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Where leaders learn

Acacia dealbata invasion and clearing in Upper Tsitsana communal areas of South Africa; human perceptions and ecological impacts

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Declaration

I, Nwabisa Coka, hereby declare that this thesis was written by myself, and that the work contained herein is my original work that I carried out under the supervision of Associate Professors Sheunesu Ruwanza and Gladman Thondhlana. All the sources and contributions have been duly acknowledged within the text and the reference list. The thesis is submitted in fulfilment for the degree of Master of Science in Environmental Science in the Faculty of Science at Rhodes University, South Africa and has not been submitted for any other degree or professional qualification except as specified.

Signature: N Coka Date:29/01/2024

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Abstract

The number of invasive alien plants in South Africa and globally continue to increase mostly due to increased human movement and climate change. It is estimated that approximately 10 000 hectares of South Africa's terrestrial land is invaded by invasive alien species. Recent studies have reported that invasion by invasive alien plants cost South Africa billions of Rands every year through loss of water and ecosystem services. Although much has been done to understanding invasion trends, patterns, and processes in South Africa, little is knowns regarding human benefits linked to alien plant invasion as well as human perceptions regarding management interventions, particularly clearing by the national Working for Water programme. This thesis took a socio-ecological approach to assess (i) local people perceptions and knowledge of *Acacia dealbata* invasion and clearing, and (ii) extent of grazing grass diversity and composition recovery following *A. dealbata* clearing. To answer the above-mentioned objectives, both qualitative (face-to-face interviews) and quantitative (vegetation surveys) methods were used in grasslands located in upper Tsitsana catchment, South Africa.

Results from the 165 interviews conducted in six villages show that most villagers are aware of *A. dealbata* in the area, but do not know that it is an invasive alien plant. Respondents accrue several benefits from the plant that include firewood (98% across all villages), construction pools (34% across all villages), and shade (3% across all villages). Respondents identified several costs associated with *A. dealbata* invasion, such as roots damage to houses (37% across all villages), hindering growth of crops (15% across all villages), and takes up yard space (29% across all villages). Most of the villages ranked the effects of *A. dealbata* on grazing as highly severe. Villages indicated that the Working for Water clearing programme presents them with socio-economic benefits such as employment and money. Some villagers noted that the clearing of *A. dealbata* in the area restores grazing grass (62% across all villages) and water (32% across all villages). Based on these interview survey results, the study concludes that *A. dealbata* has both costs and benefits that support local people's livelihoods; therefore, its management should consider views for local users.

Grass surveys conducted in 1 m^2 quadrats that were replicated 15 times across four paired *A. dealbata* cleared and grassland sites showed that the removal of A. dealbata facilitates the recovery of native grasses. Of the 14 different grazable grass species that were identified across all quadrats only one (*Bulbostylis* sp.) is not palatable to livestock. Although grass cover was significantly ($p < 0.05$) higher in the grasslands than the cleared patches, grass richness was significantly ($p < 0.05$) higher in the cleared patches an indication that recovery of different grasses is taking place. Based on these vegetation survey results; the study concludes that recovery of grazing grasses after *A. dealbata* clearing four years ago is following a positive trajectory as the cleared sites are looking like the grassland sites. Overall, the study recommends that management of *A. dealbata* in Tsitsana landscape requires a socio-ecological approach to understand user benefits whilst at the same time developing measure to control the plant. The study has provided evidence that *A. dealbata* clearing facilitates passive restoration of grazing grass and local villages are aware of these restoration benefits.

Keywords: Ecological restoration, invasion, management, socio-ecological perceptions, Working for Water.

Chapter 1
General introduction

1.1. Introduction

Invasive alien species are a well-recognised driver of social-ecological change globally (van Wilgen et al. 2011; van Wilgen et al. 2020) and a key driver of land degradation and biodiversity loss in South Africa, as they often alter ecosystem composition, structure, functioning and processes (Seebens et al. 2018; Smith et al. 2018). As a result, problems associated with invasion by invasive alien species, particularly plants, have increased rapidly world-wide in recent decades (van Wilgen et al. 2011). Invasive alien species are species that are non-native to an area or ecosystem and have potential to cause socio-ecological harm and affect human health (CBD 2006). From a plant perspective, these are introduced plants that spread outsider their native range or natural distribution and have the potential to threaten biodiversity (Richardson et al. 2000). The spread of invasive alien plants is linked to rapid globalisation and movement of people, and people are viewed as the driver of biological invasion (van Wilgen et al. 2020). For example, the migration of people from different continents to South Africa is linked with the deliberate and accidental introduction of some of the problematic invasive alien plants in the country (van Wilgen et al. 2020). For example, *Acacia* and *Eucalyptus* are the Australian species there were introduced in South Africa in the 1800s for various reasons that include forestry and sand stabilization, and today they are the most invasive in the country (Richardson et al. 2020; Hirsch et al. 2020). Consequently, the introduction of invasive alien plants in South Africa has been estimated to cost billions of Rands to the South African economy through water and biodiversity loss as well as investment in controlling these species (van Wilgen et al. 2020).

The movement of invasive alien species is human driven, through intentional and unintentional distribution of species to various parts of the world (Vanderhoeven et al. 2011). Upon arrival of invasive alien plants in new areas, alien species become invasive, thereby altering ecosystem processes, or causing problems for human activities (Richardson and Rejmánek 2011). For example, Australian *Acacias* are known to create monostands in new areas they invade, resulting in the displacement of native species (Le Maitre et al. 2011). Besides, it has been well documented that most invasive *Acacia* species tend to fix nitrogen in the soil resulting in changes in soil properties that tend to benefit the species to become more invasive (Le Maitre et al. 2011; Nsikani et al. 2019). The effects of invasive plants on natural habitats are more complex than the direct negative environmental impacts (Rai et al. 2012) since some invasive alien plants have social benefits. For example, *Acacia dealbata* is extensively used in rural communities of Eastern Cape province of South Africa for various reasons such as firewood, construction, and fodder to mention but just a few (Ngorima and Shackleton 2019). On the other hand, *Eucalyptus* species is extensively used in the forestry and bee industry in South Africa (Hirsch et al. 2020). Given that most of these invasive alien plants have costs and benefits, there is a need to understand invasive alien species using a socio-ecological thinking to develop effective methods to manage these species, an approach that was adopted in this thesis.

1.2. Alien plant invasion as a socio-ecological problem

Complex environmental challenges such as climate change, land degradation, pollution, and invasion by invasive alien plants require socio-ecological thinking and approaches to managing them. Socio-ecological systems are complex and adaptive systems that consists of bio-geo-physical units as well as actors and institutions that work and interact together within a particular ecosystem (Glaser et al. 2008). Key aspects of socio-ecological systems include hierarchical linkages, resilience, interactions between social and ecological systems, feedback, perpetually dynamic, complex, and adaptive (Berkes et al. 2001). In general, socio-ecological systems emphasise the notion that humans are part of nature, and thus people and nature cannot be separated in addressing environmental problems. Therefore, socio-ecological thinking recognises that human behaviour influences the natural environment, because the two interact, thus no management of the environment is effective without human involvement.

For several decades, the problem of invasive alien species has been viewed as an ecological challenge thus neglecting the social aspects of the problem (Shackleton et al. 2019). Indeed, there has been little research on human perceptions and benefits as compared to ecological impacts of invasive alien plants on the environment, yet humans are part of the invasion process (Shackleton et al. 2019; 2020). There is a need to understand the effects of invasive alien plants on humans, including perceptions of benefits and costs, and how humans can contribute to the management of invasive alien plants (Reynolds et al. 2020; Shackleton et al. 2019, 2020). Shackleton et al. (2019) has developed a framework for understanding human perceptions on invasive alien plants. The framework suggests six key factors to consider when trying to understand the role of humans on invasive alien plants. The factors are, (i) the individual's perceptions about the invasive alien plant, (i) the characteristic of the invasive alien plant, (iii) both negative and positive effect of the plant on humans, (iv) socio-cultural context, (v) institutional and political context, and (vi) the landscape context. These six factors interact together in shaping human views on invasive alien plants. For example, a person's views regarding an invasive alien plant are shaped by the benefits (e.g., fruits for consumption or shade provisioning) and costs (loss of water and harbouring criminals) that one gets from the plant. In some cases, socio-cultural contexts can assist in understanding why an invasive alien plant species is promoted in each landscape. For example, the invasive Jacarandas (*Jacaranda mimosifolia*) are viewed as part of the landscape in the city of Pretoria in South Africa, such that several people are against their removals (van Vollenhoven 2020). Regarding characteristics of invasive alien plants, it has been reported that some plants are viewed differently by humans due to their characteristics e.g., favourable due to flower colours and unfavourable due to thorns (Shackleton et al. 2019). Given that the social aspect of invasive alien plants is increasingly being recognised, there is a need to incorporate socio-ecological thinking in our understanding of alien plant invasion if management interventions are to be successful and recognise the role of users/humans. This is particularly important for South Africa given the long history of invasive plant invasions and the varied social, economic, and ecological landscapes which could mean varied experiences of perceptions on invasive plant species.

1.3. Invasion in South Africa and management

The number of invasive alien plant species in South Africa remains anecdotal, however recent studies have suggested that there are approximately 759 naturalised plant taxa in the country (Richardson et al. 2020). However, according to the National Environmental Management: Biodiversity Act (Act 10 of 2004) (NEM:BA-IAS regulations) only 559 taxa are in the category listing of invasive alien species, of which 383 are plants (Richardson et al. 2020). It is assumed that the number of invasive alien species in the country has been increasing and to date more that 10% of the country's land area is invaded by invasive alien species (Richadson et al. 2020). In rangelands alone, it is estimated that invasive alien plants have increased by more than 70% between 2006 and 2016, resulting in severe negative impacts on biodiversity and rangeland production (O'Conner and van Wilgen 2020; Ntalo et al. 2022). The bulk of the invasive alien plants in South Africa were introduced during the European colonisation era with most species being introduced for agricultural purposes particularly the forestry industry (Richadson et al. 2020). Therefore, these were deliberate introductions mostly for planting trees that have benefits to the country. In urban areas, most invasive alien plants were also brought for scenic beauty (Faulkner et al. 2020). In rural landscapes, most of the dominant invaders are *Opuntias*, *Acacia*s, *Eucalyptus*, *Lantana*, and *Pinus* species, whereas urban areas are dominated by *Acacias*, *Jacarandas*, *Eucalyptus*, and *Melia azedarach* (McLean et al. 2018; Richadson et al. 2020). Impacts of invasive alien plants in South Africa are varied and range from environmental (loss of native species, changes in soil properties, and water extraction) to socio-economic (loss of household income, loss of farming income, and increase crime as some species harbour criminals) (Ngorima and Shackleton 2019; Richadson et al. 2020). However, some species provide benefits to people, and in such cases management of such conflict generating species is challenging due to benefits accrued (Zengeya et al. 2017).

On realisation that invasive alien plants have severe negative effects on South African ecosystems, the South African government developed the national Working for Water (WfW) programme in 1995 to try and address the invasion problem (van Wilgen et al. 2020). The WfW programme aims to control invasive alien plants and their spread, and it has a dual mandate which also includes poverty alleviation (Fourie 2008, van Wilgen et al. 2020). To date the programme has spent more than 15 billion Rands (US$782 million based on current 2023 exchange rate) through its various nationwide control programme (van Wilgen et al. 2020). The programme uses an area-based approach rather than a species-based approach, meaning priority areas are cleared of invasive alien plants using similar approaches such as fell and stack burning or biological control (Faulkner et al. 2020; van Wilgen et al. 2020). Although the programme is viewed as a success, several challenges have been highlighted (van Wilgen et al. 2020). For example, the dual mandate has been criticised because the programme is mostly measuring success based on social indicators such as the number of people employed and paid rather than areas cleared and ecosystem conservation (van Wilgen et al. 2020). Other challenges that have been raised include funding challenges, lack of a clear restoration plan, having multiple small clearing projects, and underestimating the current invasion extent, which is likely to have implications on the rate of clearing (van Wilgen et al. 2012; 2020).

Few studies have examined restoration trajectories after alien plant removal by WfW (Ruwanza et al. 2013; Holmes et al. 2020). Studies that have assessed ecosystem recovery after removal of invasive alien plants have reported mixed results including recovery success (e.g., Ndou and Ruwanza 2016; Ruwanza et al. 2018; Fill et al. 2018) and recovery failures (Ruwanza et al. 2013; Nsikani et al. 2019). Studies that have reported ecosystem recovery success have reported vegetation improvement after removal of invasive alien plants, particularly species diversity and composition changes (e.g., Ndou and Ruwanza 2016; Ruwanza et al. 2018). These studies have attributed the positive restoration results to factors such as, (i) the availability of soil seed bank, (ii) proximity to intact areas with native vegetation, (iii) availability of seed dispersal in cleared areas, and (iv) the fact that invasion extent could have been lower prior to removal of the invader (Ndou and Ruwanza 2016; Ruwanza et al. 2018; Fill et al. 2018). In contrast, ecosystem recovery failure has been linked to depletion of soil seed bank, secondary invasion, lack of site monitoring, changes in soil properties, and environmental factors such as fire and drought (Ruwanza et al. 2013; Nsikani et al. 2019). It remains unclear how alien plant cleared sites recover overtime and more studies are required. Results on ecosystem recovery after alien plant removal are important as they can assist in evaluating WfW clearing progress (both from invader control and recovery trajectory aspect) as well as assessing if cleared areas are now able to provide ecosystem services (Holmes et al. 2020).

One key area that has hardly been assessed for vegetation recovery after alien plant removal is rangelands in communal areas, where land ownership has potential to interfere with recovery trajectory. Rangelands provide several ecosystem services such as forage production, water supply, habitat, biodiversity, carbon sequestration and recreation amongst others (Vundla et al. 2020). In South African communal areas, rangelands are important as they provide the much-needed livestock grazing. Yet most rangelands are invaded by invasive woody species such as *Acacias* (Yapi et al. 2018; O'Conner and van Wilgen 2020). This invasion has resulted in loss of native grasses for animal grazing as well as increasing land degradation in communal areas, particularly in the Eastern Cape province of South Africa (Yapi et al. 2018). Therefore, it is important to manage the invasive alien species that are causing destructions and disturbances in rangelands (Cheney et al. 2020). It remains unclear if removal of invasive alien species in rangelands results in improvement or restoration of native grasses. Furthermore, no study has assessed perceptions of local people when it comes to rangeland improvement after alien plant clearing. In this study a socio-ecological approach was adopted to assess ecological restoration of grazing lands and people's perceptions regarding alien plant clearing.

1.4. Motivation for the study

Invasion by *Acacias* pose a range of ecological and socio-economic impacts on natural ecosystems (Le Maitre et al. 2000; De Wit et al. 2001; Marchante et al. 2008; Gaertner et al. 2009; Marchante et al. 2011), yet little is known regarding costs and benefits of the species. Understanding alien plant costs and benefits presents the much-needed information that can be used to inform management interventions that incorporate all stakeholders. Without incorporating local users in the management of invasive alien plants, it will be difficult to manage these plants as some users are unlikely to cooperate management measures due to perceived risk of loss of benefits once the alien plant is removed. Therefore, studies on user perceptions, costs and benefits are needed for effective and socially meaningful alien plant management.

To date several hectares of land are under *Acacia dealbata* clearing in the Eastern Cape province of South Africa including the Tsitsana communal areas, yet an evaluation of how such clearing is improving grazing grass has never been done. Restoration of grazing grass is important to local people in the Tsitsana area as it is linked to livestock production, income generation and poverty alleviation. It is therefore important to assess recovery of native grazing grass from an ecological and social perspective if a clear restoration picture/trajectory is to be evaluated. Alien plant clearing might be viewed differently by different people within communities, therefore the need to document human perceptions on clearing and restoration. As much as clearing has been done, there is limited attention to understanding the broader socio-economic benefits of alien species clearing in rural communities. Meanwhile, there are differences in the social perceptions of invasion by invasive plant species, but little is known regarding clearing perceptions and how these might shape restoration projects like the national WfW programme in South Africa. Previous studies tend to focus on invasive species' origin (Richardson et al. 2020), ecological impacts (van Wilgen et al. 2020), and ecological benefits (Holmes et al. 2008; Le Maître et al. 2020) of invasive plant invasion and clearing, neglect social benefits of clearing that might impact ecological restoration in the long run.

On the other hand, local communities in the rural parts of the South Africa view *Acacias* as a resource that can be used to alleviate poverty (de Neergaard et al. 2005; Ngwenya 2016; Lunderstedt et al. 2017). They do benefit from that plant therefore the need to document these benefits since perceptions regarding benefits change over time (Ruwanza and Thondhlana 2022). Further, benefits accrued from plants are context specific and vary over time, thus the need to document these in different landscapes (Ngorima and Shackleton 2019).

1.5. Study area

The study was conducted in the Upper Tsitsana communal area, which is located approximately 40 km from Nqanqarhu (formerly known as Maclear), in the northern parts of Eastern Cape province of South Africa (30°53'19"S; 28°26'23"E) (Figure 1.1). The Upper Tsitsana area is a rural community that is less developed, with some of the poorest villages in South Africa (Calmeyer and Muruven 2014).

