Impact of the invasive alien plant species clearing programme on socio-economic benefits and plant biodiversity along the northern Drakensberg, Mpumalanga Province, South Africa

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Table of Contents

ACKNOWLEDGEMENTS ii

Table of Contents iii

ABSTRACT vi

ETHICAL CONSIDERATION viii

DECLARATION ix

LIST OF ABBREVIATIONS x

Chapter 1: General introduction and literature review 1

1.1 Invasive alien species **1**

1.2 Invasive alien plants in South Africa **3**

1.3 Legislative frameworks governing invasive alien plants in South Africa 7

1.4 Background of the South African Expanded Public Works Programme and alignment with Working for Water Programme 9

1.5 The South African Working for Water Programme 11

1.6 History of the Working for Water programme 11

1.7 Control methods implemented by Working for Water to manage invasive alien plants 14

1.7.1 Mechanical control method 15

1.7.3 Biological control method 16

1.7.4 Integrated control method 17

1.8 Implementation of the clearing of invasive alien plants project by the Working for Water programme 18

1.9 Working for Water programme success 19

1.10 Socio-economic benefits 20

1.11 Study area 21

1.11.1 Vegetation 21

1.11.2 Land use 22

1.11.3 Climate 23

1.11.4 Population 24

1.11.5 Water catchment area 24

1.11.6 Invasive species 26

1.12 Aim of the study 27

1.13 Objectives 27

Chapter 2: Socio-economic benefits and effectiveness of the Working for Wateprogamme as perceived by communities in the northern Drakensberg escarpment 29

2.1 Introduction 29

2.2 Material and Methods 30

2.2.1 Study sites 30

2.3 Data collection and Ethics 31

2.4 Data analysis 33

2.5 Results 33

2.5.1 Working for Water participant questionnaires 33

2.5.1.1 Level of knowledge of invasive alien plants 34

2.5.1.2 Knowledge of legislations that govern invasive alien vegetation and control 35

2.5.1.3 International studies on invasive alien plants 35

2.5.1.4 Major threats of invasive alien plants along the northern Drakensberg 37

2.5.1.5 Ecological benefits along the northern Drakensberg escarpment due to clearing of invasive alien plants by Working for Water 38

2.5.1.6 Advantages of invasive alien plants 39

2.5.1.7 Involvement of respondents in the Working for Water programme 40

2.5.1.8 Socio-economic benefits of the Working for Water programme by communities living in the northern Drakensberg escarpment 41

2.5.2 Landowner questionnaires 44

2.5.2.1 General knowledge of invasive alien plants by landowners 44

2.5.2.2 Type of land use, hectares cleared, experience with Working for Water and level of satisfaction about the work that the Working for Water programme has done on landowners properties 45

2.5.2.3 Competence of Working for Water clearing teams 47

2.5.2.4 Status of invasive alien plants as a result of the Working for Water clearing programme 48

2.5.2.5 Impact of clearing of invasive alien plants by WfW programme on restoration and/or preservation of ecosystem functions and services 48

2.5.2.6 Working for Water Programme implemetations and future improvements 49

2.6 Discussion 49

2.7 Conclusion 53

Chapter 3: Responses of plant communities to invasive alien plan-tremoval on the northern Drakensberg escarpment, South Africa 55

3.1 Introduction 55

3.2 Material and Methods 57

3.2.1 Study sites 57

3.2.2 Selection of study sites 57

3.2.3 Site characteristics 61

3.2.3.1 Graskop (B60B102957 & B60B102959) 61

3.2.3.2 Robbers Pass (B60F100066) 64

3.2.3.3 Pilgrim's Rest site (B60F100180) 65

3.2.3.4 Blyde river catchment B60B102383 66

3.2.4 Vegetation community assembly 66

3.3 Data Analysis 68

3.4 Results 68

3.5 Discussion 76

Chapter 4: General discussion, recommendations, and conclusions 79

4.1 Introduction 79

4.2 The impacts of intermittent funding on the Working for Water Programme 80

4.3 The importance of landowner engagement 82

4.4 Restoration 83

4.5 Habitat destruction in the Northern Drakensberg escarpment 83

4.5 Recommendations 85

4.8 Conclusions 88

References 89

Appendices 112

Appendix 1: Categories 1a, 1b, 2 and 3 listed Invasive Species, in terms of which certain restricted activities are prohibited in terms of section 71A (1); exempted in terms of section 71(3); required a permit in terms of section 71(1) of the NEMBA AIS, 2020. 112

