bure, mede-boer en/of kollegas sal aanraai, om probleme in die gemeenskap op te los?

- Hoogs waarskynlik
- Waarskynlik
- Onwaarskynlik
- Geensins

3047

3048

3049

3050 **Appendix F: Future workshop suggestions survey**

Werkswinkel Voorstelle

Prosopis in die Noord-Kaap: n' MSc Projek

Baie dankie vir u belangstelling in die reeling van 'n tweede Indringer Werkswinkel in 2022, in samewerking met die Rhodes Universiteit Sentrum vir Biologiese Beheer. Die beoogde werkswinkel sal dien as geleentheid om inligting uit te ruil en kennis te neem van die verskeie projekte en inisiatiewe rakende indringer beheer in die Noord-Kaap asook die navorsing en steun daaragter.

1. Besonderhede

Naam en Van

Organisasie/Besigheid/Boerdery

Epos address

Selfoon nommer

2. Ek stel belang in periodieke eposse oor die verloop van Prosopis navorsing en beheer

Ja

Nee dankie

Sit my eerder op die Whatsapp-groep

3. Voorstel van waar die volgende werkswinkel gehou moet word (dorp naam):

4. Voorstel van wanneer die volgende werkswinkel gehou moet word:

September

Oktober

November

Desember

3051

3052

Prosopis Werkswinkelreeks

1. Prosopis werkswinkelreeks: vraelys

Baie dankie vir u belangstelling in die werkswinkelreeks, in samewerking met die Rhodes Universiteit Sentrum vir Biologiese Beheer en georganiseerde landbou.

*** 1. Besonderhede**

Naam en Van

Organisasie/Besigheid/Boerdery

Epos address

Selfoon nommer

2. Ek was by die sessie gehou in:

- Brandvlei
- Kenhardt
- Upington
- Prieska
- Williston

3. Hoe het u te hore gekom van die werkswinkel reeks?

4. Sou u die sessie wat u bygewoon het, as suksesvol beskou:

- Hoogs waarskynlik
- Waarskynlik
- Onwaarskynlik
- Hoogs onwaarskynlik

5. Is u tevrede met die sprekers wat die dag teenwoordig was?

- Hoogs waarskynlik
- Waarskynlik
- Onwaarskynlik
- Hoogs onwaarskynlik

6. Watter ander onderwerpe sou u graag wou bespreek by die werkswinkel, of enige ander kommentaar oor die sessies?

7. Is u bewus van die biologiese beheer agente wat gebruik word op Prosopis?

- Ja
- Nee

8. Kan u 'n voorbeeld/voorbeelde gee van die biologiese beheer agente wat vir Prosopis gebruik word?

9. Wat is volgens u die waarskynlikheid dat die biologiese beheer agente suksesvol sal wees om die indringing van Prosopis te beheer?

- Hoogs waarskynlik
- Waarskynlik
- Onwaarskynlik
- Geensins

10. Wat is volgens u die waarskynlikheid dat die biologiese beheer agente 'n impak sal hê op inheemse bome?

- Hoogs waarskynlik
- Waarskynlik
- Onwaarskynlik
- Geensins

11. Is u tans besig met die bestuur van Prosopis op u eiendom?

- Hoogs waarskynlik
- Waarskynlik
- Onwaarskynlik
- Geensins

12. Wat verhoed die bestuur van Prosopis op u eiendom?

13. Watter hulpmiddels is volgens u nodig vir u om Prosopis op u grond te bestuur?

3056

3057

3058

01

Nuusflits Uitgawe 2 November 2022

NUUSFLITS



Baie Dankie

VIR U TEENWOORDIGHEID BY
DIE PROSOPIS SESSIES
GEHOU VANAF 26 OKTOBER

Baie dankie ook vir diegene wat steeds belangstel en betrokke is waar hulle kan, al kon julle nie die werksinkels bywoon nie, jul gewilligheid gaan nie ongesiens nie.

Prosopis werksinkel sessies

'n Reeks werksinkel sessies het plaas gevind vanaf 26 Oktober 2022 tot 1 November 2022, onderskeidelik in Brandvlei, Kenhardt, Upington, Prieska en Williston. Die sessies is gereël in samewerking met die Rhodes Universiteit se Sentrum vir Biologiese Beheer in Grahamstad asook AgriNK. Graag bedank die organiseerders die betrokke venues, sprekers en spysenieringsmaatskappye.