In this former Transkei homeland, most of the population resides in low density rural villages, often situated on the mid-slopes of Drakensberg Mountains. The population in the study area is approximately 45 000 (Huchzermeyer et al. 2018). The rural communities in the area rely heavily on natural resources and practice subsistence agriculture, predominately livestock and sheep production (Kakembo and Rowntree 2003; Blignaut et al. 2010; van der Waal 2018). The Upper Tsitsana rural communities are located within the Upper Tsitsa River catchment, which is characterised by steep topography, with the prominent Drakensburg Escarpment forming the headwaters (Huchzermeyer et al. 2018). The catchment receives austral summer rainfall (October – April), averaging 600 mm to 800 mm per year. Temperatures in the area are hot in austral summer (averaging 20°C) and cold in austral winter averaging 0°C) (Mucina and Rutherford 2006). Soils in the area are commonly shallow to moderately deep loam soils, usually with minimal soil development from hard and weathered rock (Mucina and Rutherford 2006). Soils are developed from Tarkastad Subgroup (mudstones), the Molteno (sandstones), and Elliot (mudstones) (Mucina and Rutherford 2006). Soil erosion is a key feature of the landscape, with gullies dominating the area. The upper Tsitsana River Catchment is dominated by grassland (Mucina and Rutherford 2006), although rivers are dominated by the alien invasive plant *A. dealbata* (Huchzermeyer et al. 2018).

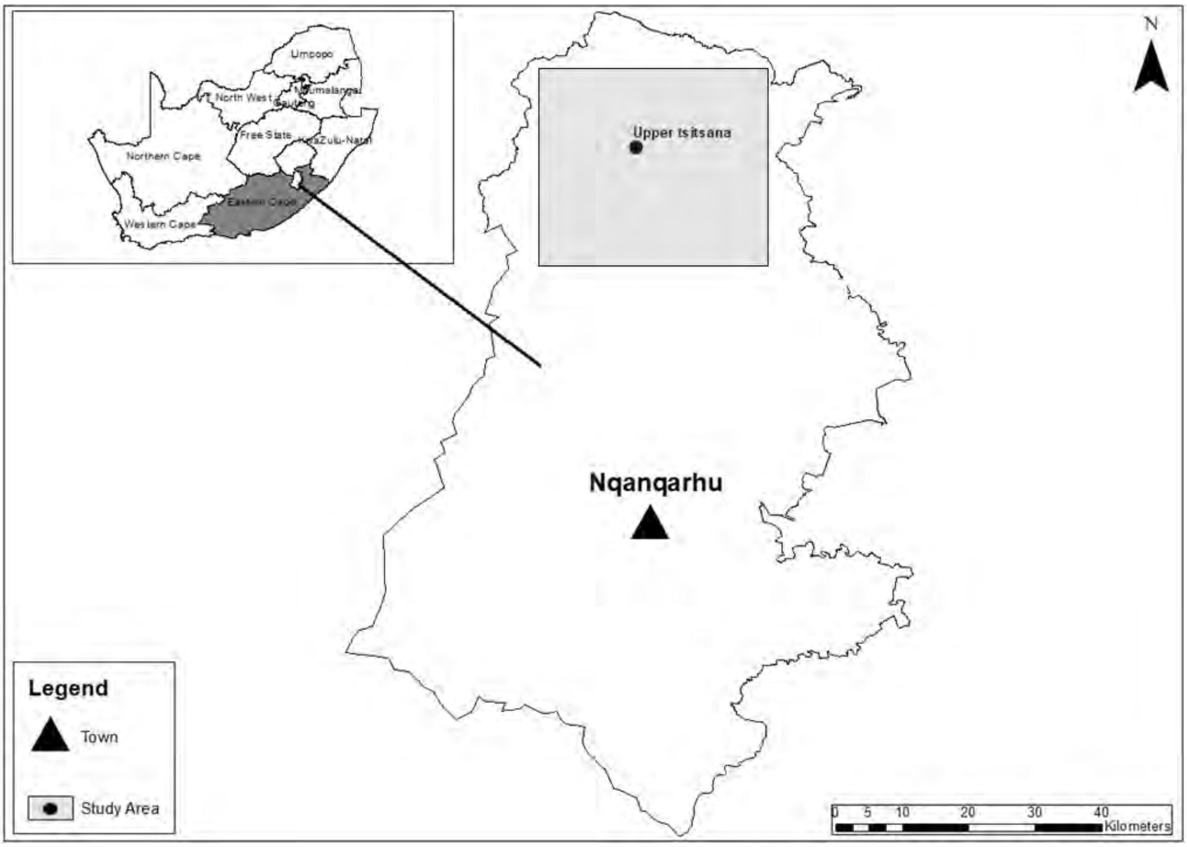

Figure 1.1. Map showing the study area in Upper Tsitsana communal areas in the Eastern Cape province of South Africa.

1.6. Study species

Acacia dealbata is dominant in the study area and studies in the Eastern Cape province of South Africa have shown the plant species is increasing in these landscapes since the 1950's (Gouws and Shackleton 2019). *Acacia dealbata* commonly known as Silver Wattle is an evergreen tree or shrub that grows fast reaching a height of 15 to 20 m in undisturbed areas (Ngorima and Shackleton 2019). The plant which originates from Australia belongs to the Fabaceae family and looks silver-grey when viewed from afar. The tree has a conical or rounded canopy crown, and the leaves are divided into pairs of pinnae with each pinnae having numerous pinnules (leaflets). Flowers are mostly yellow in colour and seeds are in pods that average 6 mm (Campbell 1988). Silver wattle was introduced in South Africa for various reasons such as tannin, firewood, and windbreak (Campbell 1988). A Silver wattle plant can produce 20 000 seeds and most seeds remain viable in the soil for close to 50 years (Campbell 1988). Besides germinating from seeds, the plant can grow from root suckers and coppicing from cut stumps. It is not clear when the plant was introduced in South Africa, but anecdotical suggestion is that it was introduced in the 1800s accidentally during *A. mearnsii* introduction, which is perceived to be more economically viable (Campbell 1988; Richadson et al. 2020). The plant grows mostly along river streams in riparian areas and disturbed areas such as abandoned agricultural fields or over grazed areas (Gouws and Shackleton 2019).

Acacia dealbata is a problematic invasive alien plant in South Africa, particularly in the Eastern Cape, Free State, and Kwa-Zulu Natal provinces of the country (Gouws and Shackleton 2019). Traits that make the plant more invasive include (i) ability to reproduce more seeds, (ii) ability to survive in disturbed ecosystems, (iii) rapid aggressive growth, (iv) ability to outcompete native plants for resources such as soil nutrients and water, (v) creation of monostands, and (vi) ability to tolerate harsh environmental conditions such as drought and fire (Gouws and Shackleton 2019). Like most leguminous plants, *A. dealbata* fixes nitrogen in the soil, a characteristic that enhance its invasion ability (Nsikani et al. 2019). The creation of monostands by *A. dealbata* facilitates the displacement of native plants, thus *A. dealbata* can displace native plants. Besides its negative impacts on the environment, the plant is used in rural communities for firewood, as fodder, construction, and making tool. Given that the plant has both costs and benefits, it is categorised as a category 2 invasive alien plant in South Africa (NEMBA: I&AS 2020). Generally, category 2 species are invasive species that require a permit for one to possess (NEMBA: I&AS 2020).

1.7. Research aims and objectives.

1.7.1. Main objectives

The main objective of this study is to assess how different stakeholders perceive the socio-economic and ecological impacts of *A. dealbata* clearing in Upper Tsitsana communal areas in the Eastern Cape province of South Africa. Given the importance of grazing in communal areas, the study further assesses recovery of native grass after *A. dealbata* clearing.

1.7.2. Specific objectives

The specific objectives of the study are to:

- Assess the perceived socio-economic and ecological costs and benefits of *A. dealbata* invasion as well as perceived clearing benefits among local villagers in Upper Tsitsana communal areas.
- Examine the effects of *A. dealbata* clearing on recruitment of indigenous native grass targeted for grazing.

1.8. Thesis structure

This thesis comprises five chapters. **Chapter 1** provides the introduction, study background, motivation of the study, and research objectives. **Chapter 2** provides a critical review of the literature, including key research themes related to invasion biology and human perceptions. **Chapters 3** and **4** address the specific objectives of the study, and each of the results chapters is written in the form of a manuscript that is ready for submission to a journal outlet. Therefore, the two results chapters have an abstract, introduction, methods, results, discussion, conclusion, and references of all sources used. **Chapter 5** provides an overall conclusion and recommendations for the study.

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Chapter 2
Literature review

2.1. Introduction

Invasive alien species are defined as species that are non-native to an area, but can establish themselves, spread quickly, and cause negative socio-economic and environmental effects (van Wilgen et al. 2020). Although the effects vary depending on species, social and landscape context, most invasive alien plants are known for reducing ecosystem functions and services by out-competing native species, harming the health of humans and domestic animals, damaging infrastructure, providing feeding niches for other pests, altering nutrient cycling, or changing fire and water regimes (Vilá et al. 2011; Richardson et al. 2020). Invasive alien species can significantly threaten biodiversity by inducing multiple environmental effects that change community composition, biotic interactions, and other ecosystem processes (Bartz and Kowarik 2019). Richardson and Rejmánek (2011) suggested that invasive alien species can be introduced accidentally or purposefully by humans resulting in self-replicating populations capable of spreading over large areas in their new habitat. In this study, the above-mentioned definition by van Wilgen et al. (2020) is adopted because it is holistic as it also defines invasive species form a socio-ecological perspective in terms of effects.

Recent studies that have attempted to quantify the economic costs of invasion by invasive alien species have reported significant monetary losses globally (Eschen et al. 2021). For example, Eschen et al. (2021) reported that the costs of alien species invasion in Africa's agricultural systems is estimated at US$ 65.58 billion. The bulk of the above-mentioned costs is linked to loss of crop yields and management interventions. Fernandez et al. (2023) conducted a global cost assessment of 72 invasive alien trees and reported a total cost of US$19.2 billion, with most of the effects being felt in the agricultural economy. Novoa et al. (2021) demonstrated that the global costs of alien plant invasion were approximately US$1.3. trillion between 1970 and 2017. In South Africa, the Working for Water programme spends an estimated 2 billion Rands (US$104 million based on current 2023 exchange rate) a year managing invasive alien plants (van Wilgen et al. 2020). The above-mentioned examples provide evidence that invasion by invasive alien plants is a global problem that needs effective management. However, to manage invasive alien plants, the social dimension needs to be considered given that some species are used for various economic benefits. For example, Chan et al. (2015) reported that *A. mearnsii* contributes US$100 million to South African and Brazilian economy. Ngorima and Shackleton (2019) estimated that *A. dealbata* contributes approximately US$224 income per household per year in the Eastern Cape province of South Africa. Given that there are both costs and benefits, the problem of invasion by invasive alien plants become complex thus requiring an understanding of both social and ecological dimensions.

2.2. Invasive Australian *Acacias* in South Africa

The study of invasive alien species represents one of those rare themes that cut across the disciplines of academic biology, while having profound environmental, philosophical, socio-economic, and legislative implications at a global scale (van Wilgen et al. 2020). South Africa is home to a large and growing number of invasive species. Many alien plants have been introduced to South Africa for a range of purposes such as crop production, timber, firewood, and ornamentals (Kull et al. 2011). In 1847, active and widespread planting of Australian *Acacia* species (wattles) as a means of stabilising dunes along the coast began (van Wilgen et al. 2020). Furthermore, plantings continued till 1940s, and the large areas planted resulted in substantial invasions (Shaughnessy 1986). Australian *Acacia* species are recognized as some of the most aggressive invaders, extending over a wide range of habitats including forest, plantation margins, riparian zones, savannas, woodland, and roadsides (Musil 1993; Dye and Jarmain 2004; Nel et al. 2004). *Acacias* are highly invasive globally and are a problem in other countries such as Portugal (Richardson and Rejmanék 2011). Most *Acacias* are native in Australia. Specifically, *A. dealbata* (silver wattle – our study species) is one of the most versatile and highly adaptive tree species which has spread all over the world.

Acacia dealbata is an evergreen tree which is native to and ubiquitous in south-eastern Australia, especially in New South Wales and Victoria (Maslin and McDonald 2004). In South Africa, it is mostly concentrated in the eastern escarpment including Eastern Cape, Kwa-Zulu Natal, Mpumalanga, and eastern parts of Gauteng province with some small invasions in the Western Cape and Limpopo province (Yapi 2019). In the Eastern Cape province, *A. dealbata* is used in households, mostly for firewood, fodder, fencing poles and for handles for tools such as hoes or axes (Ngorima and Shackleton 2019). Nonetheless, it enhances soil nutrient mineralization and decomposition rates (Castro-Díez et al. 2012), modifies the soil microbial community structure, decreases diversity and richness of invertebrate communities (Coetzee et al. 2007), and reduces understory plant richness and diversity (Lorenzo et al. 2012; Fuentes-Ramírez and Pauchard 2010; González-Muñoz et al. 2012).

2.3. Impacts of Australian *Acacias*

2.3.1. Effects on the environment

Generally, invasive alien plants reduce ecosystem functions and services by out-competing native species, however, acacia proliferates their invasion through nitrogen fixation in soils (Vila et al. 2011). Australian *Acacias* are said to be the most aggressive species on the ecosystem since its seedlings are capable of rapid growth under a variety of environmental conditions and can outcompete many other species for resources (Morris et al. 2011). They have deep roots which makes it easy to cause destruction on the environment including damaging infrastructure (Mcleod et al. 2020). *Acacia* invasion in South Africa is associated with negative effects on water supply as the species has high water intake (van Wilgen et al. 2020). The excessive use of water by *Acacia* species threatens agricultural production especially crop and livestock productivity (Ravhuhali et al. 2021; Ntalo et al. 2022). Like other

Australian *Acacias*, *A. dealbata's* deep roots result in reduced streamflow since they use more water than native vegetation (Le Maitre et al. 2020). Therefore, their invasions lead to a reduced recharge, and direct exploitation of the groundwater (Le Maitre et al. 2015). The changes in hydrological cycles, and rangeland water patterns means that most of native vegetation no longer reproduce, since they need soil moisture to grow (Hopkins and Del Prado 2007). The lack of soil moisture increases salt to the soil surface which hinders growth of native vegetation (Hermans and McLeman 2021). *Acacia* invasions can cause severe impacts on biodiversity by displacing natural communities, but also by changing fire regimes (Richadson et al. 2020). The negative effects on biodiversity are associated with a decrease in ecosystem services which negatively affect human well-being (Dickie et al. 2014).

Australian *Acacias* modify the composition of native communities by disrupting biotic interactions and spread all the negative effects throughout the community and further produce alterations on plant composition of communities, reduce regeneration rates of native species and alter landscape structure (Prior et al. 2015; López-Núñez et al. 2017). Hence, biotic interactions with local communities' shape invasion consequences, with important roles for ecological interactions and species composition (van Kleunen et al. 2018). *Acacias* may alter soil properties and biogeochemical cycles as well as other abiotic conditions that typically impact the growth of native species in invaded areas (Wilson et al. 2020). *Acacias* often attain extremely high densities in their invasive ranges, associated with significant increases in leaf litter loads (Gaertner et al. 2014). As such, *Acacias* have been found to elevate soil nitrogen and carbon content, as well as phosphorous levels (Souza-alonso et al. 2015). *Acacias* can also alter rhizosphere and soil microbial communities, these alterations may lead to the legacy effects, whereby changes to soil conditions often persist, even several years after clearing of invasive populations (Holmes et al. 2020). Therefore, Australian *Acacias* and their legacy effects can have profound consequences for ecosystem functioning as well as subsequent restoration efforts of previously invaded areas (Holmes et al. 2020).

Acacia dealbata invasion has increased its invasion range in rangelands (Gouws and Shackleton 2019). The increase in invasion extent in rangelands and grasslands reduces grazing grass cover, which negatively affect livestock (O'Connor and van Wilgen 2020). Invasion of rangelands by invasive alien trees and shrubs had markedly depress grass production (O'Connor and Stevens 2017). Woody alien species that form impenetrable monostands and thickets prevent livestock access to forage (van Den Berg 2010). For example, dense infestations of *Acacias* in the Eastern Cape province of South Africa have been reported to prevent livestock access to forage and ultimately seriously perturbed the pastoral economy of the region (Yapi et al. 2018). *Acacia mearnsii* has many traits typically associated with an aggressive invader species including prolific seed set, seeds capable of remaining dormant for up to 50 years, and a rapid sapling growth rate that promotes displacement of native grazing grass (Richardson and Kluge 2008). The invasion of rangelands by Australian *Acacias* has caused changes in the herbaceous cover and natural vegetation, thus affecting animal grazing (Mudau et al. 2022). Rangeland vegetation has transformed from herbage to woody vegetation as invasive species like *A. dealbata* spread, resulting in the rise of bare patches in some areas and decrease in herbage cover (Mudau et al. 2022). Gwate et al. (2016) reported that grass cover tends to decrease with an increase in wattle cover. The expansion of *Acacias* in rangelands decreases the forage grasses and rangeland carrying capacity with adverse effects on animal productivity (Al-bukhari et al. 2018).