Appendix 2 : Landowner and Participants questionnaires. The data is stored online and can be accessed through the following links. 115

Appendix 3: Research Ethics Approval: Environment & Biosafety Ethics Committee 130

Appendix 4: Research Ethics approval: General/ Human Research Ethic Committee (GHREC) 131

Appendix 5: Research permit obtained from the Mpumalanga Tourism Parks Agency (MTPA). 132

Appendix 6: List of plants species collected per sites during vegetation survey. 133

ABSTRACT

The Working for Water (WfW) programme started in 1995, with the aim of controlling invasive alien plants in South Africa to protect a range of ecosystem services such as water and rangeland productivity, to protect biodiversity and create employment opportunities for previously disadvantaged rural communities targeting women, youths and people leaving with disabilities. The aim of this study was to investigate the effectiveness of the WfW programme focusing on three of their main objectives: (1) create sustainable jobs; (2) remove invasive alien plants from the river courses, grasslands, and indigenous forest; and (3) increase biodiversity. This study investigated the success of these objectives in the northern Drakensberg escarpment, Mpumalanga province, South Africa, by (1) determining the perceptions of employees and landowners on the impacts of the WfW programme through questionnaires, and (2) determining the impact of clearing on plant biodiversity through field surveys comparing plant diversity and cover-abundance in plots cleared by WfW and neighbouring uncleared grasslands.

To determine whether the programme had created sustainable jobs, questionnaires were submitted to 80 community members who were employed in the WfW programme, in the study area, and 65 completed questionnaires. The surveyed family size ranged from one individual to eleven persons per household with an average of five people per household, and all had indicated that their primary source of income was from the WfW programme. The study found that most (46%) of the participants had a good knowledge of invasive alien plants (IAPs) while 86% of the respondents believe IAPs are a major problem, and 91% of the participants believed that WfW had benefitted communities living in the northern Drakensberg escarpment, with 97% indicating that the programme had improved their living conditions. This study further revealed that the programme has significantly contributed to rural communities' livelihoods, but short-term contracts and intermittent funding have significant implications for the communities now relying on the funding. In addition, a limited number of landowners (10) were interviewed on their perceptions of the WfW programme. The findings revealed that most (60%) of the landowners who responded believed the programme was beneficial, and 70% of the landowners indicated that clearing of IAPs had increased stream flow and water availability. In addition, 90% of the landowners indicated that they had seen an estimated reduction of IAPs of between 20% to 80% on their properties due to clearing by WfW.

Vegetation surveys were conducted at sites previously cleared by WfW teams (some as early as 1995) and paired with adjacent uncleared control sites. Initially, approximately 30 study sites

were selected for investigation, which were refined to five suitable sites. The diversity and cover-abundance of plant species were surveyed in plots along transects within each pair of sites. Results showed that species diversity was significantly lower in cleared sites than in natural sites at Blyde river and Robbers Pass, while Graskop had significantly lower species diversity overall in both natural and cleared habitats. The NMDs plots showed that vegetation community assembly varied between cleared plots and open veldt across all sites, and more species were shared between sites in the Blyde river catchment and Pilgrims Rest. In addition, PERMANOVA results indicated that there were significant differences in plant communities between cleared and uncleared sites with lower species diversity in cleared plots. The study showed that despite areas being cleared for over ~25 years many important native species have not returned, and the communities remain different. Presumably, species recovery might not occur without some form of additional management, therefore restoration actions including monitoring of cleared sites should be considered to accelerate native vegetation recovery. In addition, landowner cooperation is critical to the success of WfW which seemed to be a challenge and needs to be strengthened to ensure improvement in the implementation of the programme.

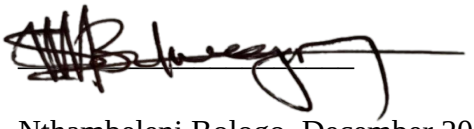
This study concludes that there is a need for quantitative, long-term, post management evaluations and assessments of the impacts of the funding models on communities used in broad scale initiatives. This will ensure that both the benefits and the failures of the project can be accurately determined to ensure its continued development and success. In addition, WfW should have dedicated funding for research to provide valuable long-term capacity. Finally, WfW should develop long-term clearing management plans with clear and realistic goals for all priority areas, and progress towards those should be routinely monitored to ensure continued improvement in the implementation of the programme.