Die sessies is baie goed bygewoon, met verteenwoordigers wat ver gery het om van die sessies by te woon. Die sessies was meer gefokus op die maontlike gebruike van Prosopis biomassa, as 'n maontlikheid van ekonomiese ontwikkeling in die platteland of as 'n manier om sommige van die koste van Prosopis beheer te verhaal.

The pillars of Integrated Pest Management

Integrated Pest Management (IPM) is defined in (Irwin, 1999) as an integrated system that functions in the context of an environment associated with a certain pest species, and the dynamics of the pest population. This system utilizes all applicable techniques to maintain pest levels at population numbers low enough as to not cause economic injury, thus these methods must be economically and environmentally sound. The integratory aspect of the management system relies on the simultaneous use of a combination of tactics, all with the aim of managing a single pest species as to lessen and control its economic injury level (Denholm et al., 1998; Irwin, 1999). IPM can function as a knowledge-intensive system to counteract the industry wide reliance on insecticide/herbicide, resulting in the possibility that increased knowledge results in lowered spraying (Stone and Flachs, 2018).



Chemical control

Chemical control is widely used by medium- and large-scale commercial farmers, as it has the advantage of being relatively easy to use effectively (with rapid visible results). It can be used as remedial or preventative measures and is often used for specific insect pests as well as weeds, bacteria and fungi- although a large number of chemicals in use pose grave health hazards to animals and humans (Irwin, 1999).



Biological control

Biological control is the natural fallback control measure when chemical control tactics prove ineffective. Biological control consists of importation and spread of natural enemies to reduce the density and resulting impact of the pest species as well as the use of the by-products and chemicals released by natural enemies to control the feeding behaviour of the pest (Irwin, 1999).



Cultural control

Cultural control can also be referend to as habitat manipulation as the habitat is changed and adapted to be more favourable to the natural enemies and less favourable to pests, resulting in the shifting of the pre-existing population dynamic towards a more balanced agroecosystem (Irwin, 1999)

Denholm, I. et al. (1998) 'Challenges with managing insecticide resistance in agricultural pests, exemplified by the whitefly *Bemisia tabaci*', *Philosophical Transactions: Biological Sciences*, 353, pp. 1757-1767.

Irwin, M. E. (1999) 'Implications of movement in developing and deploying integrated pest management strategies', *Agricultural and Forest Meteorology*, 97, pp. 235-246.

Stone, G. D. and Flachs, A. (2018) 'The ox fall down path-breaking and technology treadmill in Indian cotton agriculture', *The Journal of Peasant Studies*, Taylor & Francis, 45, pp. 1272-1296. doi: 10.1080/0306615020171291505.

Economic threshold value, economic injury value and action threshold value



Economic threshold is the density at which control measures should be determined to prevent an increasing pest population from reaching the economic-injury level. The economic threshold is lower than the economic-injury level to permit sufficient time for the initiation of control measures and for these measures to take effect before the population reaches the economic-injury level (Pringle, 1997, 2006; Stern et al., 1959).

Economic injury level is the lowest population density that will cause economic damage. This means that a given number of pests results in a given amount of injury (Pedigo et al., 1986). Economic damage is the amount of injury which will justify the cost of artificial control measures. The economic injury level varies in terms of area, season as well as due to changes to the economic values of crops (Pringle, 2006; Stern et al., 1959)

The action threshold is used in literature to emphasize the meaning of the economic threshold, since the economic threshold is the population density of a pest at which control action should be initiated as to prevent the increasing pest population from reaching the economic injury level (EIL). Thus the term 'action threshold' is used to describe the threshold level of population density that, when reached, necessitates the implementation of a pest population control action to stop the pest population from reaching the economic injury level where after yield and economic losses may occur (Pedigo, 2020).

Pedigo, L.P. 2020. Economic threshold and economic injury levels. In: E.B. Radcliffe, W.D. Hutchison, & R.E. Carnechada, eds. Radcliffe's IPM World Textbook. St. Paul: University of Minnesota. <https://ipmworld.nimn.edu/pedigo>.