2.3.2. Effects on society

Acacia invasion can result in adverse social impacts such as harbouring criminals, and affecting landscape aesthetics, recreation, and cultural areas such as graveyards (Ngorima and Shackleton 2019). Some studies have reported negative effects on local livelihood income, such as income reductions through loss of agricultural land (Shackleton et al. 2018). Studies in Eastern Cape province of South Africa show that the cost of managing invasive Acacias in agricultural land is high to the extent that some villages are now abandoning their land (Shackleton et al. 2017, 2018). In some cases, *Acacia* invasion affects humans through negative effects on access to key resources such as water, negative effects on housing infrastructure, and effects on cultural activities like rituals as the plant invades their sites (Shackleton et al. 2017; 2018; Ngorima and Shackleton 2019). Despite these negative effects, *Acacia* provides some services to local people. Ngorima and Shackleton (2019) stated that *A. dealbata* has been used in Maclear and some parts of the Eastern Cape province for fuelwood, pools, as fodder, and shade because of the scarcity of natural forests. It has been reported that villagers harvest the plant and use it for various purposes including medicine and making handheld tools. In addition, some people sell *A. dealbata* for firewood and roofing pools, making an income that can be used for their basic needs. Therefore, *Acacia* species have several livelihood benefits to local people.

2.4. Perceptions regarding invasive alien plants

Invasive alien species have different characteristics, thus offering a variety of positive and negative ecosystem effects, resulting in varied views from humans regarding alien plant invasion (Kannan et al. 2008). Some alien plants can be viewed as detrimental by some population groups, yet some may consider a similar species to be useful (Kannan et al. 2008; Mwangi and Swallow 2008). Generally, rural people evaluate the impact of invasive plant species based on how their livelihoods are affected (Rai et al. 2012). Invasive species can have a positive utility impact on people through provision of resources (Shackleton et al. 2018). For example, *Rhododendron ponticum* was first introduced to the United Kingdom (UK) as an ornamental plant and has value for gardeners due to its easy care, evergreen nature, and bright flowers (Hanley and Roberts 2019). Although attitudes towards *R. ponticum* have changed in recent years due to its fast spread and ability to outcompete native plants, removal projects are often met with public resistance (Williamson and Dehnen-Schmutz 2006; Hanley and Roberts 2019). In South Africa, *Acacias* are viewed differently by rural communities due to the dual role they play (social benefits and ecological impacts). For example, Ngorima and Shackleton (2019) reported that *A. dealbata* is used for firewood, although the amounts and frequencies differ between households. Meanwhile, it exacerbates local household vulnerability through reported reductions in cultivated areas, crop yields and forage production grew in some landscapes in which its presence is regarded as problematic, such as near homesteads, fields, as well as cultural sites (Ngorima and Shackleton 2019). It has taken up rangeland space, and as a result, some livestock, including goats, have begun to feed on it (Ngorima and Shackleton 2019).

Similarly, *Eucalyptus camaldulensis* is invasive in South Africa and stakeholders view it differently based on its impacts and benefits (Hirsch et al. 2020). It is believed that *E. camaldulensis* forms part of landscape features in many parts of South Africa. They have diverse impacts on socio-economic and ecological systems including the provision of timber, paper, poles, firewood, shelter, ornamental value, and nectar and pollen for bees (Forsyth et al. 2012). Meanwhile, *E. camaldulensis* spread easily, and their rapid growth implies substantial water uptake which results in significant hydrological impacts (Hirsch et al. 2020). Some people argue that removal of *E. camaldulensis* in South Africa would affect the flowers and therefore negatively affect the bee industry thus having a negative effect on the broader economy (Zachariades et al. 2017). This has resulted in many authors regarding *E. camaldulensis* and other *Eucalyptus species* as a conflict generating species (species that have both positive and negative effects and difficult to manage (Zengeya et al. 2017). Similar varied human attitudes can be said about *Jacaranda* invasion in Pretoria (South Africa) as some local people view it as a city heritage (named after the city radio – Jacaranda FM), yet others view it as a problem species that causes health problems like sinus (van Vollenhoven 2020).

Due to the inherent linkage between biological invasions and human activities, invasive plant species have become an important footprint and a part of social and economic processes linked to global environmental change (Vitousek et al. 1997). This implies that the social components of biological invasions need to be well articulated in managing invasive plants (Shresta et al. 2019). Therefore, the various stakeholders need to be involved in any decision with regards to management of invasive plants species. The understandings towards *Acacias* are diverse (García-Llorente et al. 2008), opposing attitudes towards these invasives can only be understood by implementing social perspectives in research and decision making (Kapitza et al. 2019). As a result, local communities may refuse to engage in, and even oppose, management measures concerning invasive plants if their perspectives are ignored or misunderstood (Simberloff 2011; Woodford et al. 2016). While decision-makers and scholars hold more extreme views in relation to invasion (Fischer et al. 2014), local communities tend to view invasive alien species as plants that have become integrated into local livelihoods (Lunderstedt et al. 2017; Kapitza et al. 2019). For example, it has been reported that *A. dealbata* has been in Eastern Cape for decades to the extent that local people now view it as a native species (Ngorima and Shackleton 2019). This goes on to show that although people's perceptions about alien plant invasion are shaped by benefits and the species itself, they are also shaped by invasion extent and how long the plant has been in the area (Shackleton et al. 2019).

The impacts of alien plant species can generally be reliably evaluated through an assessment of local knowledge and the social benefits associated with that alien plant species (Atyosi et al. 2019). Whether an individual or group of people regards an invasive alien plant as problematic, beneficial or do not mind either way, depends on several factors that influence their perceptions of the species and its effects (Kueffer, 2013). It is therefore important to consult local communities and take their considerations into account. For example, the invasive alien plant guava is viewed as beneficial in the Limpopo province of South Africa due to its positive fruit benefits, yet its expansion in the area is beginning to negatively affect people's views, as expansion is linked to negative effects such as harbouring snakes and mosquitos which cause malaria (Ruwanza and Thondhlana, 2022). This requires a balance between clearing stands of invasive species that easily spread into the surrounding landscape and keeping contained woodlots for local resource use (de Neergaard, 2005; Huchzermeyer et al. 2018).

Baral et al. (2017) state that incorporation of local knowledge into alien plant species management significantly contributes to the change of public perceptions and values associated with alien plant species. Furthermore, there is a need to understand what the users know and what they need to know about alien plant species. Research by Shackleton et al. (2007) showed that several households in the Eastern Cape province of South Africa traded alien plant species products to generate supplementary income. Similarly, Kull et al. (2011) argued that control of invasive *Acacias* should be carefully managed to avoid adverse impacts on poor communities that are often directly dependent on the species for their livelihood needs. Therefore, alien plant species that have both costs and benefits ought to be managed in a way that allows benefits to be realised whilst simultaneously reducing costs. Therefore, this calls for the involvement of all stakeholders in developing management interventions that are likely to be effective.

2.5. Management of invasive alien plants

It is estimated that biological invasions cost South Africa's economy billions of Rands annually (van Wilgen and Wilson 2018). The costs of clearing can be associated with the density of alien invasions, management costs, and accessibility to areas (Mantel et al. 2018). Due to the huge costs associated with alien plant clearing (Hulme 2006), it is often more efficient and cost-effective to prevent their introduction (Leung et al. 2002; Simberloff 2006; Simberloff et al. 2013). Preventions can take the form of management measures that include interventions directed at restricting the importation of high-risk alien species and regulating their movement (Zengeya et al. 2017).

Several methods for controlling invasive alien plants exist in South Africa. These are broadly categorised into mechanical, chemical, and biological control (van Wilgen et al. 2012). Mechanical control involves the physical destruction or total removal of plants including felling, strip-barking, ringbarking, hand-pulling, and mowing (McDonald and Mboyi 2017). For example, plant cutting involves the cut-felling of tree using machinery or other handheld tools. In contrast, chemical control involves the use of chemicals/herbicides to kill targeted plants (McDonald and Mboyi 2017). For example, if there are invasive alien plants among native plants, herbicides are sprayed to kill the invasive alien plants and they are sprayed at a minimal amount to avoid damage on the native plants and the environment. Biological control involves the release of natural enemies that will reduce plant health and reduce population vigour to a level comparable to that of the natural vegetation (van Wilgen et al. 2020). It also involves the use of other animal to graze the alien plant (van Wilgen et al. 2020). Biological control is centred on the natural enemy release hypothesis which states that invasive alien plants dominate new areas because they have escaped their natural enemies (Colautti et al. 2004). Therefore, to manage the alien plant, the natural enemy is introduced so that it can utilise the alien plant. Most of the above-mentioned methods can be used integrative. For example, the mechanical cut-felling of invasive alien plants can be combined with herbicide application on cut stumps to avoid re-sprouting of invasive alien plant, a model that Working for Water uses. The financial costs of invasive species management invasive alien plant using the above-mentioned methods are high, yet funds are not always readily available (Le Maitre et al. 2000, van Wilgen et al. 2012). Therefore, recent suggestions have pointed towards considering local people alien plant utilisation has a potential control method (van Wilgen et al. 2020: Le Maitre et al. 2020). Utilisation of invasive species as a management option involves use of the species by people with the potential to eradicate species that occur in low numbers over limited areas, containing invasions that have expanded, and reducing the extent and impact of well-established invaders (van Wilgen et al. 2020).

Few studies have assessed the efficacy of the above-mentioned methods. Blanchard and Holmes (2008) reported that the clearing of invasive alien plants through mechanical control is effective at reducing the invader extent but hardly facilitates alien plant removal. However, this was species dependent. Use of chemicals is effective for managing small trees, grasses, and herbs but can be ineffective at managing big trees and shrubs (van Wilgen et al. 2020). Biological control is viewed as a cost-effective method due to its reduced management costs, however, effectiveness seems to take time and to date no study has evaluated the restoration efficacy of biological control of invasive plant species (Hill et al. 2020).

2.5.1 Working for Water programme and ecological restoration trends South Africa

The government of South Africa established the Working for Water programme through the Department of Environment, Forestry and Fisheries (DEFF) to clear invasive species because of the negative impacts on water resource (van Wilgen et al. 2011). The Working for Water programme is said to curb these impacts through alien clearing and management (Huchzermeyer et al. 2018). However, the programme has combined the alien plant management with external benefits such as job creation, capacity development and poverty reduction (Morokong et al. 2017) thus it has a dual mandate. Since its inception in 1996, the programme has cleared millions of hectares of land (McConnachie et al. 2012). At a broader outlook, the programme aims to recover ecosystem services from invasive alien plants-related loss (van Wilgen and Wannenburgh 2016). The programme has been regarded as a success; however, some challenges have been noted e.g., challenges with dual mandate means funds are distributed across different goals (van Wilgen et al. 2012). Further, the programme is said to have underestimated the current invasion extent, implying it will take several years to achieve complete clearing of invasive alien plants in South Africa. Indeed, funding challenges have also being highlighted as a challenge, as the few available financial resources are shared across multiple small projects being administered in the entire country (van Wilgen at al. 2012). A major challenge that Working for Water programme is facing is the failure to incorporate native vegetation recovery goals in their programme. At this stage, Working for Water clears alien plants based on the assumption that native species will recover on their own (passive restoration). It has been reported that a clear passive or active restoration plan or goals are missing within Working for Water programmes (Esler et al. 2008).

Some research has shown that passive restoration may be difficult to achieve after alien plant clearing especially where key biotic and abiotic thresholds have been crossed and resilience has been reduced (Le Maitre et al. 2011; Gaertner et al. 2012). Biotic and abiotic thresholds can be crossed through (i) high invasion extent, (ii) long invasion duration, (iii) the type of the invader, and (iv) loss of soil seed bank, and (v) changes in soil nutrients (Holmes et al. 2008; Ruwanza et al. 2013). Whenever, biotic, and abiotic thresholds have been passed due to invasion, active restoration (assisted restoration) should be implemented (Ruwanza et al. 2013). This involves, the planting of native seeds, soil manipulation after alien plant removal or soil and vegetation transfer (Ruwanza et al. 2013; 2018). However, in most cases the recruitment of native species following active restoration is affected by low germination of introduced species and the fact that active restoration is generally costly (Holmes et al. 2008; Ruwanza et al. 2013; 2018). Experiments in the Western Cape province of South Africa have shown that few seeds germinated in both passive and active restoration plots after *E camaldulensis* removal along the Berg River (Ruwanza et al. 2013; 2018). Besides high seedling mortality, other factors such as hot summer temperature and competition from alien herbs and graminoids (secondary invasion) were also reported in the above-mentioned studies (Ruwanza et al. 2023; 2018). Competition by secondary invaders or re-invasion by the same alien plant species after plant clearing negatively affect the growth of native seedlings.

Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (Clewell et al. 2004). In the case of biological invasion, the degrader is the invasive alien plant or species in general. Therefore, the recovery of ecosystem after removal of the invader depends on several factors such as changes in soil properties, proximity to remnant species, understory vegetation that co-occur with the invader, availability of funds, restoration goals, and environmental factors such as climate, drought, and flooding. Results of vegetation recovery after alien plant removal has sown mixed results. Some success has been reported for *Eucalyptus* and *Accacia* in the Western Cape (Fill et al. 2017; Ruwanza et al. 2018). In some cases, both soil and vegetation have positively recovered after alien plant removal (Ndou and Ruwanza 2016). However, failures have also been reported due to secondary invasion and disturbance by natural events such as fire (Ruwanza et al.

2013). It is important to note that recovery after alien plant removal is site and species specific, thus responses could be different.

The removal of *A. dealbata* in rangelands does not guarantee recovery of native vegetation (Stephens et al. 2016). Sometimes the use of heavy machinery to clear invasive alien species can derail native vegetation recovery through compaction (Havrilla et al. 2017; Rubin and Robyal 2018). In some cases, the rangeland grass is affected by grazing and fire, especially in areas where the two abovementioned factors are not excluded. However, a relatively recent assessment by Yapi et al. (2018) reported that positive grazing land recovery is possible where alien plants are removed. In rangelands, the outcome of grass restoration could depend largely on the (i) clearing method applied, (ii) grazing exclusion, and (iii) if seedbank of native grasses is still available (Mndela et al. 2020). In some cases, recovery of grass in rangelands may be driven by proximity to intact areas that were never invaded as sides could be dispersed by birds.

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Chapter 3

Perceptions of *Acacia dealbata* invasion and clearing in upper Tsitsana rural community in the Eastern Cape Province of South Africa

Abstract

Invasion by invasive alien plant is increasing, this likely to intensify negative socio-ecological and environmental impacts. However, some invasive alien plants have both costs and benefits making management complex due to varied stakeholder perceptions. In South Africa, perceptions on invasive alien plants mainly focus on costs and benefits, negating views on clearing by the Working for Water programme. Using household surveys administered in six villages located in upper Tsitsana communal areas, Eastern Cape Province of South Africa, the study gathered information on local people perceptions and knowledge of *Acacia dealbata* invasion and clearing. Comparisons across villages were done using descriptive statistics and chi-squared test since data was qualitative. Results from 165 questionnaire interviews showed that most respondents are aware of *A. dealbata* invasion but do not know that it is an invasive alien plant. Respondents noted both *A. dealbata* benefits such as firewood and construction pools as well as costs such as loss of grazing land and water. From a clearing perspective, respondents were aware of the Working for Water clearing programme and both socio-economic (income and employment) and environmental (restoration of grazing land and increased water availability) benefits were mentioned. Although some respondents are clearing *A. dealbata*, a small percentage does not want the plant to be cleared due to its benefits. The study concluded that *A. dealbata* has both costs and benefits and that clearing is supported by some local people due to observed socio-economic and environmental clearing benefits. For clearing to be effective, there is a need to incorporate views from all stakeholders to reduce invasion costs but realise the benefit.

Keywords: Knowledge, management, perceptions, plant invasion.

NOTE: *This chapter is written and structured in the format of a paper that is ready for peer review journal submission. Therefore, some sections e.g., study area are repeated in this chapter since they are part of a journal paper manuscript. The target journal is Forests, Trees, and Livelihoods.*

3.1. Introduction

Climate change, habitat destruction, resource exploitation, pollution, and invasion by invasive alien species are recognised as the main drivers of biodiversity loss globally (IPBES 2019; Rai and Singh 2020). Invasive alien species are species that are non-native to an area or ecosystem and have potential to cause significant socio-economic and environmental damage (Rai and Singh 2020; Richardson et al. 2020). Particularly, invasive alien plants are a major driver of global environmental change, which subsequently results in loss of ecosystem services, resulting in significant effects on human well-being and livelihoods (Teel et al. 2018). Impacts of invasion by invasive alien plants vary and include loss of native biodiversity, changes in soil properties, and loss of water resulting in major losses of ecosystem services and functions (Rai and Singh 2020). For example, it has been reported that the invasion of South African terrestrial ecosystems by invasive alien plants such as *Acacia*, *Eucalyptus*, *Lantana*, and *Pinus* species has significantly resulted in water loss, with knock-on effects on the economy (Richardson et al. 2020). Further, most of the above-mentioned invasive alien species are associated with negative ecological effects such as altered soil nutrients, native vegetation displacement and changing fire regimes (Richardson et al. 2020).

In South Africa, most invasive alien plants were introduced during the colonial era for various purposes that include food provisioning, forestry purposes, as ornamental plants, and environmental reasons such as erosion control and dune stabilisation (Zengeya et al. 2017; Richardson et al. 2020). For example, *A. mearnsii* was introduced in South Africa from Australia in the 1800s for tannin and woodchip production (Chan et al. 2015), whilst *Eucalyptus* and *Pinus* species were introduced for forestry purposes and to date the plants continue to contribute billions of Rands to the South African economy (van Wilgen and Richardson 2014; Hirsch et al. 2020). Although the above-mentioned examples show that invasive alien plants are beneficial to human beings and the economy, they also have huge negative effects to both the environment and society (Richardson et al. 2020). For example, *E. camaldulensis* contribute significantly to the bee industry in South Africa, yet its growth along riparian zones is associated with significant water losses (Hirsch et al. 2020). In India, *L. camara* is used to treat tetanus and malaria, yet it displaces native plants and cause livestock death if consumed by animals (Negi et al. 2019). There is no doubt that invasive alien plants have both benefits and costs, therefore the need to conduct more species- and site-specific studies aimed at developing local context specific interventions that incorporate user perceptions.