ETHICAL CONSIDERATION

Ethical considerations were considered before data was collected. The research questionnaires and informed ethical consents were approved by the General/ Human Research Ethics Committee -(GHREC) (reference number UFS-HSD2021/1102/21) and the Environment & Biosafety Research Ethics Committee (reference number UFS-ESD2021/0210/21). The researcher observed all COVID-19 protocols and POPIA act legislative requirements. The researcher obtained the required permit from the Mpumalanga Tourism Parks Agency for the collection of plant specimens before the vegetation survey was conducted. Furthermore, permissions were requested from the Landowners where work had been done by the Working for Water programme on their properties as well as project participants who have worked in the project to remove invasive alien plant species. All participants were informed of the objective, risk, and benefits of their participation, and that their participation was voluntary. The rights and welfare of the participants were upheld when conducting interviews, all the participants and landowners had voluntarily signed the consent form to participate in the research project and the information collected was kept confidential. The research was conducted in a manner that shows respect and honour to patents, copyright, and other forms of intellectual property by giving appropriate credit to the sources of information that were used to substantiate the research.

DECLARATION

I, **Nthambeleni Bologo** declare that the master's thesis that I herewith submit at the University of the Free State, is my independent work and that I have not previously submitted it for qualification at another institution of higher education.



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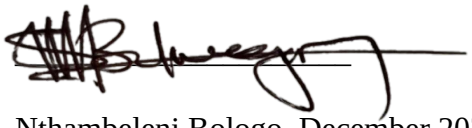

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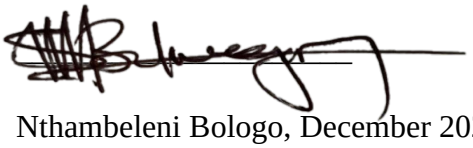

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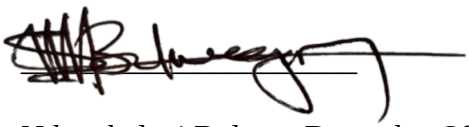

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LIST OF ABBREVIATIONS

APO-Annual Plan of Operation

AS- Alien species

Arc GIS- Aeronautical Reconnaissance Coverage Geographic Information System

ANOVA- Analysis of Variance

CARA- Conservation of Agricultural Resource Act

DEA- Department of Environment Affairs

DFFE- Department of Forestry, Fisheries, and the Environment

DME- Drakensberg Mountain Centre

DPWI- Department of Public Works and Infrastructure

DWA- Department of Water Affairs

EDRR- Early Detection and Rapid Response

EPWP- Expanded Public Works Programme

ESRI- Environmental Systems Research Institute

FTEs- Full-Time Equivalents

GDS- Growth Development Summit

IAPs- Invasive Alien Plants

IAS- Invasive Alien Species

NBAL- Natural Biodiversity Alien

LC50- Lethal Concentration of 50%

LD50- Lethal Dose to 50%

LMEE- Limpopo Mpumalanga Eswatini Escarpment

NMDS- Non-metric Multidimensional Scaling

NEMBA- National Environmental Management Biodiversity Act

PDs- Person Days

PERMANOVA- Permutational Multivariate Analysis of Variance for Non-parametric

POPIA- Protection of Private Information Act

SANBI- South African Biodiversity Institute

SANBI ISP- South African National Biodiversity Institute for Invasive Species Programme

SMMEs- Small Micro Medium Enterprises

SIMPER-Similarities Percentage

USD- United State Dollar

WIMS- Working for Water Management Information Systems

WfEco- Working for Ecosystem

WfW- Working for Water

WoF- Working on Fire

Chapter 1: General introduction and literature review

1.1 Invasive alien species

Globalisation has accelerated the spread of alien species across continents to the point now that alien species are widely distributed in every type of ecosystem throughout the world (Diagne *et al.*, 2020; Pathak *et al*., 2021). Alien species are non-indigenous organisms translocated outside of their natural geographic range usually by human intervention, but not always, and some of these alien species have the potential to become invasive. Invasive alien species (IAS) are species which become established in a natural or semi-natural ecosystem or habitat and threaten native biological diversity or have significant other environmental, economic, or social impacts (IUCN, 2016; Atyosi *et al*., 2019; Vitule *et al*., 2019). IAS are considered key drivers of human-induced global environmental change (Pejchar and Mooney, 2009).