Pedigo, L.P., Hutchins, S.H. & Highty, L.G. 1986. Economic injury levels in theory and practice. *Annual Review of Entomology*, 31(1):341-368.

Pringle, K.L. 1997. Economic thresholds, statistical error rates, the environment and reality. In: Proceedings of the Joint Congress of the Entomological Society of Southern Africa (11th congress) and the African Association of Insect Scientists (12th congress), Stellenbosch.

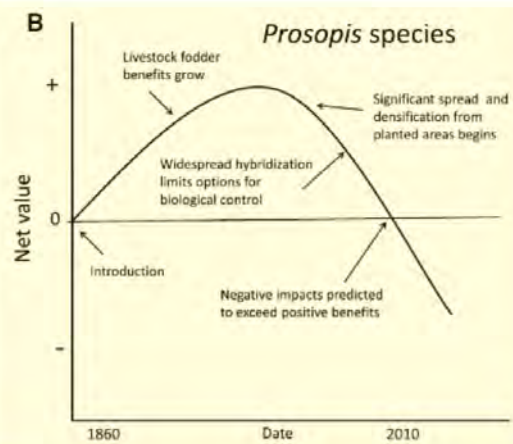
Pringle, K.L. 2006. The use of economic thresholds in pest management: apples in South Africa. *South African Journal of Science*, 102(5-6):201-204.

Stern, V.M., Smith, R.J., van den Bosch, R. & Hagen, K.S. 1959. The integrated control concept. *Hilgardia*, 29:81-101.

IPM and Prosopis

Considering *Prosopis* on a property, each management unit can be analyzed according to the graph on the right.

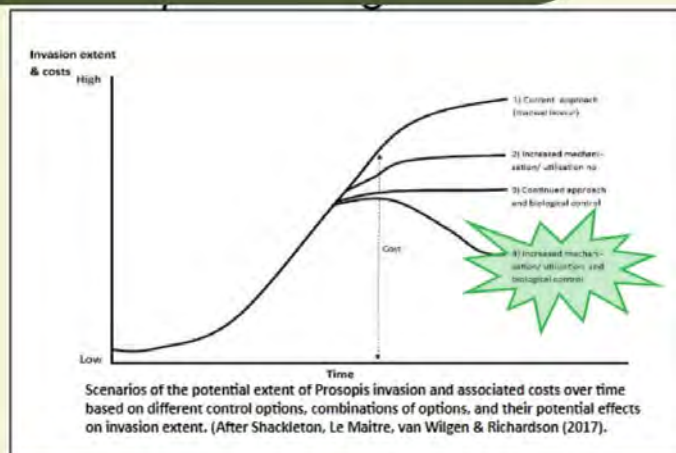
When first introduced to a new area, or management unit, *Prosopis* has benefits for the area in terms of shade, fodder and wood. The costs of control is lower than the perceived benefits (below economic threshold). As the density increases so does the net value of the invasion in each management unit (closer to action threshold), until eventually the invasion is so dense that the benefits are no longer received by the property owner due to increased negative impacts. The cost of control is now considerably higher.



Wise, R.M., van Wilgen, B.W. and Le Maitre, D.C. (2012). Costs, benefits and management options for an invasive alien of *Arid Environments* 84, 80 – 90.

The potential extent of *Prosopis* invasion and associated costs over time can be described via four scenarios:

1. The current approach of only using manual labour, sometimes in conjunction with herbicide. This approach has so far been inadequate to address the invasion of *Prosopis* in the Northern Cape, especially with rising costs and safety concerns.
2. Controlling *Prosopis* via increased mechanisation may be more successful, unfortunately this increases the initial cost of control, but the efficacy is improved.
3. The continued approach of waiting for biological control to address the problem on their own.
4. A integrated, whole-farm approach, with increased mechanisation, utilisation and implementation of biological control



Scenarios of the potential extent of *Prosopis* invasion and associated costs over time based on different control options, combinations of options, and their potential effects on invasion extent. (After Shackleton, Le Maitre, van Wilgen & Richardson (2017)).

Prosopis Biocontrol

WHY?