Communal areas in the Eastern Cape Province of South Africa are heavily degraded, with invasion by invasive alien plants being one of the land degradation drivers (Itzkin et al. 2021). Several studies have reported that degradation in the Eastern Cape is associated with soil erosion, gallies, loss of soil fertility, loss of grasses, and the dominance of invasive alien plants (Yapi et al. 2018; Itzkin et al. 2021). The dominance of invasive alien plants in these degraded landscapes has resulted in reduced capacity of land to provide important ecosystem services to rural communities. Specifically, the loss of grazing land due to both invasion and land degradation has resulted in severe negative impacts on livelihoods, largely because most people are dependent on livestock and subsistence agricultural (Yapi et al. 2018; O'Connor and van Wilgen 2020). For example, Yapi et al. (2018) reported that the invasion of grazing lands by invasive wattles in Eastern Cape has the potential to reduce livestock carrying capacity by approximately 72%. The same study reported that alien plant invasion reduces grass cover by more than 40% and this is likely to affect livestock production. However, a lot of this work is based on purely ecological assessments of invasive alien plants and their adverse impacts on ecosystem services. Ecological insights/data are useful but do not capture people's perceptions of invasive alien plants, especially in context where these plants have been integrated into people social and livelihood activities. Little is known about communal people's perceptions of invasion driven grazing loss; therefore, it is important to capture such information for informing management options. Although invasion biology tends to be viewed as a purely ecological issue, we argue that this approach is insufficient as there are socio-ecological complexities related to invasion extent, use and management. Thus, this research contributes to debates on understanding invasion by invasive alien plants from a socio-ecological perspective.

Human perceptions involve the gathering, identification, and interpretation of information to learn and construct meaningful information which shapes actions and behaviours (Schermerhorn et al. 2000). Human perceptions and knowledge about invasive alien plants are shaped by several factors that include the characteristics and attributes of the alien plant, costs, and benefits of the alien plant, as well as institutional, policy, socio-cultural, and landscape contexts (Shackleton et al. 2019). The bulk of the studies on human perceptions on invasive alien plants are on how individual characteristics such as knowledge and behaviour and how invasive alien plant traits, ecology, and biology shape perceptions (Novoa et al. 2017; Shackleton et al. 2019). For example, the scenic benefits associated with *Jacaranda mimosifolia* in Pretoria, South Africa are behind residents' position against its removal (Dickie et al. 2014). Other studies have also reported that human perceptions and knowledge of invasive alien plants are shaped by education level and socio-economic status (Shackleton and Shackleton 2016; Potgieter et al. 2019). For example, a study in Cape Town, South Africa reported differences in invasive alien plant knowledge across different socio-economic groups, with well-educated residents in affluent areas having more knowledge about urban invasive alien plants than the less educated residents in less affluent areas (Potgieter et al. 2019). In a rural setting, Shackleton et al. (2015) reported that farmers who interact with the invasive alien plant *Prosopis* had high awareness and knowledge levels of the species. It has been well documented that knowledge on invasive alien plants among rural communities tend to be species dependent, with most people being familiar with common invasive plants such as *Acacias* and *Eucalyptus* than less known plants such as *Melia azedarach* and *Morus alba* (Shackleton et al. 2020). This could be linked to several factors such as benefits, invasion duration, introduction reasons and invasion densities (Shackleton et al. 2020). Therefore, perceptions and knowledge about invasive alien plants among people can be context and species dependent (Shackleton et al. 2020), hence the need for more studies to understand human perceptions and knowledge of invasive alien plants in different context and for different species.

Management of invasive alien plants in South Africa is mainly conducted by the Working for Water (WfW) programme, a national government programme that is aimed at controlling invasive plants through clearing (van Wilgen et al. 2020). The control method adopted by WfW involves the cutting of plants and application of herbicides to prevent resprouting. The clearing method assumes that removal of the invasive alien plants will facilitate passive restoration of native vegetation (van Wilgen et al. 2020). Several studies have assessed the efficacy of WfW clearing on native vegetation and soil recovery, with results showing both success and failure (Ruwanza et al. 2013, 2018; Fill et al. 2017). However, little has been done to understand people's perceptions of the WfW clearing and the few studies that have attempted to gather such information have concentrated on insights from private and commercial farmers (Urgenson et al. 2013; van Wilgen and Wannenburgh 2016). van Wilgen and Wannenburgh (2016) reported that most private landowners support the WfW clearing initiative but have different views regarding the programme's financial costs and benefits. The same study also reported that private landowners are more inclined to ecological benefits associated with the WfW clearing than to social benefits (van Wilgen and Wannenburgh 2016). A recent study by Ruwanza and Thondhlana (2022) looked at how local people receive clearing assistants from WfW but did not examine local people views on clearing effectiveness. The above-mentioned study reported that few local villagers receive assistance from WfW, with the nature of the assistance ranging from management information and provisioning of chemicals to clear *Psidium guajava*. To our knowledge no study has looked at rural people's perceptions of the effectiveness of WfW clearing and whether residents are observing clearing benefits, yet such information is important to evaluate the success of WfW clearing in rural areas.

This chapter aimed to assess how local people perceive the socio-economic and ecological benefits of *A. dealbata* invasion and clearing in upper Tsitsana rural community in the Eastern Cape Province of South Africa. The objective of the study was to assess perception and knowledge around *A. dealbata* impacts, costs, benefits, and clearing among local people. The research questions were: (i) what are the impacts, benefits, and perceptions of *A. dealbata* to rural livelihoods, and (ii) how local people perceived clearing of *A. dealbata*?

3.2. Methods

3.2.1. Study species

Acacia dealbata (also known as silver wattle) is a naturalised invasive alien tree that was introduced in South Africa in the 1850s for commercial plantation. The plant species originates from South-eastern Australia and Tasmania and it is invasive in other countries such as Portugal, Greece, China, Chile, and USA (Kull et al. 2007). The evergreen tree grows to a height of about 15 – 20 m and it has a rounded crown. Its leaves are bipinnate, bark has a grey-brown to blackish colour, flowers are yellow, and fruits are in flattened pods (Kull et al. 2007). The plant is widespread and abundant in South Africa and has been reported to transform natural ecosystem (Le Maitre et al. 2011; Gouws and Shackleton 2019). Its invasion traits include the ability to change soil properties (N-fixation), enhanced competition for resources, phenotypic plasticity, high soil seedbank, creation of monostands, adaptability to environmental change, ability to reproduce vegetatively, and allelopathy (Le Maitre et al. 2011; Souza-Alonso et al. 2014). *Acacia dealbata* thrives in disturbed ecosystems, grows fast along riparian zones, and reaches maturity age rapidly (De Neergaard et al. 2005). Besides transforming native ecosystems that it invades, *A. dealbata* has several uses such as household fuelwood, construction pools, as green manure, charcoal production, livestock fodder, and sand dune stabilisation (Kull et al. 2007). In South Africa, *A. dealbata* is listed as a category 2 invasive alien plant under the 2020 national list of alien invasive species published by NEMBA (National Environmental Management: Biodiversity Act 10 of 2004). This implies that *A. dealbata* is deemed to have invasion potential but has socio-economic benefits, so a permit is required for possession.

3.2.2. Study area

The study was conducted in six villages, namely Ndingeni (30°50'18"S, 28°18'02"E), Komkhulu 1 (30°49'42"S, 28°18'11"E), Komkhulu 2 (30°50'05"S, 28°18'48"E), Sakhuthe (30°50'51"S, 28°19'41"E), Mabalane (30°49'32"S, 28°20'48"E) and Pholweni (30°50'58"S, 28°20'58"E) (Figure 3.1), located in the upper Tsitsana community, about 45 km outside Maclear (officially Nqanqarhu) town in the Eastern Cape Province of South Africa. The upper Tsitsana community is in the upper Tsitsa River catchment (Huchzermeyer 2017). The catchment receives summer rainfall and is characterized by steep topography, with the prominent Drakensburg Escarpment forming the headwaters (Huchzermeyer 2017). Annual rainfall in the areas is approximately 600 mm to 800 mm and most of the rain falls in austral summer. The area is characterised by hot summers and cold winters, with summer temperatures averaging 20°C whilst winter temperatures average 0°C (Mucina and Rutherford 2006). Soils in the area are poorly drained, commonly shallow to moderately deep loam soils usually with minimal soil development on hard or weathering rock (Mucina and Rutherford 2006). The upper Tsitsa River catchment is dominated by grassland (Mucina and Rutherford 2006); however, the river catchment is heavily invaded by Australian *Acacias* with the most dominant taxon being *A. dealbata* which has been prioritized for clearing by the Working for Water (WfW) programme (Huchzermeyer 2017). *Acacia dealbata* clearing by WfW in the study area started around 2018 and has been on-going. The population in this former Transkei homeland is approximately 45 000 and most people are unemployed and reside in low-density rural villages, often situated on the mid-slope of hillsides (Huchzermeyer 2017). The area has some of the poorest and least developed communities in South Africa (Huchzermeyer 2017) and villagers are heavily dependent on social grants. Besides social grants, villagers in the area rely heavily on natural resources and practice subsistence agriculture, mostly livestock and crop farming. Most of the people in the study area speak isiXhosa.

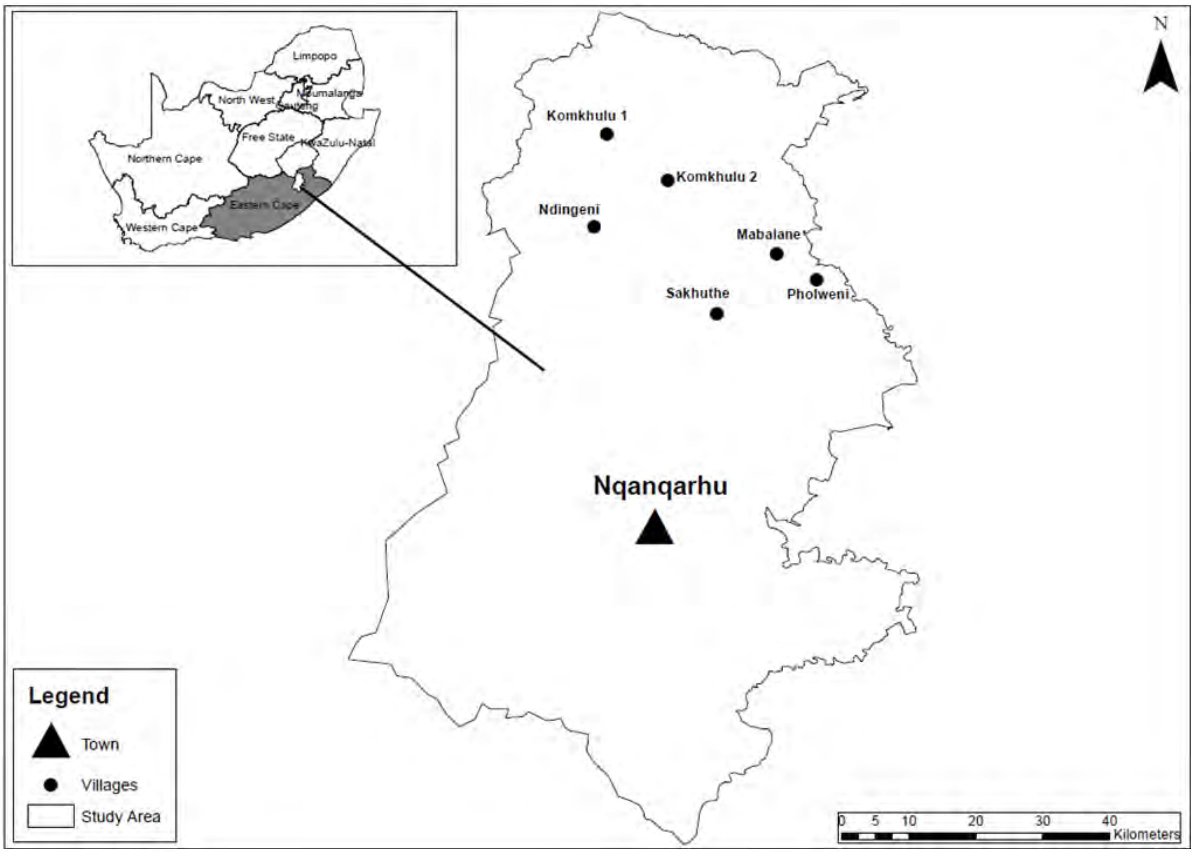

Figure 3.1. Location of upper Tsitsana sampled communities in Eastern Cape Province of South Africa.

3.2.3. Data collection and analysis

Data for this study were collected in November and December 2021 using face-to-face household interviews. The six villages (Ndingeni, Komkhulu 1, Komkhulu 2, Sakhuthe, Mabalane, and Pholweni) were purposively selected for this study. The criteria for selection included, (i) being close to either *A. dealbata* invaded or cleared areas, (ii) being aware of the WfW clearing activities taking place in the areas, and (iii) having knowledge of the problematic invasive alien plant *A. dealbata*. Households living in the selected six villages were approached for interviews, and all interviews were conducted in isiXhosa, which was the preferred language by the participants. Semi-structured questionnaires with open and closed-ended questions were used for data collection to allow free flowing discussions on *A. dealbata* invasion and clearing in the area (see appendix 1 for interview guide). A total of 165 questionnaires were administered to household heads across all six villages, with varying number of respondents per village (Ndingeni = 38; Komkhulu 1 = 30; Komkhulu 2 = 25; Sakhuthe = 30; Mabalane = 23, and Pholweni = 19). The questionnaires were distributed according to the number of households per village. Therefore, some villages had many households like Ndingeni while others had few households like Pholweni. The interviews were administered between 08h30 and 16h30, with each interview taking approximately one hour.

At each household, the head of the family was interviewed and in the absence of a household head, any available person who was 21 years or above was interviewed. The questionnaire had four sections. The first section was designed to collect socio-demographic information such as age, gender, source of income, and education level. The second section collected information on the household's understanding of *A. dealbata* invasion in the area. The respondents were asked to indicate whether they knew that it is invasive, and their perceptions on *A. dealbata* impacts and benefits. The third section focused on the impacts of *A. dealbata* on native vegetation and severity of invasion on grazing lands and other effects on the land. The fourth section gathered information on the perceptions of respondents towards *A. dealbata* clearing that was taking place in the area. The respondents were asked about their views on clearing, their involvement in clearing, and if there were noticeable changes in their landscape from a grazing, water availability, and native vegetation recovery perspective.

Before commencement of data collection, ethical approval was granted on 19 August 2021 by the Rhodes University's Human Ethics Committee (Ethics Number: 2021-5187-6234). Permission to conduct research in the area was sought from and granted verbally by the local headman. Participation was voluntary and all participants were informed about their right not to answer any questions, as well as to withdraw from participation at any time without any negative repercussions. Before the administration of the questionnaire, informed consent for the interview was obtained either by signing a consent form or agreeing verbally following assurance of anonymity and confidentiality. The purpose and importance of the study were explained, and no personal information was collected. All data were anonymised by assigning questionnaires numbers to avoid linking responses to any individual.

Questionnaire responses were grouped into categories based on villagers' perceptions of *A. dealbata*, its benefits, costs, and clearing benefits. Descriptive statistics were used to show distribution of socio-demographic data and proportion of responses presented in the form of tables and graphs. Qualitative data were initially transcribed and thereafter underwent content analysis to identify, summarise, and categorise the perceptions on the benefits of clearing of *A. dealbata.* The frequency of responses on reported knowledge of *A. dealbata,* perceived impacts*,* and benefits of clearing were presented quantitatively in the form of counts and proportions. Understanding of *A. dealbata* invasion impacts on native vegetation and severity of invasion on grazing lands and other effects on the land, as well as perceptions of respondents towards *A. dealbata* clearing were predictors. Meanwhile, socio-demographic information such as age, gender, source of income, and education level were the response variables. Differences in responses across the six villages were examined using chi-squared tests. All statistical analyses were performed using TIBCO STATISTICA version 14.0 software (TIBCO Software Inc 2020).

3.3. Results

3.3.1. Socio-demographics of the sampled population

The average age across all six villages was 56 years, ranging from 23 to 90 years. Across all villages, most respondents were females (63%), with a higher representation in Komkhulu 1 (80%) and Mabalane (78%) villages than other villages. Education levels were generally low, mirroring trends in the Eastern Cape Province. Roughly 22% of the respondents across all villages had no education, meaning they never attended formal schooling in their entire life. More than a third (38%) of all the respondents had primary education only, with Komkhulu 1 having the most respondents (63%) with primary education. Only a few individuals in Ndingeni (5%) and Mabalane (4%) had tertiary level education. Across all villages, only 5% of the respondents were permanently employed, while 17% were either self-employed or dependent on casual jobs. The major source of income across all villages was government social grants (57%). Comparisons across villages showed that more than 50% of the respondents receive government social grants, except in Pholweni (42%). About 21% of the respondents were unemployed and did not receive any income.