Invasive alien species consists of organisms from all six Kingdoms of life; however, Invasive Alien Plants (IAPs) are considered the most damaging of IAS, attributed with the greatest environmental and economic impacts (McGeoch *et al*., 2010). IAPs have contributed significantly to the transformation of natural ecosystems and in many instances become the drivers of environmental change, disrupting ecosystem integrity, and provisioning necessary for human survival (Blackburn *et al*., 2011; Chikowore *et al*., 2021). Furthermore, the loss of native plant diversity due to IAPs can reduce ecosystem functioning (Linders, 2019). It is worth noting that some IAP's were introduced for useful reasons into certain ecosystems but have become invasive resulting in undesirable qualities far exceeding their desirable effects. In addition, not all impacts are negative and some species in certain scenarios may have beneficial aspects and can provide key services that benefit livelihoods as they deliver assets in the form of capital and creation of job opportunities (Shackleton *et al*., 2019). This includes the provision of fuelwood, food, poles, charcoal, timbers, paper, fodder, tanning agents to produce soft leather, and medicinal products (Atyosi *et al*., 2019; Shackleton *et al*., 2019). Invasive Alien species also provide other benefits for livelihoods such as soil improvement through nitrogen fixation and green manure, fencing, and cultural services, such as aesthetic values and recreation (Shackleton *et al*., 2019). For example, in South Africa, IAPs such as *Acacia dealbata* Link (Fabaceae), *Acacia mearnsii* De Wild (Fabaceae). *Opuntia ficus-indica* (L.) Mill. (Cactaceae), *Opuntia robusta* J.C. Wendl. (Cactaceae) and *Opuntia stricta* (Haw.) Haw. (Cactaceae) provide supporting and regulatory services such as green manure, fodder,

firewood, medicine, building materials, horticultural material, food, and income to the local communities through the selling of various plant products (Shackleton *et al*., 2015; Atyosi *et al*., 2019). However, in general, the negative impacts of IAPs outweigh derived benefits as the benefits are more associated with availability and not out of preference (Shackleton *et al*., 2018).

Invasive alien plants often have severe economic effects because they can greatly reduce the amount and flow of ecosystem services from invaded areas (Scheepers and Griffiths (2020). The estimated global economic cost of IAP invasions over the last 50 years is approximately USD 1,288 trillion (2017 US dollars), with a mean annual cost of USD 1.268 billion to 1.4 trillion (5% of global GDP) and the number is steadily growing over time (Howard, 2019; Diagne *et al*., 2021a; Zenni *et al*., 2021). According to Pimentel (2011), the overall cost of invasive species amounts to more than USD 300 billion per year in the United States, Australia, Europe, India, British Isles, and South Africa. However, the present and future projections of numbers and types of IAS differ throughout ecosystems (van Kleunen *et al*., 2015; Essl *et al*., 2020), and impacts and costs also differ extensively across time and space (Angulo *et al*., 2021b; Diagne *et al*., 2021a). In Africa, the overall annual cost of IAS to agriculture alone is estimated at USD 65,58 billion and the average annual cost without research costs amounted to USD 1,366 billion per country (Eschen *et al*., 2021). There are large differences in economic costs of IAS among countries; for example, economic losses for Botswana, Djibouti, Equatorial Guinea, Gambia, Guinea-Bissau, Liberia, Mauritania, and Somalia were less than USD 50 million, whereas for Nigeria alone it's estimated to be over USD 15 billion (Eschen *et al*., 2021). De Lange and van Wilgen (2010) estimated that the economic losses of water resources, biodiversity and livestock production totalled to USD 773, USD 45 and US 57 million per year. Furthermore, these estimations were conservative, since 2010 invasive species have continued to spread, and more species have become invasive.

The overall amount spent on the control of alien species by the South African government so far is unknown, but it is currently at least ZAR2,6 billion (USD 142 million) as this is the amount used by the Department of Forestry, Fisheries, and the Environment (DFFE) control programmes including Working for Water programme (van Wilgen *et al*., 2020).. The Working for Water (WfW) programme is a government funded conservation initiative established by the South African government with the primary aim to prevent, contain and reduce the density and distribution of established IAS to reduce their negative effects on the environment (Angelstam

et al., 2017; O'Connor and van Wilgen 2020) while providing job opportunities to marginalised sectors of society (Ntshotsho *et al*., 2015). According to van Wilgen *et al*. (2022), the WfW projects spent ZAR 7.1 billion (adjusted to 2020 values of ZAR) between 1998 and 2020 on interventions to control alien plant invasions of which the largest proportion (ZAR 5,27 billion) was spent on teams that were contracted to remove IAPs.