Natural herbivores are not present in introduced range



Biological control is used to try and reduce plant populations to similar levels as in native ranges



Cost effective method to address continued *Prosopis* invasion



Environmentally safe, compared to incorrect herbicide use



Biocontrol was originally limited to agents that reduce viable seed

History of seed feeding beetles for biological control of *Prosopis*



Algarobius prosopis

- If pods are left undisturbed on the ground, *Algarobius* can cause >90% damage to these seeds
- Even though livestock and wildlife eat pods and disperse the seed, the beetle still manages to locate and damage seeds

1987



Bruchidius submaculatus

- Indigenous
- Less than 1% seed damage

1991



Neltumius arizonensis

- Less abundant than *Algarobius prosopis*
- Only lays eggs in pods which are still in good condition
- More vulnerable to attack by parasitoids
- Prefers mature seeds above green pods

1992

Graham Harding: Die bestuur van *Prosopis*, en hoekom dit belangrik is

Dr Graham Harding is al dekades betrokke by die beheer van verskeie indringer plante in Suid-Afrika. Tans is hy werksaam by sy eie maatskappy, Invader Plant Specialists (Pty) Ltd. Hy het in 1983 met *Prosopis* navorsing in die Van Wyksvlei omgewing begin. Gedurende sy tyd in die Noord-Kaap het hy gifproewe vir 'n aantal maatskappye gedoen, sowel as verskillende beheermetodes getoets (insluitende giftoediening deur die gebruik van 'n helikopter). Sy navorsing het ook die benutting van *Prosopis* materiaal ingesluit, byvoorbeeld die produksie van houtskool en die gebruik van peule vir veevoer.

Dr. Harding is van mening dat almal 'n rol te speel het in indringerbeheer, en dat die grondeienaar self 'n aktiewe rol daarin moet speel, veral siende dat hul die meeste kennis het oor hul grond en die beste geposisioneer is om effektiewe beheer toe te pas.

Hy het by die werkwinkel praktiese voorbeelde uitgewys van hoe die bestuur van *Prosopis* benader moet word, uit 'n boerdery beplanning oogpunt. Hy het klem daarop gelê dat mens nie moedeloos moet word en jou vas staar in die digte bosse nie, maar om altyd perspektief te behou.



Graham Harding: Die bestuur van *Prosopis*, en hoekom dit belangrik is

Graham raai aan om te begin deur die plaas te karteer op byvoorbeeld GoogleEarth, en al die sleutel landmerke, eienskappe en enige addisionele data by te voeg.

Daarna word die ingedringde areas gemerk in grade van digtheid (swaar, medium, lig, geen).

Soos wat mens dan ingaan op die plaas in GoogleEarth, word meer en meer detail sigbaar, wat dan geïdentifiseer en gemerk kan word.

Die neem van fotos is ook krities belangrik om perspektief te behou, en natuurlik om die vordering vas te lê.

Die kaart en fotos dien dan as 'n konkrete beginpunt, wat verhoed dat die skaal van indringing op die besitte grond oorweldigend raak (wat baie mense verhoed om 'n begin te maak).

In sy praatjie het Graham ook die gereedskap wat beskikbaar is vir indringing bestryding, bespreek.

Biobeheer is die verbeelde ideaal, siende dat dit geen insette vanaf die boer vereis nie. Ongelukkig is dit meer effektief om biobeheer met ander beheer metodes te kombineer.

Dit is krities belangrik om die regte plantdoder en die regte toediensingsmetode te kies.

By blaarbespuiting is die bedekking die bepalende faktor in of die bome gaan vrek, en of die probleem vererger. Dit is ook die geval by 'cut stump' behandelings, die hele stomp moet deeglik bedek word direk nadat die boom afgesny is, anders gaan dit onvoldoende wees om die boom te dood. Die boom moet ook verkieslik enkelhoogte afgesny word.

Indien van lugbespuiting gebruik wil word, beklemtoon Graham die belang van professionele hulpgebruik 'n geregistreerde PCO (Plant Control Officer) vlieënier wat nadink watter voertuig hul gebruik (drone, helikopter of vliegtuig).

Prosopis foliar spray times

Graham Harding het dekades se ervaring met die toediening van plantdoder op verskeie indringer plante in Suid-Afrika. Hier deel hy belangrike punte rakende die toediening van gif op Prosopis spesies.

The following is an exact from the GARLON Max label of Corteva. These points relate specifically to their product, but I see no reason why these restrictions should not apply for any foliar applied herbicide.