3.3.2. Knowledge and benefits of A. dealbata invasion

Across the villages, all respondents were aware of *A. dealbata,* known locally as *Idywabasi*. However, only a few respondents (23%) knew *A. dealbata* as an invasive alien plant with significant differences across villages ($\chi2 = 22.3$; $P = 0.001$). Villagers in Ndingeni had the highest proportion (50%) of respondents who knew *A. dealbata* as an invasive alien plant, while Sakhuthe (10%) and Pholweni (5%) had the lowest level of knowledge. Of those who knew *A. dealbata* as an invasive alien plant, 15% said they knew it because of the WfW alien clearing programme. Across all the villages, about 41% of the respondents reported that *A. dealbata* is present on their yard, although statistical comparisons across villages showed no significant differences ($\chi2 = 7.7$; $P = 0.05$). Only 6% of the respondents in Sakhuthe village indicated that they have planted it on their yard (Table 3.1). In contrast, 91% of the respondents across all villages reported that the plant grows naturally on the yard, although statistical comparisons across villages showed no significant differences ($\chi2 = 5.2$; $P = 0.05$). Most of the respondents across all villages said *A. dealbata* was beneficial to them, with significant differences across villages ($\chi2 = 28.3$; $P = 0.01$). All villagers in Sakhuthe, Mabalane, and Pholweni and a substantial proportion of the respondents in Ndingeni (82%), Komkhulu 1 (93%), and Komkhulu 2 (96%) reported that *A. dealbata* is beneficial (Table 3.1). Regarding benefits, the use of *A. dealbata* for firewood was mentioned by 98% of the respondents across all the villages (Table 3.1). Most of the respondents said that the availability of fuelwood from *A. dealbata* saved them from electricity costs given most of them were not gainfully employed and relied on social grants. Use of *A. dealbata* as poles for roofing rondavels and fencing was also mentioned, although with a relatively low proportion (34%) of respondents across all villages. Comparison by villages showed that more respondents in Pholweni (79%) and Komkhulu 2 (54%) than in Komkhulu 1, Mabalane, Sakhuthe and Ndingeni villages reported the use of *A. dealbata* poles, stating they could not afford to buy building materials from local hardware stores. Less than 15% of the respondents in Ndingeni and Sakhuthe villages identified shade as a benefit (Table 3.1).

Table 3.1. Knowledge and benefits of A. dealbata in six villages located in upper Tsitsana community in Eastern Cape Province of South Africa.

Interview questions	Ndingeni	Komkhulu 1	Komkhulu 2	Sakhuthe	Mabalane	Pholweni	Across villages		
							%	χ2	P-value
Do you know *A. dealbata*? (% of yes)	100	100	100	100	100	100	100	-	-
Do you know that *A. dealbata* is an invasive alien plant? (% of yes)	50	30	32	10	13	5	23	22.3	**0.001**
Do you have *A. dealbata* in your yard? (% of yes)	68	43	32	20	52	32	41	7.7	**0.175**
Did you plant it in your homestead? (% of yes)	0	0	0	6	0	0	1	3.2	**0.666**
Have you tried to remove *A. dealbata*? (% of yes)	89	93	95	76	94	100	91	5.2	**0.394**
Is *A. dealbata* beneficial to you? (% of yes)	82	93	96	100	100	100	95	28.3	**0.010**
Does *A. dealbata* have any contribution to your livelihood? (% of yes)	100	90	96	100	100	100	98	10.3	**0.068**
Listed benefits									
1. Firewood	94	100	92	100	100	100	98	23.6	**0.001**
2. Poles	15	14	54	13	30	79	34	205.3	**0.001**
3. Shade	12	0	0	7	0	0	3	43.4	**0.001**

Table 3.2. Community responses on costs associated with *A. dealbata* invasion in upper Tsitsana community in Eastern Cape Province of South Africa.

Costs associated with A. dealbata	Ndingeni	Komkhulu 1	Komkhulu 2	Sakhuthe	Mabalane	Pholweni	**Across villages**		
							All	χ2	P-value
Roots damage houses	64	33	35	24	44	23	37	49.9	**0.001**
Hinders growth of crops	0	0	35	5	17	31	15	94.6	**0.001**
Takes up yard space	13	33	25	38	33	31	29	19.0	**0.002**
Absorb water	5	0	5	10	0	0	3	25.9	**0.001**
Hiding place for criminals	5	7	0	19	0	0	5	56.1	**0.001**
Cause gullies	0	0	0	5	0	15	3	56.9	**0.001**
Attracts snakes	0	4	0	0	0	0	1	20.1	**0.001**
Costs associated with vegetation and grazing									
Do you think *A. dealbata* have an impact in native vegetation? (% of yes)	50	40	28	40	30	53	40	5.2	**0.397**
Do you own or manage livestock? (% of yes)	53	66	67	48	57	53	57	3.1	**0.687**

% of respondents who use mountains for grazing	21	45	29	32	29	24	30	2.4	**0.552**
% of respondents who use grazing land	11	0	5	3	0	3	4	1.0	**0.657**
Is the grazing land enough? (% of yes)	46	42	38	53	58	33	45	2.4	**0.787**
% of respondents who prefer having grazing land than *A. dealbata*	95	97	100	93	91	100	96	9.3	**0.506**
% of respondents who prefer *A. dealbata* than grazing land	0	0	0	0	0	0	0	-	-

Table 3.3. Respondents' views regarding *A. dealbata* management and clearing in upper Tsitsana community in Eastern Cape Province of South Africa.

							Across villages		
	Ndingeni	Komkhulu 1	Komkhulu 2	Sakhuthe	Mabalane	Pholweni	All	$\chi2$	P-value
Do you think clearing of *A. dealbata* a good or a bad thing? (% of good)	89	97	92	97	96	100	95	8.2	**0.650**
Were you open to the idea of clearing? (% of yes)	87	90	92	97	96	100	94	17.9	**0.057**
Were you consulted prior to clearing of *A. dealbata*? (% of yes)	53	72	80	43	35	53	56	30.5	**0.001**
Were you involved yourself in *A. dealbata* clearing Programme? (% of yes)	19	13	12	3	17	21	14	4.5	**0.481**
Did you benefit anything during clearing of *A. dealbata*? (% of yes)	53	80	48	50	74	42	58	12.6	**0.027**
Have you taken it upon yourself to remove *A. dealbata* beside being involved in any clearing programme? (% of yes)	58	77	64	83	91	89	77	13.5	**0.019**
Do you know any other community members who actively remove *A. dealbata* from the area? (% of yes)	53	77	56	70	87	89	72	21.3	**0.009**
Has clearing of *A. dealbata* improved grazing land? (% of yes)	74	66	40	60	57	74	62	29.3	**0.001**
Has clearing of *A. dealbata* improved water availability? (% of yes)	53	59	28	60	65	32	49	23.3	**0.009**

3.3.3. Costs of A. dealbata invasion

The respondents reported seven costs associated with *A. dealbata* invasion. Across all villages, 37% of the respondents said *A. dealbata's* roots damaged their house foundations and caused cracks to house walls, with the highest number of respondents saying so in Ndingeni village (64%). Some respondents (15% across all villages) said the invasive alien plant hindered the growth of crops in home gardens by competing for resources such as nutrients. About 29% of all the participants across all villages said that *A. dealbata* takes up yard space as it spreads fast than local native plants (Table 3.2). A small number of respondents (less than 10%) across all villages indicated that the plant contributed towards water shortages because it absorbed water (3%). Similarly, a small percentage of respondents (5%) across all villages reported proliferation of crime in the area as the plant is used by criminals for hiding. Few respondents reported that the plant causes gullies (3%), and it attracts snakes (1%) (Table 3.2).

Acacia dealbata was noted to impact native vegetation negatively by about 40% of respondents across the study villages (Table 3.2), but comparison across villages did not show significant differences ($\chi2 = 5.2$; $P = 0.05$). When respondents were asked to elaborate on the impacts of native vegetation, they indicated that *A. dealbata* outcompetes species for resources such as nutrients and water, suppress native vegetation growth, spread everywhere, and kill native species. With respect to grazing impacts, approximately 46% of respondents across all villages indicated that the impacts of *A. dealbata* on grazing were highly severe, with most respondents being in Ndingeni (63%), Komkhulu 2 (52%), and Sathuthe (50%) villages (Figure 3.2). However, around 17% of respondents across all villages said the effects on grazing were not severe, whilst 8% and 9% reported slight to moderate effects, respectively (Figure 3.2). Villagers noted that the spread of *A. dealbata* in nearby grazing lands reduced the amount of fodder for livestock, something that is likely to affect a significant number of villagers who own livestock (57% across all villages), although most are now taking their livestock to mountains for grazing (30%) as compared to the invaded grazing lands (4%) (Table 3.2). Statistical comparisons across all villages for livestock grazing sites showed no significant differences for mountain grazing ($\chi2 = 2.4$; $P = 0.552$) and invaded grassland grazing ($\chi2 = 1.0$; $P = 0.657$). The livestock owners reported that the mountains have less invasion, have healthier and grazeable grass, and the grass is evergreen even during the dry winter months. The choice to graze in mountains is supported by the fact that 45% of respondents across all the villages reported that the grazing lands are no longer enough due to *A. dealbata* invasion (Table 3.2). Comparisons across all villages showed no statistically significant differences ($\chi2 = 2.4$; $P = 0.787$). Overall, most respondents across all villages preferred having grazing land than *A. dealbata* invasion (96%), with statistically insignificant differences across all the villages ($\chi2 = 9.3$; P = 0.506) (Table 3.2). Villagers noted that the grass was no longer growing in grazing lands and some grazing lands had empty patches where the soil is exposed and eroded.

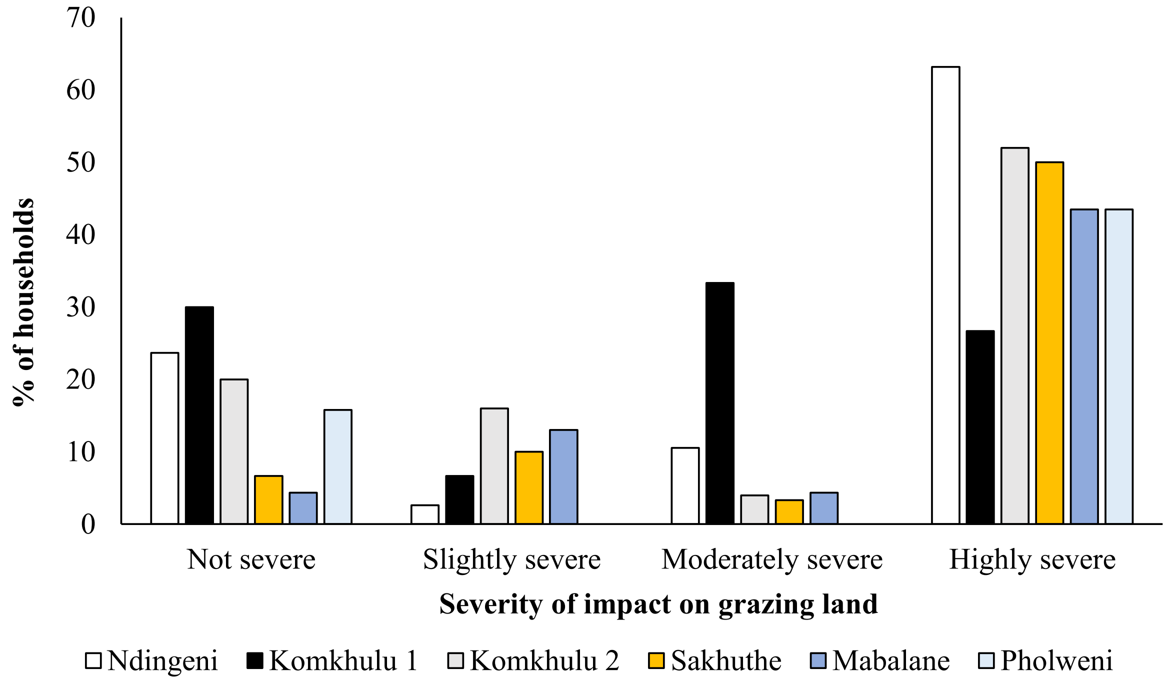

Figure 3.2. Severity of *A. dealbata* impact of grazing land in upper Tsitsana community in Eastern Cape Province of South Africa.

3.3.4. Perceptions on Acacia dealbata clearing

Although the respondents felt *A. dealbata* contributed to their livelihoods, a substantial proportion (95%) across all six villages believed that clearing of *A. dealbata* was a good strategy, with no statistical differences across villages ($\chi 2$ = 17.9; P = 0.057). Some of the reasons mentioned for its removal include reduction of *A. dealbata* spread and opening of grazing lands, with statistically insignificant differences between villages ($\chi 2$ = 8.2; P = 0.650) (Table 3.3). The idea of clearing *A. dealbata* was supported by most respondents across all villages (94%). According to the respondents, clearing helped to restore grazing lands, springs, crop fields and reduce the crime rate particularly livestock theft. Specifically, 62% of respondents across all villages said that clearing *A. dealbata* improved grazing, with most (74%) of these respondents being in Ndingeni and Pholweni villages (Table 3.3). Although the regrowth of grass was associated with *A. dealbata* removal in grazing lands, rapid seedling regrowth after clearing was also mentioned as a concern. *Acacia dealbata* clearing benefits associated with water availability were mentioned by nearly half (49%) of the respondents across all villages, with statistically significant differences across all villages ($\chi 2$ = 23.3; P = 0.009). When asked if villagers were consulted before the commencement of the clearing programme, only 56% agreed saying that consultations were done though general community meetings. Although consultations prior *A. dealbata* clearing were done, involvement of local villagers in the clearing programme was low (14%) (Table 3.3). For those who were involved in clearing, 58% mentioned benefits ranging from employment to collection of dry firewood from cut stamps. However, those employed in the clearing programme mentioned that the employment was temporary, ranging from months to years. A significantly high number of respondents (77%) across all villages were clearing *A. dealbata* on their own ($\chi2 = 13.5$; $P = 0.019$). Similarly, a significantly high number of respondents (72%) across all villages are aware that community members are actively removing *A. dealbata* from the area on their own ($\chi2 = 21.3$; $P = 0.009$). Removal of *A. dealbata* by community members was reported to be mostly on their household yards, walking paths, and near water collection sources.

Respondents were asked to rate perceived clearing improvements associated with quantity and quality of grazing, water availability, and native vegetation (Figure 3.3a-c). A sizeable proportion number of respondents in Ndingeni (51%) and Sakhuthe (53%) strongly agreed that clearing had improved the quality of grazing, whereas most respondents in Komkhulu 2 (60%) disagreed (Figure 3.3a). Only 27% of the respondents across all villages strongly agree that *A. dealbata* clearing has improved water availability, whilst 28% disagree (Figure 3.3b). A significant number of respondents (44%) in Ndingeni were neutral regarding water availability benefits (Figure 3.3b). Regarding the rate of native vegetation improvement linked to clearing, some 33% strongly agree that *A. dealbata* removal has improved native vegetation, whereas 32% disagree (Figure 3c). Most of the respondents who strongly agreed were in Pholweni (37%), whilst those who disagreed were in Komkhulu 2 (68%) (Figure 3.3c).

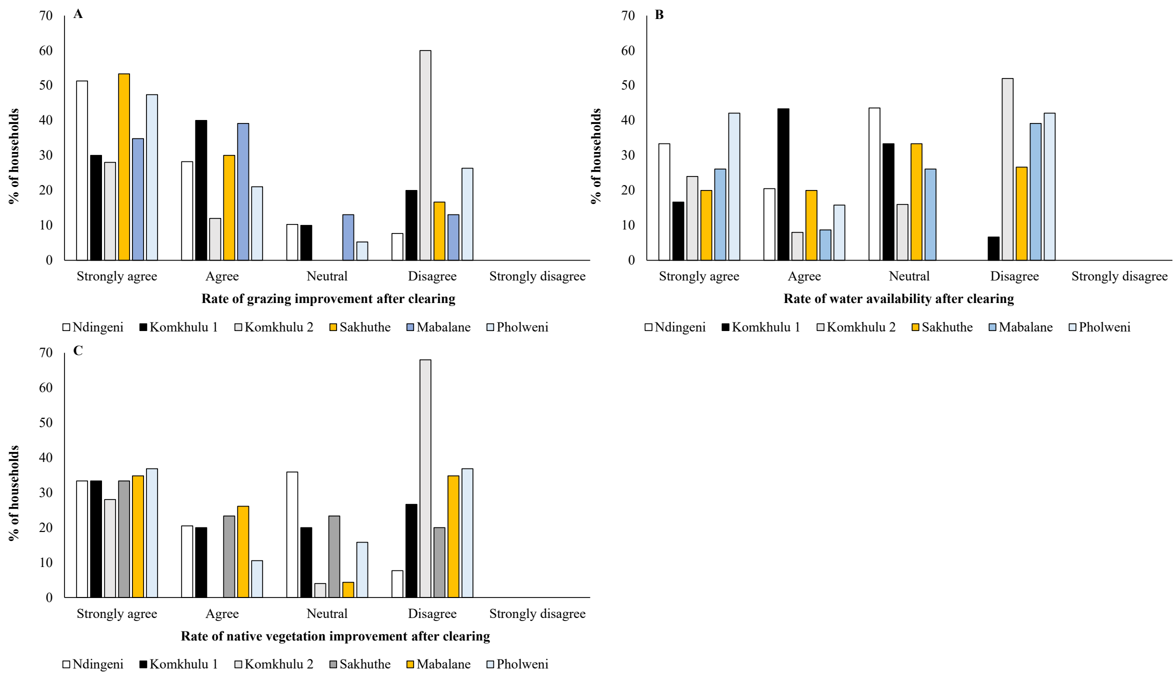

Figure 3.3. Perceptions on rate of clearing improvements on (a) quantity and quality of grazing, (b) water availability, and (c) native vegetation in upper Tsitsana community in Eastern Cape Province of South Africa.