One of the most damaging impacts of IAPs is their impact on water resources (Le Maitre *et al*., 2016; Preston *et al*., 2018; Chikowore *et al*., 2021). According to Le Maitre *et al*. (2020), in South Africa, the estimated impacts of IAPs on surface water runoff are at 1,44–2,44 billion m^3 annually (Le Maitre *et al*. 2020). The Eastern Cape, Western Cape, and KwaZulu-Natal Provinces are the most affected primary catchments (>5% reduction in mean annual runoff). Le Maitre *et al*. (2020) suggest that if no corrective action is taken there can be expected increased reductions in surface water runoff of 2,59–3,15 billion m^3 per year, about 50% higher than current reductions.

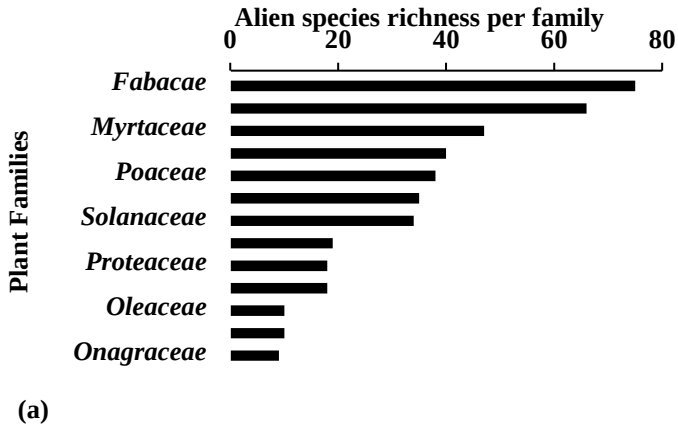
In addition to water resources IAPs also threaten wetland environments through the alteration of the wetlands' habitat, biodiversity conservation, species number, and water quality; alteration of nutrient cycling; reduction of light penetration below the water surface, affecting aquatic plants and animals; consumption of oxygen that is much needed by aquatic organisms; and ultimately affecting ecosystem services provided by wetland environments (Pathak *et al*., 2021). For example, Pandey *et al.* (2020) investigating the Koshi Tappu Wetlands showed that the extensive coverage of IAS adversely affected water quality and fish communities. Mukul *et al*. (2020) assert that IAS are increasingly threatening the native fauna, flora and ecosystems in Bangladesh and consequently result in the deterioration of wetland health including a range of goods and services.

1.2 Invasive alien plants in South Africa

The introduction of IAS into South Africa occurred at the start of colonialism in the country (Pooley, 2009). The first records of deliberately introduced exotic species were in 1652 when a Dutch horticulturalist Hendrick Boom started a garden in Cape Town, Western Cape Province, for the Dutch East India Company (Pooley, 2009; Pooley, 2018). Global travel and trade have since continued to contribute to both accidental and intentional introductions of exotic species, especially during the 19th century (Sala *et al*., 2000; Keane and Crawley, 2002; Richardson *et al*., 2003; McKinney, 2006). Many intentional introductions of IAPs were for

their aesthetic value, economic value or to try to curb environmental problems such as erosion or dune stabilisation. For example, *Eucalyptus globulus* Labill. (Blue Gum, Tasmanian Blue Gum) and *Pinus palustris* Mill. (Pinaceae), *Pinus radiata* D. Don (Pinaceae) and many others were introduced for the supply of timber; *Prosopis juliflora* Swartz. (Fabaceae) was introduced for fodder (Mtengwana *et al*., 2021); and certain Australian acacias for dune stabilisation. Recent literature suggests unintentional introductions and the horticultural industry have been the main contributors to the introduction and spread of IAS (Martin and Coetzee, 2011; van Wilgen *et al*., 2012; Faulkner *et al*., 2017; Cronin *et al*., 2017; Hulme *et al.*, 2018).

To date, thousands of alien plant species have invaded nearly 80 000 km² of the South African landscape and hundreds of species have naturalised (Henderson, 2020; van Wilgen *et al*., 2020), occupying roughly 7% of the country with many species entered stages of exponential growth (van Wilgen, 2018). According to Lukey and Hall (2020), there is no thorough inventory list of aliens, naturalised, and invasive plants for South Africa, but 327 plant taxa, most of which are invasive, are listed in national legislation. Furthermore, there are collated records of 759 plant taxa in 126 families and 418 genera that have naturalised in natural and semi-natural ecosystems, of which half of these naturalised taxa are trees or shrubs with under a tenth in the families Fabaceae (73 taxa) and Asteraceae (64). The most problematic terrestrial IAPs in South Africa are the Australian *Acacia* spp. and *Eucalyptus* spp., North America *Opuntia* spp. and Mexican *Pinus* spp. (Mtengwana *et al*., 2020; Richardson *et al*., 2020)). These species are mostly problematic, because they consume huge quantities of water and consequently lead to depletion of water supplies, reduced agricultural productivity, intensified veldfires and threatened biodiversity (Le Maitre *et al*., 2016; O'Connor and van Wilgen 2020; Figure 1.1).