The herbicidal response is **strongly influenced by foliage condition, stage of growth and environmental conditions**. For optimum control, **apply when new growth foliage has turned from light to dark green**, when soil temperature is above 24° C at a depth of at least 30 cm and soil moisture is adequate for plant growth. Product performance may be adversely affected if application is **made before the plant foliage has turned from light to dark green or if foliage has been injured or removed by a late frost, insects, hail or plant diseases**.

Do not treat if plants exhibit new (light green) terminal growth in response to recent heavy rainfall during the growing season.

Do not spray target plants when drought signs are evident or showing signs of stress, such as leaf drop. After a drought some plant species remain under stress and require a recovery period following rainfall. Signs of stress may not be evident during this recovery period. Allow time for plants to fully recover after rainfall before applying foliar treatments. Should this occur, provision should be made for follow-up treatments.

Avoid spraying trees in autumn when the waxy layer on the leaves have accumulated.

Unsatisfactory control will be obtained if spraying earlier in spring, when most of the new growth present consists of recently emerged stems with immature leaves.

In this respect it is recommended that **spraying should not be undertaken before November**, by which time most of the new stems will have emerged and produced mature leaves – turned from light to dark green.

—Graham Harding

Africa Data Technologies: houtskool en biochar



Wihan Bekker en **Jean Pierre du Plessis** is mede-stigters van African Data Technologies, 'n maatskappy wat hom beywer vir meer omgewingsvriendelike praktyke. Hul werk in die gebruik van die hout verkry vanaf indringer boom beheer is 'n interessante projek, met moontlikhede in die Noord-Kaap.

African Data Technology (ADTech) is 'n maatskappy met die fokus om oplossings tot volhoubaarheid kwessies te bewerkstellig. Hulle werk tans aan 'n platform vir die ontwikkel van projekte wat klimaatsverandering aanspreek.

Wihan Bekker:
wihan@africandata.tech
071 859 6656

Die maak van "biochar" in lae koste "kilns" uit indringerhout en ander landbou materiaal wat gewoonlik gebrand word, bied 'n moontlike oplossing om koolstof te stoor, wat ook 'n aantal voordele vir grondgesondheid inhou. Daar is tans 'n groot belangstelling in die befondsing van sulke projekte internasionaal deur "carbon credits".

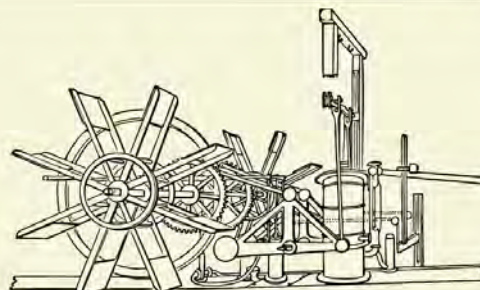
Video: [ADTech in die VSA](#)

ADTech is tans besig met 'n paar projekte in die Wes-Kaap, insluitend die maak van biochar met die hulp van internasionale befondsing. Hulle is ook in gesprek met Philip Ivey van Rhodes Universiteit oor die moontlikheid om soortgelyke projekte in die Noord-Kaap te loots, met *Prosopis* as die brandstof.

Video: [ADTech proses in Tulbagh](#)

Die ondersoek sal nou afhanklik wees van die insigte van boere om te bepaal of daar 'n nut aan biochar is in boerdery praktyke, die praktiese probleme en kostes wat met indringer beheer gepaardgaan, sowel as modelle en koste benodig om 'n biochar model sinvol toe te pas. —*Jean Pierre du Plessis*

NES: Natural Engineering Consultants



Dirk Oosthuizen van NES Consult was een van die sprekers teenwoordig tydens die werkwinkel reeks. NES Consult en Natural Homes is maatskappy wat dien as voorbeeld vir die gebruik van indringer biomassa, insluitende Prosopis. Sodoende kan belangstellendes gaan vir opleiding oor hoe om hul eie produkte te maak, of 'n gevoel vorm van die NES Consult struktuur om sodoende die biomassa op hul eiendom te gebruik.