3.4. Discussion

The findings of this study suggest that most villagers are aware of *A. dealbata* in the area, but most do not know that it is an invasive alien plant. A similar study done by Ngorima and Shackleton (2019) in another Eastern Cape rural community reported that *A. dealbata* is prevalent and has been in the area for at least eight decades and integrated into people's livelihoods to the extent that most people view it as native. Invasive alien plants that have established in an area are mostly perceived as native by local people who have been with the plant for decades (Kull et al. 2014; Ngorima and Shackleton 2019). Therefore, our results concur with the notion that invasion history and duration can influence how local people perceive invasive alien plants, with plants that have been in the area for a long time being perceived as native because they seem to have been integrated into local people's daily living (Kull et al. 2014; Ngorima and Shackleton 2019; Ruwanza and Thondhlana, 2022). Most of the respondents did not plant *A. dealbata* on the yards, an indication that they could have found the species in the area when they moved. A study by Ruwanza and Thondhlana (2022) reported similar results for the invasive alien plant *P. guajava* in rural communities of Vhembe Biosphere Reserve in Limpopo, where planting on household yard was found to be rare because of the abundance of the plant in the area.

Most respondents reported some benefits from *A. dealbata,* include firewood, construction materials (e.g., pools for fencing kraals and roofing) as well as shade provisioning. Several studies have reported that some invasive alien plants provide important services to rural communities (Kull et al. 2011; Ngorima and Shackleton 2019; Ruwanza and Thondhlana 2022). Apart from the benefits listed above, Ngorima and Shackleton (2019) reported that *A. dealbata* is also used for livestock forage and traditional medicine, although these benefits were reported by few villagers. Kull et al. (2011) reported that Australian *Acacias* are used for various purposes around the globe such as for construction purposes in South Africa, fuel for distillery in France, fuelwood in India, agroforestry in Niger, and furniture making in Vietnam. Estimates in South Africa suggest that the monetary benefits associated with *A. dealbata* contribute approximately US$224 per year to household savings (Ngorima and Shackleton 2019). The above-mentioned financial benefits can assist in reducing living costs among rural communities who are mostly unemployed, thus providing the much-needed economic safety-net for rural communities (Ngorima and Shackleton 2019). There is no doubt that invasive alien plant species contribute significantly to rural livelihoods, however some studies have reported that these benefits also shape people's knowledge and perceptions of the plants (Shackleton et al. 2018; Ruwanza and Thondhlana, 2022). For example, Shackleton et al. (2018) reported that positive benefits and uses of invasive alien plants in rural communities can result in people having a positive perception about the plant, simply because of the benefits that the plant provides. Such positive perceptions could help local people generate knowledge on the plant, e.g., knowledge on growth and flowering patterns, plant's response to environmental changes, and how to manage the plant in such a way that people maximize benefits.

Apart from benefits, several negative effects associated with *A. dealbata* invasion in the area were reported. These include structural damage to buildings by roots, negative effects on crop fields and yields, contribution to crime, loss of grazing land and loss of water. Similar adverse effects were reported for *A. dealbata* (Ngorima and Shackleton 2019), and for other woody invasive alien plants such as *E. camaldulensis* (Hirsch et al. 2020), and *P. guajava* (Ruwanza and Thondhlana 2022), with all these studies having been conducted in South Africa. In addition, studies that assessed other problematic woody invasives such as *Lantana camara* showed that it is associated with loss of pastures in Kenya (Walton 2006), harbours tsetse flies which cause nagana and sleeping sleekness in Rwanda (Day et al. 2003), and loss of livestock through ingestion related photosensitivity in the East African countries of Kenya and Tanzania (Shackleton et al. 2017). Recent studies have reported that negative impacts caused by invasive alien plants tend to increase with increase in invasion extent and spread in an area (Shackleton et al. 2019). For example, lowland farmers in Madagascar view the invasive alien plant *A. mangium* negatively because the plant continuously spread in the area causing significant negative effects on soils, to the extent that costs on soils are now outweighing benefits such as shade (Kull et al. 2019). In Vietnam, the spread of the Australian invasive species *A. auriculiformis* and *A. mangium* since the 1990s has the potential to cause land degradation, although the species provides several benefits to local communities such as wood furniture (Nambiar et al. 2015). It is argued that as spread increases, the negative effects (costs) are likely to outweigh the benefits that the species provide (Shackleton et al. 2019) and once costs start to outweighing benefits, people's perceptions about the plant tend to become negative, with some advocating for removal.

Rural communities in Eastern Cape Province of South Africa are heavily dependent on livestock (van Sittert 2002), therefore it was not surprising to notice that the effect of *A. dealbata* invasion on grazing land was mentioned by several villagers. In this study, respondents reported that grazing lands are no longer producing sufficient fodder due to rapid *A. dealbata* encroachment. Previous studies have reported that invasive *Acacias* displace native grasses, and the displacement intensifies with increase in invasion extent or density (De Neergaard et al. 2005; Yapi et al. 2018). Yapi et al. (2018) reported that *A. mearnsii* invasion in Eastern Cape can reduce grazing land area although the effects are invasion density dependent. Generally, it is believed that between 2006 and 2016, alien plant invasion in South African rangelands has increased by nearly 670%, resulting in significant loss of grazing land. The subsequent livestock production loss associated with the above-mentioned alien plant invasion in rangelands is estimated at R340 million (US$18 million) annually (O'Connor and van Wilgen 2020). The loss of grazing grass after *A. dealbata* invasion is linked to several factors such as (i) the ability of *Acacia* species to out-compete native species for resources such as water and nutrients, (ii) reduction in light penetration underneath invaded monostands, (iii) the plant's ability to change soil nutrients through N-fixation, and (iv) loss of soil moisture underneath the plant canopy (Yapi et al. 2018). For example, Yapi et al. (2018) reported lower soil moisture and high soil litter and nitrogen content under dense *A. mearnsii* invaded areas relative to grasslands. Loss of soil moisture, increased litter and soil nitrogen can result in grass displacement, particularly where the invasion density is high (Yapi et al. 2018). In this study, some respondents reported that *A. dealbata* invasion is linked to water loss, an important factor that could also result in loss of grass in grazing lands. Although this was not assessed in this study, the loss of grazing grass following *A. dealbata* invasion could also be indirectly linked to increased fire intervals and intensity in grasslands (O'Connor and van Wilgen 2020). Grasslands are fire prone so it is possible that increased *A. dealbata* invasion in grasslands could increase fire intervals and intensity leading to displacement of grasses through loss of soil seedbank.

The findings show that both benefits and costs associated with *A. dealbata* invasion were reported, an indication that managing the plant could be complex (Zengeya et al. 2017; Shackleton et al. 2019). Indeed, Shackleton et al. (2019) reported that most Australian *Acacias* in South Africa contribute both benefits and costs to local livelihoods, although this is socio-ecological context dependent. For example, most of the benefits that *A. dealbata* provides are provisioning services with less regulating and supporting services, although the plant also harms the environment. The environmental harm has the potential to reduce the provisional services leading to increased household vulnerability. Although managing *A. dealbata* could be difficult given that the plant has both benefits and costs (Shackleton et al. 2019), understanding perceptions of the plant could inform management interventions needed in different contexts. This speaks to the notion that interventions and management of invasive alien plants that provide both benefits and costs cannot be uniform but need to be context-dependent with one such context being the perceived balance between benefits and costs by users. Therefore, managers of invasive alien plants in rural communities need to think of user context and species-specific interventions that incorporate community views and perceptions to avoid conflicts.

The South African government has decided to control *A. dealbata* invasion through the WfW clearing programme. The results regarding clearing perceptions show that villagers appreciate the WfW clearing initiative for two reasons, (i) the socio-economic benefits such as employment and income, and (ii) the potential ecological benefits such as increased water availability, restoring degraded grazing lands, and native vegetation recovery. The socio-economic benefits of clearing invasive alien plants in South Africa have been extensively documented, and these mostly include skills training and income that can be used to benefit households (Magadlela and Mdzeke 2004; Morokong et al. 2017). Although some studies have criticised these socio-economic benefits based on their temporary nature (Hough and Prozesky 2013), it is widely acknowledged that these benefits are important to rural people. An important result in this study was that rural communities also appreciate the ecological benefits associated with *A. dealbata* clearing. Previous studies have reported ecological benefits such as water availability and recovery of native vegetation, however, these sentiments have been coming from private landowners and scientific researcher (Marais and Wannenburgh 2008; Urgenson et al. 2013; Stafford et al. 2017), with rural community's views being rarely documented. The reported ecological benefits associated with *A. dealbata* clearing tend to show that rural people understand the clearing benefits and the few who participate in the clearing process are also learning by doing. Indeed, one of the motivations behind WfW alien plant clearing in South Africa is ecological integrity, particularly improving water availability, and it seems like the rural communities understand this mandate, which was previously reported by most private landowners (van Wilgen et al. 2020). However, although the respondents are open to the idea of clearing *A. dealbata* for ecological benefits, some reported mixed feelings, citing that these ecological benefits were not being realized. Disagreement with the notion of ecological benefits from *A. dealbata* clearing could be attributed to the value they place on *A. dealbata* benefits, such that clearing has the potential to reduce these benefits. Clearing invasive alien plants that have both costs and benefits is complicated since these species are regarded as conflict-generating species (Zengeya et al. 2017). As previously suggested, human perceptions towards the management of conflict-generating species are largely influenced by the relationship between benefits and costs (Zengeya et al. 2017), with communities likely to advocate for removal when costs outweigh benefits. Generally, the fact that we reported a significant number of participants who are now clearing *A. dealbata* on their yard seem to suggest that the costs are now outweighing the benefits. This potentially explain why participants now perceive clearing as a good management option that extends beyond the accrued invasion socio-economic benefits but also an appreciation of clearing ecological benefits.

3.5. Conclusion

The results show that *A. dealbata* is an invasive alien plant with both benefits and costs to the villagers in upper Tsitsana in Eastern Cape Province of South Africa. Although this has been reported in previous studies (Ngorima and Shackleton 2019), we have gone further to show that the clearing of *A. dealbata* in the area is viewed positively by local people, with ecological benefits such as recovery of grazing land, native vegetation, and increased water availability being acknowledged. The acknowledgement of the above-mentioned clearing ecological benefits by rural communities show that rural people understand the benefits associated with WfW clearing, a notion that has been associated mostly with private and large-scale commercial farmers. From a management standpoint, local people’s views need to be incorporated in developing management options that accommodate benefits and costs. Stakeholder involvement is important if management of conflict generating species is to yield positive results. Lastly, utilisation of *A. dealbata* by local people should be incorporated in management plans since it has the potential to reduce invasion extent and spread. However, more research on utilisation efficacy is needed before it is incorporated in management plans. Also, there is a need for more research on perceptions on alien plant clearing so that ecological restoration linked to alien plant clearing are accompanied by human views. If alien clearing for ecological restoration purposes is based on the need to restore ecosystems for human well-being, then it is plausible to explore how the benefits are perceived by people.

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Chapter 4

Does *Acacia dealbata* clearing passively restore grazing grasses in upper Tsitsana grasslands, Eastern Cape province of South Africa?

Abstract

Invasive alien plants have severe impacts on South African socio-ecological systems. Significant investment has been made to manage *Acacia dealbata* in South Africa's grasslands, yet little is known regarding restoration trajectories of native grazing grass after clearing. This study investigated grazing grass diversity and composition recovery following *A. dealbata* clearing in grasslands located in upper Tsitsana catchment, South Africa. Grass surveys were conducted during the rainy season in 1 m^2 quadrats that were replicated 15 times across four sites that had paired *A. dealbata* cleared and grassland patches. We enumerated 14 different grass grazing species that were present in both *A. dealbata* cleared and grassland patches except for *Panicum* species. *Cynodon dactylon* dominated both patches, whereas the palatable grass species of *Paspalum dilatatum, Sporobolus africanus, Cyperus* sp., and *Aristida congesta* had frequency occupancy of more than 40% in the cleared patches. Although grass cover was significantly ($p = 0.05$) higher in the grasslands than the cleared patches, grass richness was significantly ($p = 0.05$) higher in the cleared patches. Although the results contradict the general assertation regarding passive restoration, we concluded that passive restoration of grazing grass species after *A. dealbata* clearing is following a positive trajectory since the cleared sites have species similarity with the grassland sites.

Keywords: Alien plants, livestock grazing, passive restoration, rangelands, Working for Water.

NOTE: *This chapter is written and structured in the format of a paper that is ready for peer review journal submission. The study area and refences are included/repeated in this chapter since the paper is a draft manuscript. The target journal is Ecological Restoration.*

4.1. Introduction

Invasive alien species are a major threat to biodiversity globally (Richadson et al. 2020; Bitani et al. 2022). Major impacts on biodiversity that are associated with invasive alien species include displacement and loss of native species (Richadson et al. 2020), changes in ecosystem processes and functions (Andersen et al. 2004; Ruwanza and Shackleton 2016), loss of rangelands (O'Connor and van Wilgen 2020), and loss of water (Le Maitre et al. 2020). Although these negative impacts are species dependent, invasion by invasive alien species is largely associated with huge economic losses (Eschen et al. 2021), that ultimately affect human wellbeing (O'Connor and van Wilgen 2020; Shackleton et al. 2020). Recent evaluations of the economic impacts of invasive alien species suggest that global costs of invasion sum up to billions of US$ (Cuthbert et al. 2021; Eschen et al. 2021; Haubrock et al. 2021). For example, Haubrock et al. (2021) suggested that the cost of invasive alien species in Europe alone was estimated at US$140 billion in 2020, whereas Eschen et al. (2021) estimated it at US$65 billion to agriculture in Africa. It is anticipated the impacts associated with invasive alien species will increase in future due to several factors that include increased human movement, globalisation, and climate change (Turbelin and Catford 2021).

In South Africa, invasion by invasive alien plants such as *Acacias*, *Pinus*, *Lantana*, *Eucalyptus*, and *Opuntia* species has resulted in severe biodiversity losses (Richadson et al. 2020). Most of these plant species are invasive and were intentionally introduced over a century ago for various purposes such as agriculture and ornamental (van Wilgen at al. 2020; Richadson et al. 2020). Although actual records of how many invasive alien plants are in South Africa vary, recent reports indicate that 759 invasive alien plants have naturalised, with most of these plant species found in the fynbos and grassland biomes (Richadson et al. 2020). Species richness of naturalised invasive alien plants in South Africa seem to show invasion dominance along moist coastal regions and within cities, the later likely to be linked to human population concentration (Richadson et al. 2020). In the grassland biome, invasive alien plants are associated with loss of water resources and grazing rangelands, thus resulting in losses to the agricultural sector (O'Connor and van Wilgen 2020). Recent studies have suggested that the loss of palatable grasses in rangelands following invasion by invasive alien plants such as *Acacia*, *Opuntia*, and *Campuloclinium* species has resulted in livestock production losses estimated at 340 million Rand (estimated at US$17 million at current 2023 exchange rate) annually (O'Connor and van Wilgen 2020). Several factors can explain the loss of grazing grass following alien plant invasion, including, increased fire, change in soil nutrients, competition for resources, creation on invasion monostands, and loss of soil moisture (Yapi et al. 2018; O'Connor and van Wilgen 2020). For example, Yapi et al. (2018) reported that the dominance of Acacia species in South Africa's montane grassland ecosystem reduced grazing grass capacity from 2 to 8 hectares to support a large livestock unit. De Neergaard et al. (2005) reported that invasive woody species such as *Acacias* can displace native grasses, thus converting grasslands to woodlands. Moyo and Fatunbi (2010) reported that fast growing invasive trees and shrubs tend to outcompete native grasses for nutrient and water resources thus outcompeting and displacing them by creating monostands once they have invaded an area.

Although the above-mentioned studies provide evidence that invasive alien plants negatively affect grazing grass and ultimately livestock production, few studies have examined the recovery of native grass following alien plant removal (Yapi et al. 2018). The Working for Water (WfW) Programme has invested billions of Rands in controlling invasive alien plants throughout South Africa, yet little is known about the recovery of native grasses in communal areas, where livestock production is valued due to its contribution to livelihoods. Several studies have shown mixed vegetation recovery trajectories following alien plant removal, with both successes (Fill et al. 2017; Ruwanza et al. 2018) and failures (Blanchard and Holmes 2008; Ruwanza et al. 2013). Where vegetation recovery success has been observed, it has mostly been linked to availability of soil seed bank, proximity to intact native areas, role of remnant plants, seed dispersal, and suitable environmental conditions that favour native vegetation germination and growth (Holmes et al. 2008; Fill et al. 2017; Ruwanza et al. 2018). In contrast, vegetation recovery failures following alien plant removal have been linked with secondary invasion, reinvasion, lack of soil seedbank, and unfavourable environmental conditions such as drought that supress plant germination and growth (Ruwanza et al. 2013). Given the extensive alien plant clearing that has been happening in South African rangelands, it is not clear if this clearing investment is yielding positive results such as restoration of native grazing grass, hence the need to monitor grazing grass recovery after alien plant clearing.