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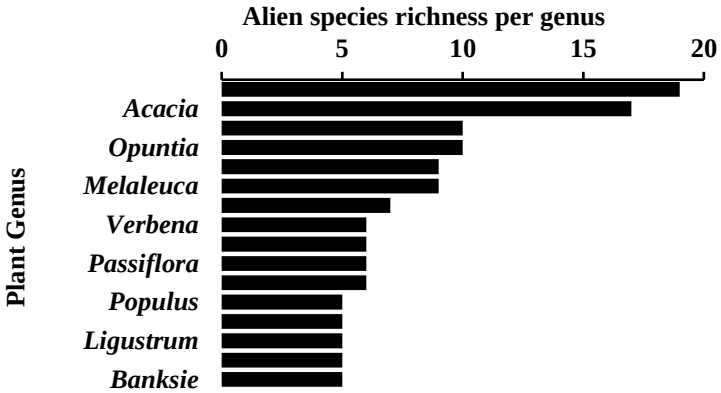

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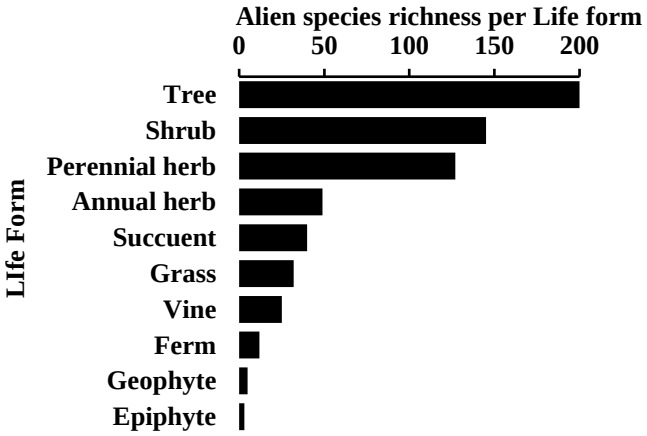

(c)

Figure 1.1: Features of South Africa's naturalised alien flora, showing the dominant (a) families, (b) genera, and (c) plant life forms (adapted from Richardson *et al*., 2020).

Invasive alien plants are found growing in all biomes in South Africa with Fynbos being the most invaded biome (Henderson, 2020). These plants are mainly found in the moist areas of the country, particularly mountainous areas, and along perennial rivers, posing an extensive threat to water availability (Mtengwana *et al*., 2021; Canavan *et al.,* 2021, 2022). The impacts of these invasions are reasonably well documented, and the significant impacts include reductions in surface water runoff, rangeland productivity, native biodiversity, and groundwater resources (van Wilgen *et al*., 2022). South Africa is mainly semi-arid to arid, with an average annual rainfall of around 464 mm/year (compared to a global average of 786 mm) of which only 8% forms surface run-off (Wilson *et al*., 2020). South Africa has hot summers, combined with aridity that produces significant water stress, and the problem is exacerbated by the presence of IAPs, as they have high evaporation rates and often use more water than indigenous plants, which has a direct impact on stream flow and groundwater reserves (Le Maitre *et al*., 2015; Richardson *et al*., 2020). For example, studies conducted in Cape Agulhas indicated that IAPs were consuming water equivalent to the long-term average run-off (Mkunyana *et al*., 2018).

At a national level it is estimated that IAPs are using approximately 1,44 billion m^3 of water (Le Maitre *et al*., 2020). It has been estimated that this water could provide 3,38 million households of four inhabitants each with water for a year or irrigate 120,000 hectares of cropland (WWF, 2016). Unfortunately, it is estimated that this figure could rise to 2,59–3,15 billion m^3 per year if no action is taken, which is about 50% higher than the current reductions (Le Maitre *et al*., 2016).