"We pride ourselves on being approachable, reliable and honest by making sure that we deliver on our promises. As an associate and managed by Dirk Oosthuizen, NESconsult practices a remarkably simple business ethic of providing quality and personalised engineering services from the humble head office in Bos 7 Kuilsriver, Cape Town in the Western Cape for Africa. We have established Associate offices in Kuilsriver, Brackenfell, Knysna, Vredenburg, Nelspruit, Pretoria. We have directly and indirectly been involved in projects as far as Malawi and the Congo. By personally overseeing each design from start to finish, Dirk and the team are able to turn client's visions into reality. Through guidance and assistance at every phase of any project the NES team's expertise and personal approach ensures that you get exactly what you need with no surprises along the way. With now over over 200 years combined experience, Dirk and the team of NES Consultants understand all aspects of the business, construction process and through a close in house association of architects, engineers, surveyors, planning authorities, agents and interior designers, NES is able to offer a one-stop capital project , construction design solution for our customers. This includes on appointment vendor negotiations to ensure you get the best possible solutions at the best possible price. NES is driven by passion and pride with a track record that speaks for itself. NESconsult and its associates are registered members of various Registration councils and a Builders regulatory body as of the related industry whose goal is to assist and protect consumers against substandard work and poor quality materials."

- From the NES Website

NES Consult

021 903 2493

NES website

Natural Homes Website

Mannabrew: die gebruik van *Prosopis* peule

Brandt Coetzee en sy familie het in Prieska begin om onder ander gesondheidsprodukte van Prosopis peule te maak. Die vervaardiging van 'n alternatief vir koffie, was 'n natuurlike gevolg.

"The story of MannaBrew starts in South Africa, deep in the heart of the Karoo in a small town called Prieska. It is here, on the banks of the mighty Orange River, where farmlands are being taken over by thousands of invasive thorn trees, known as Mesquite (*Prosopis*) trees. While most local people regard these trees as a nuisance, one family has discovered that the deep-yellow seed pods that grow on these trees are in-fact an amazing superfood.

Through 26 years of working with the Mesquite trees, the two brothers, Aam and Brandt Coetzee discovered that, besides other superfood products, you can actually make "coffee" with the Mesquite seedpods. Well, each year, a small window of only 2 to 3 weeks allows us to harvest a year's supply of the Mesquite seedpods before the summer rains start to fall. But this small harvesting window brings a smile to the faces of the locals in this poverty-stricken Karoo town. For these people, it is an opportunity to go into the field and collect the pods, which are then purchased from them according to the weight they have collected. This helps to provide them with seasonal work and supports their local economy. The pods are sorted by hand to ensure they are of the highest quality, before being weighed, put into bags, and transported to Somerset West, in the Western Cape province of South Africa.

MannaBrew contains no caffeine, but the essential sugars from the Mesquite beans are known to energise and uplift, like caffeinated coffee, but without the any side effects. Once you have tasted MannaBrew, everything else might taste a bit bland in comparison."

-From the MannaBrew website

[MannaBrew Website](#)



[MannaBrew Youtube](#)



Algemene kommunikasie kanale



082 443 0728



Centre for
Biological
Control-CBC



t.me/NKprosopis



Rhodes
University,
Grahamstown,
EC



@rhodesunicbc



grethavs5@gmail.
com



p.ivey@ru.ac.za

3072

3073

3074

3075 **Appendix I: Follow-up questionnaire 2023**

11/2023, 8:04 PM Prosopis in die Noord-Kaap: Opvolg vraelys

Prosopis in die Noord-Kaap: Opvolg vraelys

Baie dankie vir jou volgehoue belangstelling en deelname in die beheer van Prosopis in die Noord-Kaap. Die onderstaande vraelys vorm deel van 'n Meestersgraad studie aan die Rhodes Universiteit se Sentrum vir Biologiese Beheer.
Thank you for your continued interest and participation in the control of Prosopis in the Northern Cape. The below questionnaire forms part of a Masters degree study at the Rhodes University Centre for Biological Control.

1. Email *

2. 1. Maak jy gebruik van 'n Prosopis bestuursplan op jou eiendom? Hoekom of hoekom nie? Indien ja, sou jy bereid wees om dit te deel?
Do you have a Prosopis management plan for your property? If so, are you willing to share it? If not, is there a reason why not?