Acacia dealbata Link (belonging to Fabaceae family and originally from Australia) is one of the dominant invasive alien plants in grasslands of the Eastern Cape province in South Africa (Gouws and Shackleton 2019). The small-to medium-sized evergreen tree commonly known as Silver Wattle (Van Wyk and Van Wyk 2013), was introduced to South Africa for timber and tannin production, however, due to its reduced commercial value the plant species has now invaded many natural ecosystems (Gouws and Shackleton 2019). *Acacia dealbata* transforms natural ecosystems through its ability to change soil nutrients, change water and fire regimes, and create monostands that decrease resources such as sunlight to underneath native species (Lorenzo et al. 2017; Gouws and Shackleton 2019). Species specific traits that make *A. dealbata* invasive include its ability to produce abundant seeds, reaching reproduction maturity fast, rapid germination, thriving in disturbed habitats, allelopathy, and formation of symbiotic relationships with soil nitrogen fixing bacteria that allows nitrogen fixation (De Neergaard et al. 2005; Passos et al. 2017; Gouws and Shackleton 2019). The species is regarded as a transformer alien tree that changes the invaded ecosystem to its benefit (Gouws and Shackleton 2019). In contrast, *A. dealbata* offers several benefits to humans such as timber production, used in communal areas for firewood, construction pools, fodder for animals, medicinal, and offers provisional services like shade (van Wilgen et al. 2011; Ngorima and Shackleton 2019). Besides these benefits, recent studies have shown that negative effects associated with *A. dealbata* tends to outweigh the benefits, thus the need to manage through clearing. There is no doubt that the current *A. dealbata* clearing interventions by WfW to control the plant, however, little is known regarding native vegetation recovery particularly is grazing grass in grasslands. Consequently, this study sought to assess grazing grass recovery following *A. dealbata* clearing in grasslands located in upper Tsitsana catchment, South Africa. The key research question guiding the study was: does grazing grass diversity and composition follow a positive trajectory (mimic uninvaded grasslands) following *A. dealbata* clearing? Results are envisaged to inform clearing managers and restoration ecologists on the effects of *A. dealbata* clearing on native grazing grass recovery to guide future alien plant clearing restoration interventions.

4.2. Materials and methods

4.2.1. Study area

The study was conducted on the Upper Tsitsana (30°49'0"S; 28°19'0"E), some 45 km from Maclear (officially Nqanqarhu) town in the Eastern Cape Province of South Africa (Figure 4.1). The catchment is situated in the Southern Drakensberg Highland Grassland (Mucina and Rutherford 2006) and receives Austral summer rainfall (ranging from 600 mm to 800 mm mean annual rainfall). Temperatures in the area are characterised by hot summers (averaging 42°C) and cold winters (averaging 0°C) (Mucina and Rutherford 2006). Soils in the area are loamy and shallow usually with minimal soil development on hard weathered rock (Mucina and Rutherford 2006). The area is heavily invaded with Australia *Acacias,* particularly *A. dealbata* which dominates riparian zones and eroded gullies (Huchzermeyer 2017). The area has some of the poorest communities in South Africa and villagers are heavily dependent on social grants and subsistence agriculture mostly livestock production. Most of the people in the area speak isiXhosa.

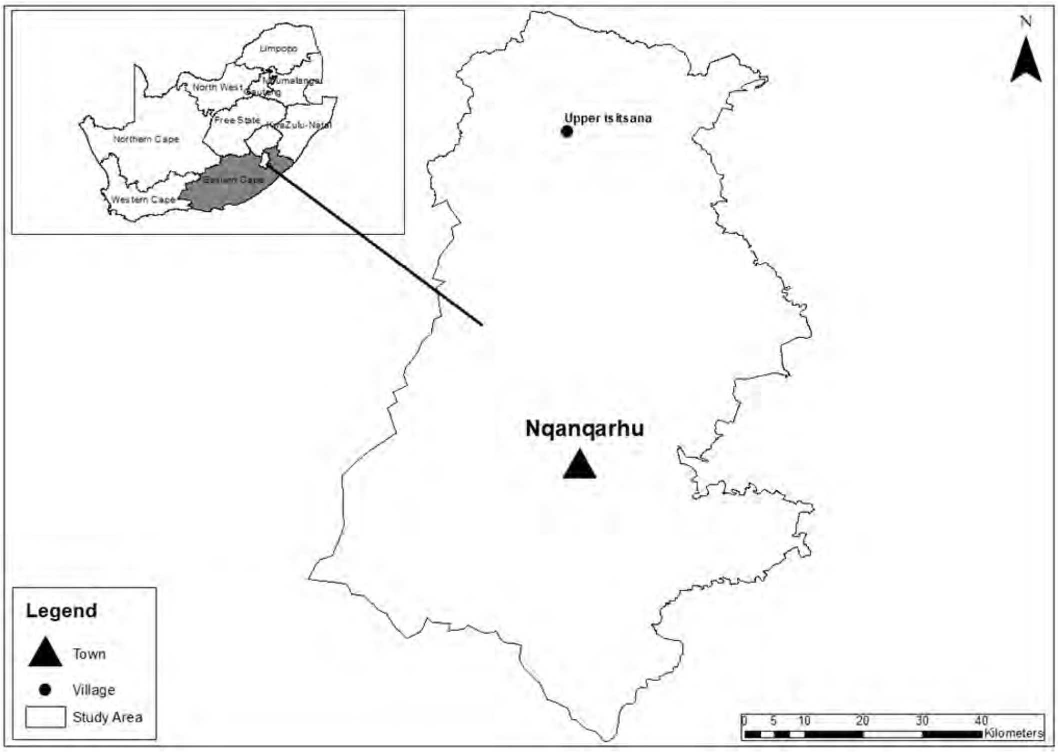


Figure **4.1.** Map showing the study area in Upper Tsitsana in the Eastern Cape Province of South Africa.

4.2.2. Experimental design and data collection

We sampled grazing grass in four sites that had paired *A. dealbata* cleared and grassland patches. The uninvaded grassland patches acted as the reference patches and were dominated by grasses with no trees and shrubs. The distance between each of the four sites was approximately 5 km, whereas the distance between the *A. dealbata* cleared and reference patches within each site was approximately 4 m (i.e., separated by gravel roads). The cleared patches had *A. dealbata* cleared by WfW from 2017 to 2018 and clearing involved mechanical cutting of *A. dealbata* close to the base, followed by herbicide application on cut stumps to prevent resprouting. The felled *A. dealbata* trees were stacked before being collected by the residents for fuelwood and for construction pools, whereas the remaining residual big trees were burnt on site. During grass sampling all burnt patches were avoided. In summer (February 2022) detailed grass surveys were conducted on all four sites with paired cleared and grassland patches. At each site, 15 quadrats were set up in each cleared and grassland patch along a 100 m transect that ran across the centre of each patch. The 1 m^2 quadrats were 5 m apart with the first quadrat positioned 10 m from the patch boundary. In total 120 quadrats were surveyed (15 quadrats x 2 patches x 4 sites). In each quadrat we recorded the following information; the total number of individual grasses per plant species (for creeping grasses distinct clumps were considered as individuals). Grass cover estimates were recorded for individual grass species within each quadrat using the Braun-Blanquet approach, where an 8-point scale was used: rank 1: 0 - 5%; 2: 5 - 20%; 3: 20 - 35%; 4: 35-50%; 5: 50 - 65%; 6: 65 - 80%; 7: 80 - 95% and 8: 95 - 100% cover (Ben-Shahar 1991). Samples for each grass species were collected for identification at the Selmar Schonland Herbarium located at Rhodes University in Makhanda, South Africa.

4.2.3. Data analysis

All statistical analyses were performed using TIBCO STATISTICA version 14.0 software (TIBCO Software Inc 2020). A normality test was conducted using Kolmogorov-Smirnov tests and homogeneity of variances was done using Levene's test, and data were normally distributed. Grass abundance, richness, Shannon-Wiener index, evenness, and cover estimates were calculated per quadrat and compared between cleared and grassland sites using an independent sample t-test since data were normally distributed. Grass abundance was calculated as the sum of the counted grasses per quadrat, whereas species richness was the total number of the different grass species per quadrat. Shannon-Wiener index and evenness were calculated based on the abundance and richness data. In addition, species occupancy frequency was calculated as the number of times a grass species was present in different quadrats. A Principal Component Analysis (PCA) was performed using presence and absence data in CANOCO 5 (Šmilauer and Lepš 2014) to investigate how quadrats in both cleared and grassland patches changed grass species composition.

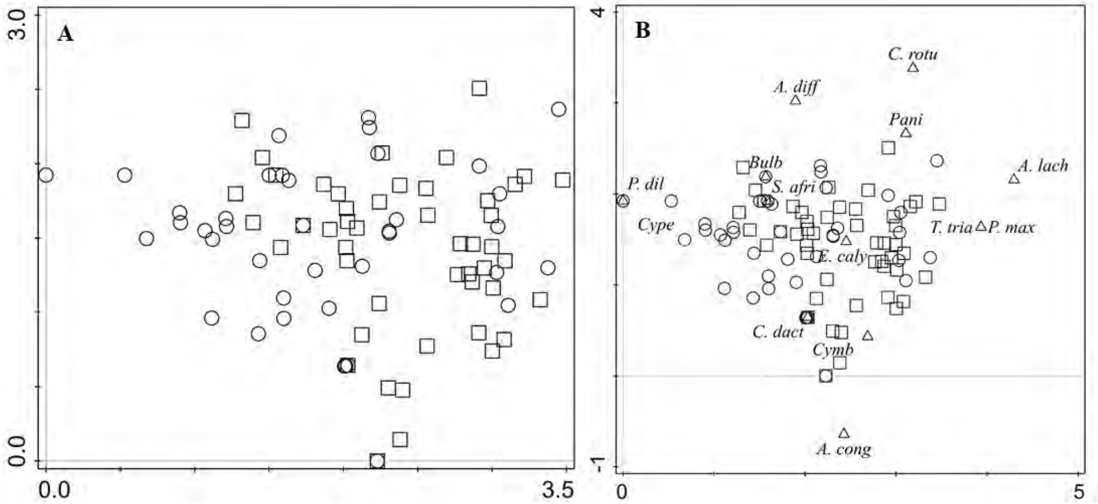
4.3. Results

We enumerated 14 different grass species of which 11 were poaceae and 3 were cyperaceae (Table 4.1). All the grass species were native, except for *Paspalum dilatatum* and *Bulbostylis sp* (Table 4.1). Except for *Panicum sp*., all other species were recruiting in the cleared patches. *Cynodon dactylon* dominated both the cleared and grassland patches with frequency occupancy of more than 60% in the cleared sites and 80% in the grasslands (Table 4.1). *Paspalum dilatatum, Sporobolus africanus, Cyperus sp.,* and *Aristida congesta* had frequency occupancy of more than 40% in the cleared patches (Table 4.1). All the recruiting species in the cleared patches were palatable except for *Bulbostylis sp.* (Table 4.1). *Panicum maximum* and *Themeda trianda* were the only two species that dominated grasslands but had low frequency occupancy of below 20% in cleared sites (Table 4.1). The PCA of the quadrats without grasses showed no separations between the cleared and grasslands in ordination space determined by the first two axes (Figure 4.2A). In contrast, biplots of quadrats and grasses (Figure 4.2B) showed little grass separation between the cleared and grassland quadrats. Grass species such as *P. dilatatum* and *Cyperus* sp. assembled more in cleared quadrats compared to *A. congesta* which assembled more in grasslands (Figure 4.2B). The first two PCA axes showed low eigenvalues and accounted for 29% of the total variance.

Table 4.1. Fourteen frequently occurring grass species in cleared and grasslands. (*) indicates that the grass species was present and is based on calculated frequency occupancy categorized as *(1-20%), **(21-40%), ***(41-60%), ****(61-80%) and *****(81-100%). (-) indicates that the species was not present. Plant names denoted with (A) superscript indicate that the species is alien and (S) indicate that it is a sedge.

Plant name	Family	Palatability	Cleared	Grasslands
Ehrharta calycina	Poaceae	Yes	*	***
[A]*Paspalum dilatatum*	Poaceae	Yes	**	*
Cynodon dactylon	Poaceae	Yes	***	****
Sporobolus africanus	Poaceae	Yes	**	**
[S]*Cyperus rotundus*	Cyperaceae	Yes	*	*
[S]*Cyperus sp.*	Cyperaceae	Yes	**	*
Cymbogon sp.	Poaceae	Yes	*	*
Aristida diffusa	Poaceae	Yes	*	*
Aristida congesta	Poaceae	Yes	**	**
[S/A]*Bulbostylis sp.*	Cyperaceae	No	*	*
Agrostis lachnantha	Poaceae	Yes	*	*
Panicum maximum	Poaceae	Yes	*	**
Panicum sp.	Poaceae	Yes	-	*
Themeda trianda	Poaceae	Yes	*	**

Figure 4.2. Principal Component Analysis (PCA) biplots of measured grasses (Δ) from the sampled quadrats (O = cleared and □ = grasslands). (A) shows plots only and (B) shows plots and grasses. The first four letters of the grass names are presented with full names in Table 1.



Both grass abundance and cover were significantly ($p < 0.05$) higher in the grasslands (mean = 30.35 ± 2.52 and 18.93 ± 1.97) than the cleared (mean = 19.96 ± 1.98 and 13.23 ± 1.47) patches respectively (Table 4.2). In contrast, species richness and Shannon-Wiener index of diversity were significantly ($p < 0.05$) higher in the cleared (mean = 3.77 ± 0.17 and 0.89 ± 0.05) than grassland (mean = 3.33 ± 0.14 and 0.75 ± 0.04) (Table 4.2). Generally, grass cover and abundance were more in the grasslands than the cleared patches, although diversity measures of richness and Shannon-Wiener index showed the opposite trend. Grass evenness showed no significant differences between the cleared and grassland patches (Table 4.2).

Table 4.2. Comparisons of grass diversity measures in cleared and grasslands. Data are mean ± standard errors and t-test results are shown.

	Cleared	**Grasslands**	***t*-value**	***p*-value**
Species abundance	19.96 ± 1.98	30.35 ± 2.52	3.24	0.002
Species cover	13.23 ± 1.47	18.93 ± 1.97	2.32	0.022
Species richness	3.77 ± 0.17	3.33 ± 0.14	2.01	0.046
Shannon-Wiener index	0.89 ± 0.05	0.75 ± 0.04	2.17	0.032
Species evenness	0.66 ± 0.03	0.65 ± 0.03	0.06	0.949

4.4. Discussion

The clearing of invasive alien plants in South Africa assumes that native species will passively recover without interventions. We found evidence that *A. dealbata* clearing improved grazing grass species composition and diversity, but it had no effect on species cover and abundance. Except for *Bulbostylis* sp. which is not palatable and *Panicum* sp., which was not present in cleared patches, all other recruiting grasses were present in the cleared patches. This result shows that recruiting grasses in the cleared sites are mimicking those in the grasslands, an indication that passive restoration is taking place after *A. dealbata* removal. Therefore, a positive recovery trajectory from cleared to grasslands is being followed. The recovery of grazing grass following *A. dealbata* removal has been reported in the past, and it could be linked to several factors such as excess resource availability, reduced competition, and availability of native grass seedbank (Yapi et al. 2018). *Acacia dealbata* is known for changing soil nutrient resources (particularly N fixation) for its growth benefits, so its removal could have resulted in excess nutrients being made available for use by recruiting grazing grass (Nsikani et al. 2017). A recent study by Nsikani et al. (2021) reported that excessive soil N found in *Acacia* cleared sites favours the growth of native species, although effects on germination was not observed. Excessive nitrogen in the soils tends to favour growth of grasses, although this is species dependent (Tian et al. 2021). Further, it has been reported that excessive nitrogen in soils influences soil macronutrient acquisition, and this is more common in grasses than forbs, shrubs, and trees (Tian et al. 2016, 2021). Besides increased soil N availability following *A. dealbata* removal, it is possible that other resources such as sunlight and water were also available in access amounts after clearing. It has been well documented that monostands of invasive Australian *Acacias* reduce sunlight penetration (Le Maitre et al. 2011; Yapi et al. 2018). Therefore, removal of the *A. dealbata* canopy increased the sunlight penetration, rendering it available to recruiting plants, in this case grasses. Sunlight is an important resource for plant growth, therefore its availability in excessive amounts after *A. dealbata* removal could explain the recovery of grazing grass in the cleared sites.

Previous studies have reported that *A. dealbata* negatively affects soil moisture content due to its high demand for water (Lopez-Hortas, et al. 2021). Therefore, its removal could have made soil moisture content available for the recruiting grass species, thus accelerating their growth (Souza-Alonso et al. 2015; Lopez-Hortas et al. 2021). Fay and Schultz (2009) showed that although plant germination and growth responses to soil moisture vary, grasses tend to germinate and establish better under high soil moisture availability than other plants. Besides, it has been reported that moist soils facilitate litter decomposition through increased bacterial activity which then make soil nutrients available to recruiting grasses (Bian et al. 2022). From a competition standpoint, *A. dealbata* is a fast-growing species that outcompetes native species (Le Maitre et al. 2011; Lopez-Hortas et al. 2021), therefore, its removal creates suitable conditions for grazing grass to recruit without competition for resources (Yapi et al. 2018). It has been shown that the removal of invasive *Acacias* in grasslands can improve grazing capacity by 66% from the baseline within 5 years, mainly because of reduced competition between the woody invaders and grazing grass species (Yapi et al. 2018). Recruitment of grazing grass following removal of invasive alien plants only happens if seedbank of grazing grass is available. Native seed can be available in the soil stored seedbank, dispersed from remnant understory plants that existed before clearing, or from nearby intact areas (Holmes et al. 2008). We did not examine the source of recruiting grazing grass, however previous studies on soil seedbank after invasive alien plant removal have shown higher seed bank densities of grasses in cleared sites relative to invaded sites (Mndela et al. 2020). It is also possible that germinating grazing grass species in the cleared sites were dispersed from nearby intact grassland sites since our paired surveyed sites were close (separated by gravel roads).