Invasion by IAPs in the rangelands can lead to a reduction in native grass diversity and a change in grass community composition, ultimately leading to rangeland degradation (O'Connor and van Wilgen, 2020), and catastrophic reduction in non-graminoid plants. On average, only one in six species in a grassland is a graminoid, and therefore non-graminoid loss is the major biodiversity loss aspect from woody invasions. In addition, most grassland is made up of many other plant forms who are also directly impacted by woody invasive alien plants. This rangeland degradation has a significant effect on grazing capacity which in turn compromises livestock production (Gwate *et al*., 2016; Chikowore *et al.,* 2021). The presence of IAPs in the grassland biome alters the environment by changing thermal regimes and light penetration because of the shading effect of IAPs' higher canopy cover, especially by woody species (Chikowore *et al.,* 2021), resulting in the formation of new environments wherein native

species are unable to adapt and compete (Lazzaro *et al*., 2018; Chikowore *et al*., 2021). For example, the study by Chikowore *et al*. (2021) suggests that *Robinia pseudoacacia* Peaboy (Fabaceae) is transforming grassland arthropod ecosystems through altercation of micro-climatic conditions in the eastern Free State in South Africa. Furthermore, the presence of IAPs in grassland ecosystems can decrease plant species richness, and this may trigger changes in functional group composition which may reduce the ability of the ecosystem to provide ecosystem services. Due to the number of impacts caused by IAPs in South Africa, the Government has developed extensive policies, frameworks, and programs to try to alleviate the impacts.

1.3 Legislative frameworks governing invasive alien plants in South Africa

The management of biological invasions in South Africa is governed by the National Environmental Management: Biodiversity Act (NEMBA), 2004 (Act no. 10 of 2004) Alien and Invasive Species (AIS) regulations, which became law on 01 October 2014, with revised regulations in 2016 and 2020 respectively. The NEMBA regulations are aimed at mitigating the destructive and negative impacts of invasive species and effective management plans. Notably, the regulations list alien species and requires landowners to take reasonable measures to control these species, noting that there are specified exemptions and permits that may be issued in some cases for otherwise prohibited activities (van Wilgen *et al*., 2022). The AIS component of the NEMBA regulations list four categories of invasive species that must be managed, controlled, or eradicated from areas where they cause harm to the environment, or that are prohibited from being brought into South Africa.

The categorisation of invasive species is as follows; Category 1a includes invasive species that must be combatted or eradicated, and any form of trade is strictly prohibited; Category 1b includes invasive species which must be controlled and wherever possible, removed and destroyed, and any form of trade or planting is strictly prohibited (furthermore, Category 1a and 1b include weed species that are of no value); Category 2 includes invasive species or species deemed to be potentially invasive, in which a permit is required to carry out a restricted activity and this includes species that have commercial value such as pine, gum and wattle trees; and Category 3 includes alien invasive species with ornamental value, historical or authentic conditions, which may remain in prescribed areas or provinces and any further planting, propagation or trade is prohibited (van Wilgen, 2018). For the last two categories, the regulations state that certain restricted activities are prohibited in accordance with section 71

(A); exempted in accordance with section 71 (3); and require a permit in terms of section 71 (1) of the National Environmental Management Biodiversity Act 10 of 2004 (van Wilgen, 2018). For a summary of controlled activities for invasive species listed in Categories 1a, 1b, 2 and 3, see Appendix 1 (NEMBA AIS Regulation, 2020), which outlines the restricted activities prohibited in terms of section 71A (1); exempted in terms of section 71(3); or that require a permit in terms of section 71(1) of the NEMBA AIS, 2022.

The NEMBA regulations also cater for contentious groups of plants that may not have been included in the national legislation. This is achieved through the establishment of a designated unit to detect and document new invasions, provide reliable and transparent post-border risk assessments, and provide the cross-institutional coordination needed to successfully implement national eradication plans in South Africa. For example, in 2008, the then Department of Water Affairs and Forestry's WfW Programme contracted the South African National Biodiversity Institute Invasive Species Programme (SANBI ISP) to develop, in partnership with other stakeholders, a programme focusing on 'emerging' plant invaders called Early Detection and Rapid Response (EDRR) for IAPs. The name EDRR was later dropped in favour of SANBI ISP as the programme was used as a management approach that can apply to any stage of the invasion process at any spatial scale (Wilson *et al*., 2013).

The NEMBA Act, section 69 places a "duty of care relating to alien species" on all private and public landowners to take reasonable steps to control species on their land. The regulations require that all state organisations in all spheres of government comply to invasive species monitoring, control, and eradication plans for land under their jurisdiction (Potgieter *et al*., 2020). Furthermore, the act states that those landowners who fail to comply with the regulations may be liable for hefty fines and/or imprisonment. However, the implementation of these punitive or corrective measures has not been implemented fully as there have been no prosecutions to date (van Wilgen, 2018). The NEMBA Act under the Alien and Invasive Regulations requires regular reporting (at least every three years) on the status and impact of invasions, and the effectiveness of management and policy interventions (Wilson *et al*., 2017).