3. 2. Is jy bewus van Prosopis biologiese beheer agente en maak jy gebruik van hulle op jou eiendom? Hoekom of hoekom nie?
Are you aware of Prosopis biological control agents and do you use them on your property? Why or why not?

<https://docs.google.com/forms/d/1AKDMG70HXyK8EYVQzMP1L08IMG2YapTDw47500x4wdt> 1/5

3076

3077


3078

3079

4. 3. Benoem asseblief die onderstaande insek, en sy funksionering as *Prosopis* biologiese beheer agent.
Please name the below insect, and their function as *Prosopis* biological control agent.



5. 4. Noem asseblief die insek spesie wat die onderstaande letsels op *Prosopis* peule veroorsaak.
Please name the insect species that cause the below lesions on *Prosopis* pods.

Captionless image

3080

3081

6. 5. Wat meer sou jy van die Rhodes Universiteit Sentrum vir Biologiese Beheer wou gehad het?
What more would you have liked from the Rhodes University Centre for Biological Control?

7. 6. Is jy bewus van die werk wat die Rhodes Universiteit Sentrum vir Biologiese beheer op *Prosopis* doen?
Are you aware of the work that the Rhodes University Centre for Biological Control is doing on *Prosopis*?

8. 7. Is jy tevrede met die navorsing/werk wat die Rhodes Universiteit Sentrum vir Biologiese beheer lewer?
Are you satisfied with the research/work carried out by the Rhodes University Centre for Biological Control?

3082
3083
3084
3085
3086

9. 8. Wat is die hoof bekommernisse wat jy het as boer/grondeienaar? (Veral in terme van boerdery bestuur).
What are the major concerns you have as a farmer/property-owner?
(Especially in terms of farm management).

10. 9. Is *Prosopis* deel van jou top vyf bekommernisse op jou eiendom?
Is *Prosopis* one of your top five concerns on your property?

11. 10. Was jy teenwoordig gewees by enige van die *Prosopis* werksinkels gehou in 2022? Hoekom of hoekom nie? Was dit vir jou van waarde?
Did you attend any of the *Prosopis* workshops hosted in 2022? Why or why not?
Was it of value to you?

3087

3088

3089

- 12. 11. Sou jy in die toekoms nog *Prosopis* werksinkels bywoon? Hoekom of hoekom nie?
Would attend further *Prosopis* workshops in the future? Why or why not?

- 13. 12. Dink jy daar is 'n rol te speel (deur 'n instelling of 'n individu) om die beheer van *Prosopis* in die Noord-Kaap te koördineer en bestuur?
Do you think there is a role to play (either by an institution or an individual) to coordinate and drive the management of *Prosopis* in the Northern Cape?

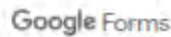
- 14. 13. Sosiale media skakels
Social media links:

Telegram: <https://t.me/NKprosopis>
WhatsApp groep: <https://chat.whatsapp.com/JCnC7RG3eABCxdvP2d2UHG>

Mark only one oval.

Dankie! Thank you!

This content is neither created nor endorsed by Google.



3090
3091
3092
3093
3094
3095
3096
3097
3098
3099

**PROSOPIS BESTUUR
IN DIE NOORD-KAAP**

Rhodes Universiteit
Sentrum vir Biologiese
Beheer

**15 JUNIE 2022:
GROBLERSHOOP**

INDRINGER WERKSWINKEL

PROSOPIS VESTIGING EN BEHEER GESKIEDENIS

BIOLOGIESE BEHEER IN DIE NOORD-KAAP

BIOLOGIESE BEHEER AGENT TELING EN VRYLATING

KLEINSKAALSE PROSOPIS BESTUURPLAN

**GROBLERSHOOP: THE
HEDGEHOG PADSTAL
AND ORANGE RIVER
CELLARS TASTINGROOM**

**REGISTREER AANLYN BY:
[HTTPS://WWW.SURVEYMONKEY.COM/R/KMP5899](https://www.surveymonkey.com/r/kmp5899)**

@PROSOPIS_BESTUUR

3103
3104
3105
3106
3107
3108
3109
3110
3111
3112
3113
3114
3115
3116
3117
3118
3119
3120
3121
3122
3123
3124
3125
3126
3127
3128
3129
3130
3131

Fin