Although *C. dactylon* was the most frequently occurring grazing grass in the cleared quadrats, *P. dilatatum* and *Cyperus* sp. assembled more in cleared quadrats compared to the grassland quadrats. The dominance of these grasses in the recovering cleared quadrats, particularly *C. dactylon* could be linked to ability to utilise excessive nutrients left by *A. dealbata* (Yapi et al. 2018). Besides, previous studies have reported that *C. dactylon* proliferates in disturbed areas (Zwerts et al. 2015). Since the clearing of *A. dealbata* leaves soil rich in nitrogen, *C. dactylon, P. dilatatum* and *Cyperus* sp. could have taken advantage of the excess nitrogen to establishment (Zwerts et al. 2015). Other studies have reported that an increase in soil nutrients, particularly nitrogen and phosphorus can result in the dominance of lawn-forming grasses like *C. dactylon* (Zwerts et al. 2015). However, the cleared sites are open to grazing by livestock, which could explain why tufted grasses like *P. dilatatum* are present as these tend to dominate nutrient rich soils whenever grazing is introduced (Amiaud et al. 2008). Besides the above, clearing related soil disturbances could explain the dominance of grasses such as *C. dactylon* in the cleared quadrats since it thrives on disturbed areas (Fernandez 2003). Moreover, *C. dactylon* has the capacity to regenerate from stolons and rhizomes, this probably explaining its success in cleared quadrats. It is not clear why *Panicum* species is not recruiting in the cleared sites, however, lack of soil seedbank in the cleared areas could explain its absence.

4.5. Conclusion

The results of this study provide important insights regarding recruitment of grazing grass following *A. dealbata* clearing. We have demonstrated that passive restoration of grazing grass species follows a positive restoration trajectory since the cleared sites have species similarity with the grassland sites. Therefore, clearing *A. dealbata* can help restore grazing grasses, which could ultimately improve the capacity of grasslands in Upper Tsitsana which is essential in these communities that are livestock dependent. Soil legacy effects after *A. dealbata* clearing, particularly increased soil resources such as soil nitrogen, sunlight, and soil moisture could explain the recruitment of grazing grass. The dominance of some grasses such as *C. dactylon, P. dilatatum* and *Cyperus* sp. in the cleared sites could be explained by resource utilisation, competition, and availability of soil seedbank in the cleared sites. The overall implications are that *A. dealbata* clearing is recommended to facilitate grazing grass recovery, which subsequently supports livestock grazing and production in these communal areas. Improved livestock grazing in Eastern Cape grasslands following *A. dealbata* removal can be associated with improved livelihoods as communities are dependent on livestock grazing.

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Chapter 5

Synthesis, recommendations, and conclusions

5.1. Introduction

Invasive alien species can cause significant negative environmental and socio-economic impacts outside their native ranges (Richardson and Rejmánek 2011; Richardson et al. 2020). Recent studies have shown that these impacts can trigger severe negative effects on human beings and global economy, with billions of US$ being lost due to alien species invasion (Eschen et al. 2021; Haubrock et al. 2021). The problem of invasion by invasive alien plants continues to grow due to factors such as globalisation, human travel, urbanisation, and climate change (van Wilgen at al. 2020; Haubrock et al. 2021). Despite the negative impacts caused in invasive alien plants, several studies have also provided evidence that these species are beneficial to human livelihoods (Vaz et al. 2017; Shackleton et al. 2019; Ruwanza and Thondhlana 2022). For example, some invasive alien plants such as Australia *Acacias* provide humans with important resources such as fuelwood and pools for construction (Ngorima and Shackleton 2019). Other studies have reported that invasive alien plants are used for medicinal purposes (Ruwanza and Thondhlana 2022), soil stabilization (Richardson et al. 2020), aesthetics and as ornamental plants (Potgieter et al. 2019).

Given that invasive alien species, particularly plants, have both benefits and costs to the environment and humans, there is a need to approach their management using a socio-ecological approach (Shackleton et al. 2020). The invasion landscape is a socio-ecological system because human behaviour, decisions, and actions can facilitate ecological invasion and processes (Yletyinen et al. 2021). For example, the harvesting of some alien invasive plants by humans can promote the movement of that species into new areas (Shackleton et al. 2020), whilst on the other hand harvesting and utilisation can act as a control mechanism that reduces ecological spread. Indeed, socio-ecological systems are interconnected and complex, so is the biological invasion landscape, that is why terms such as conflict generating species (Zengeya et al. 2017) are now being used to describe some of these invasion complexities. Therefore, the management of invasive alien species needs to take a socio-ecological approach, particularly the involvement of all stakeholders to come up with effective solution. This study took that approach and tried to understand both perceptions (research chapter 3) and clearing ecological benefits (research chapter 4).

In South Africa, the WfW program was implemented to manage invasive alien plants while creating job opportunities for people. There are various methods used to control invasive alien plants such as complete removal, burning, and ring barking (Le Maitre et al. 2020). Few studies have looked at both the social and ecological benefits of WfW clearing, yet billions of Rands have been invested in the programme. The question remains, are alien plant cleared sites recovering and are local people seeing the benefits associated with WfW clearing. In this study we took the approach of assessing both human perceptions on clearing benefits and ecological benefits of restoration through assessing grass recovery. If clearing is yielding ecological benefits, what are the social benefits associated with grazing and are local people noticing these benefits. The study used *A. dealbata* as a model species to assess socio-ecological effects of invasion and benefits linked to its removal.

5.2. Summary of results

Objective 1. To assess the knowledge, costs, benefits, perceptions, and management of A. dealbata on rural communities in Tsitsa communal areas, Eastern Cape Province of South Africa.

Our results showed that *A. dealbata* is extensively used by local people in the upper Tsitsana area. However, our results also reported that local people observed negative impacts linked *to A. dealbata* invasion. Both benefits and costs were recorded, however, the clearing by some individuals seem to suggest that the costs outweigh the benefits and villagers generally think that A. dealbata should be removed in the area. Previous studies have shown similar results, e.g., the use of *A. dealbata* to generate income thus acting as a primary source of livelihood (Ngorima and Shackleton 2019). In the Eastern Cape province, households use *Acacia* species on a regular basis and in meaningful quantities to the extent that they enjoy a significant income that can be used as a safety net (Shackleton et al. 2007, Ngorima and Shackleton 2019).

The assessment of human perceptions towards WfW clearing showed that local rural communities are aware of the benefits associated with *A. dealbata* removal. Several benefits such as recovery of grassland, water and landscape restoration were mentioned during interviews. This shows that local rural people appreciate the benefits associated with WfW clearing, a perception that tends to be mostly associated with commercial farmers (Hough et al. 2013). Besides, recognising these benefits, local villagers also received financial benefits if they were involved in WfW clearing, a benefit that has been reported elsewhere (Hough et al. 2013; Le Maitre et al. 2020). With a large proportion of people in this area leaving under the poverty datum line, the clearing benefits mentioned have the potential to assist them e.g., through direct cash income and improved grazing areas that sustain their livestock, which subsequently generates the much-needed income. Therefore, *A. dealbata* clearing has the potential to improve their livelihoods through direct income and restoration of landscapes which can then be used for other income generating activities.

Overall, the results suggest that management of *A. dealbata* needs consultations with all stakeholders including rural communities. This is because *A. dealbata* is integrated into local landscapes and used extensively by local people, yet it is known to have negative environmental effects. Therefore, *A. dealbata* can be classified as a conflict generating species, implying it has both costs and benefits. Given that it has both costs and benefits, its management need involvement of all stakeholders to balance the needs of users. Several studies have reported the need for stakeholder consultation when managing invasive alien plants and our results reiterate the same calls (Zengeya et al. 2017; Shackleton et al. 2020; Ruwanza and Thondhlana 2022).

Objective 2. To examine the effects of A. dealbata clearing on recruitment of indigenous native grass targeted for grazing.

Australian *Acacia* species in South Africa pose on-going management challenges, perpetuating high long-term management costs (McConnachie et al. 2012), and are particularly difficult to control despite intensive management effort. *Acacias* are highly invasive globally (Le Maitre et al. 2011). Invasive alien plants may also disrupt ecological processes, which may result in reducing palatable grasses (Brooks et al. 2004; Holmes et al. 2020) and knock-on effects of livestock. Grass cover decreases in a negative exponential manner with an increase in *Acacia* cover (Gwate et al. 2016). Therefore, alien control measures may be sufficient to restore structure, function, and ecosystem processes, if the control method is effective (Holmes et al. 2020). However, implementing ecological restoration after alien plant removal is complex due to several challenges such as previous invasion extent, restoration goals, measures put in place to assist recovery, and resource availability (Holmes et al. 2020).

In chapter 4, the clearing of *A. dealbata* seems to be facilitation spontaneously/passive restoration since we observed some vegetation similarities between cleared sites and reference grassland sites. Most of grass species found in the cleared areas were also present in the grassland reference sites although cover was low. Interestingly, the recruiting grasses were mostly palatable, thus suitable for animal grazing. Although these factors were note tested, the recruitment of native grass species in the cleared sites may have been influenced by several factors such as proximity to the natural/reference grasslands, availability of resources, availability or remnant grass species, and seed dispersal. These factors have been reported in several studies that have reported that passive recovery of native species after alien plant removal is facilitated by the above-mentioned factors (Blanchard and Homles 2008; Ruwanza et al. 2013; Yapi et al. 2019; Mndela et al. 2022).

5.3. Conclusions and recommendations

Drawing on the results, the following conclusions and recommendations are suggested.

1. Local people noted both benefits and costs of *A. dealbata* invasion. They also noted that the ongoing clearing initiative in the area has noticeable benefits such as restoration of grazing land and water. Given the above, it is recommended that any management intervention for *A. dealbata* in the area needs involvement of all stakeholders to balance the reported benefits and costs that local people are getting from the plant. Local stakeholders need to be engaged more, informed about invasive alien plants and control measures. They must be involved in decision-making and that will make them to be keen and volunteer in controlling invasive alien plants.
2. The presence of palatable grass species in the cleared sites points to successful passive restoration of species composition and diversity. Over time, it is possible that cleared sites will look like grasslands, provided no external factors like extensive grazing and fire negatively affect the cleared sites. It is therefore recommended that clearing and removal of *A. dealbata* is prioritised so that

restoration of native grazing takes place. It is also recommended that cleared sites need to be monitored regularly so that recovering grass is protected. This can be achieved through WfW follow-up control, reduces grazing of cleared areas by local people, and investment into grass planting as a mechanism to fast tract the recovery process. There is a need for a temporary exclusion of grazing in cleared sites to allow successional recovery of grass. The removal of grazing can trigger recovery of some grasses in the cleared area that were not present. This grazing removal can be done through, negotiations with villagers to exclude grazing or by fencing off cleared areas. The fencing of cleared areas in rural communities might face challenges such as theft, however, leaders have developed local rules and bylaws that can assist in reducing theft.

3. Chapter 3 showed that local people value grazing benefits associated with *A. dealbata* clearing, and chapter 4 provided evidence that grazing grass recruitment is taking place. Therefore, human knowledge and ecological evidence seem to complement each other, thus local people knowledge about *A. dealbata* clearing can be used to inform ecological management interventions. Therefore, stakeholder workshops and meetings to discuss invasion spread, impacts, and potential management are recommended. Having, these stakeholder workshops and meeting creates potential for developing effective interventions that are acceptable by everyone. Top-down approaches to manage invasive alien plants in these rural communities might face resistance, therefore bottom-up approaches are recommended. Such bottom-up approaches need to incorporate local people's views and suggestions.
4. From a research standpoint, future research in biological invasion needs to adopt socio-ecological thinking in understanding invasion processes. Humans are an integral part in the biological invasion process, therefore, research that factors human perceptions and views has better chances of providing effective recommendations than ecological studies only. We recommend that biological invasion research take an inter-and-transdisciplinary approach to understand and solve the problem rather than a disciplinary approach.

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Appendix 1

Questionnaire survey instrument for a study conducted in upper Tsitsana community in Eastern Cape Province of South Africa

Questionnaire number ………………………………..

Date of interview……………………………………

District………………………………………………

Village……………………………..........................

Section 1: Personal information of the respondent

1.1. Age……………………………………….………………………………………….

1.2. Gender: Male [ ] Female [ ] Prefer not to say [ ]

1.3. Level of education: No formal education [ ] Primary school [ ] Secondary school [ ] Tertiary Education [ ] Other [ ]

1.4. What is your main source of income or occupation?

……………………………………………………………………………………………

Section 2: Understanding of *A. dealbata*

2.1. Do you know *A. dealbata*? Yes [ ] No [ ]

2.2. Do you have *A. dealbata* in your homestead? Yes [ ] No [ ]

2.3. If yes, did you plant it, or it just grew in your homestead? Yes [ ] No [ ]

2.4. If it just grew in your homestead, have you tried to remove it? Yes [ ] No [ ]

2.5. Please provide a reason for the above answer

……………………………………………………………………………………………

2.6. Did you know that *A. dealbata* is an invasive alien plant? Yes [ ] No [ ]

2.7. If yes, when did you discover that *A. dealbata* is an invasive alien plant?

……………………………………………………………………………………………

2.8. Is *A. dealbata* beneficial to you? Yes [ ] No [ ]

2.9. If yes, how?

……………………………………………………………………………………………

Section 3: Impacts of *A. dealbata*

3.1. Do you think *A. dealbata* have an impact on native vegetation? Yes [ ] No [ ]

3.2. If yes, how?

……………………………………………………………………………………………

3.3. Do you own or manage livestock? Yes [ ] No [ ]

3.4. Where do you graze your livestock?

....

3.5. If yes, is the grazing land enough? Yes [ ];No [ ]

3.6. Why is it so?

……………………………………………………………………………………………

3.7. Do you think *A. dealbata* have an impact on grazing land? Yes [ ] No [ ]

3.8. How severely do you believe *A. dealbata* impact is on the quantity and quality of grazing land?

……………………………………………………………………………………………

3.9. If you had to choose between having grazing land or *A. dealbata* close by your homestead which one would you choose? Grazing land [ ] *A. dealbata* [ ]

3.10. Why?

……………………………………………………………………………………………

3.11. What other effects does *A. dealbata* have on the land?

……………………………………………………………………………………………

Section 4: Perceptions on *A. dealbata* management

4.1. Does *A. dealbata* have any contribution to your livelihood? Yes [ ] No [ ]

4.2. If yes, please explain?

…………………………………………………………………………………………..

4.3. Do you think clearing of *A. dealbata* a good thing or a bad thing? Good [ ] Bad [ ]

4.4. Please provide reason(s) for the above answer.

……………………………………………………………………………………………

4.5. Were you open to the idea of clearing? Yes [ ] No [ ]

4.6. Were you consulted prior clearing of *A. dealbata*? Yes [ ] No [ ]

4.7. If yes, how?

……………………………………………………………………………………………

4.8. Were you involved in *A. dealbata* clearing Programme? Yes [ ] No [ ]

4.9. How long were involved? Days [ ] Months [ ] Years [ ]

4.10. What were the reasons for being involved in the clearing Programme?

……………………………………………………………………………………………

4.11. Did you benefit anything during clearing of *A. dealbata*? Yes [ ] No [ ]

4.12. What is it that you benefited?

……………………………………………………………………………………………

4.13. Have you taken it upon yourself to remove *A. dealbata* beside being involved in any clearing programme? Yes [ ] No [ ]

4.14. Why?

……………………………………………………………………………………………

4.15. Do you know any other community members who actively remove *A. dealbata* from the area? Yes [ ] No [ ]

4.16. If yes, why do you think they do so?

……………………………………………………………………………………………………

4.17. Have clearing of *A. dealbata* improved grazing land?

Please explain your answer:

……………………………………………………………………………………………………

4.18. Has clearing of *A. dealbata* improved water availability? Yes [ ] No [ ]

Please explain your answer:

……………………………………………………………………………………………………

4.19. Please, rate how you perceived improvements to the following clearing aspects:

Aspect	**Strongly Agree**	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
Quantity and quality of grazing					
Water availability					
Native vegetation					
Other…					
Other…					

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19/08/2021

Dr. Sheunesu

Ruwanza Email:

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Review Reference: 2021-5187-6234

Dear Dr. Sheunesu Ruwanza

Re: Stakeholder perceptions associated with alien plant clearing in South Africa: case study of Acacia clearing in

Tsitsa communal areas. Principal Investigator: Dr. Sheunesu Ruwanza

Collaborators: Miss Nwabisa Coka, Prof. Gladman Thondhlana,

This letter confirms that the above research proposal has been reviewed by the Rhodes University Human Ethics Committee (RU-HEC) and
PROVISIONALLY APPROVED PENDING PERMISSION/GATEKEEPER LETTER(S).

Gatekeeper permission is required from:

a) Headman – Mr. M Mnyazana
b) Headmen – Mr. M Mdletye

Once the Gatekeeper permission letter/s have been received please forward it to the Ethics Coordinator, (s.manqele@ru.ac.za) in

order to finalize your ethics approval. Sincerely,

Prof. Arthur Webb

Chair: Rhodes University Human Ethics Committee, RU-HEC

cc: Mr. Siyanda Manqele, Ethics Coordinator