In addition to the NEMBA Act, the control and management of IAPs in South Africa is also governed by the Conservation of Agricultural Resources Act, 1983 (CARA) (Act no 43 of 1983) which legislated IAPs into three categories, namely; Category 1 which includes invader plants that must be removed and destroyed immediately and any form of trade is strictly prohibited; Category 2 which includes invader plants that may be grown under controlled

conditions in permitted zones and no trade is allowed; and Category 3 includes invader plants that may no longer be propagated or sold and existing stands/ plants do not need to be removed. Regulation number 15 of CARA makes provision for the declaration of weeds and invader plants, which was later revised and amended to support the WfW Programme alien plant clearing programme to manage and control existing stands of IAPs and also prevent the introduction of new alien species through secondary invasions. The amendments to regulation 15 of declared weeds and invader plants were aimed at the long-term management and prevention of invasions of plants that are harmful to human welfare and the environment. Furthermore, the amendments to the regulations declared all aliens must be effectively controlled, and landowners are legally under obligation to control IAPs occurring on their properties (Badenhorst, 2014; Bennett and Van Sittert, 2019; van Wilgen *et al*., 2022).

Furthermore, the National Environmental Management: Protected Areas Act (Act 57 of 2003) requires the relevant authorities responsible for all protected areas to prepare management plans which are to be made available to the public and accessible online. It further directs authorities to ensure that the management plan contains a section that deals with biological invasions, and that the protected area plans are all of a high standard, providing statements of intent with clear targets and implementation strategies (van Wilgen *et al*., 2022). Other related pieces of legislation governing Natural Resource Management through the WfW IAPs clearing programme include the National Environmental Management Act, 1998 (Act 107 of 1998); Mountain Catchment Areas Act (63 of 1970); Water Act, 1998 (Act 36 of 1998); National Forests Act, 1998 (Act no 43 of 1998); National Veld and Forest Fire Act, 1998 (Act no 101 of 1998); and Fertilizer, Farm Feeds, Agricultural Remedies and Stock Remedies Act, 1947 (Act 36 of 1947). These pieces of legislation are infrequently implemented and or enforced whereas CARA, Act 43 of 1983, and NEMBA, Act 10 of 2004, have been dominating the legislations, but implementation or enforcement seems to be lagging, contributing significantly to the negative effects of IAPs on native species and major ecosystem services.

1.4 Background of the South African Expanded Public Works Programme and alignment with Working for Water Programme

The Expanded Public Works Programme (EPWP) is one of the government's medium to long-term strategies to reduce and alleviate poverty through the creation of work opportunities using labour-intensive methods (Vaughan, 2016; RSA: DPWI, 2019). The EPWP was initiated in 2003 during a Growth and Development Summit (GDS) held in Gauteng Province. The

programme was launched by the South African Government in 2004 in line with the broader strategy of addressing structural poverty in South Africa and is currently implemented in four sectors, namely Infrastructure, Social, Environment and Culture, and Non-State. All spheres of government and State-owned entities are expected to implement the EPWP (van Wilgen and Wannenburgh 2016; Vaughan, 2016; RSA: DPWI, 2019).

The EPWP works on a five-year cycle; the first phase was implemented in 2004 until 2009 with the main goal being to take a minimum of one million people in the country out of unemployment with employment targets of 40% women, 30% youth and 2% people with disabilities. The second phase of EPWP which began in 2009 was to create the equivalent of 4,5 million, 100-day work opportunities (2 million work opportunities) in five years with an employment target of 55% women, 40% youth and 2% people with disabilities (DPWI, 2019). The aim was to contribute to halving unemployment by 2014 and also to strive towards tenure and job security. The target for phase three of EPWP which began in 2014 was to create six million work opportunities or equivalent to 2.55 million Full-Time Equivalent (FTE) (person-years) or 585 million workdays in 2019. The EPWP is presently in its fourth cycle, which began in 2019 and the goal is to create five million work opportunities (equivalent to 2,37 million full-time jobs) to alleviate unemployment with employment targets of 60% women, 55% youth and 2% people with disabilities (van Wilgen and Wannenburgh, 2016; Vaughan, 2016; RSA: DPWI, 2019).

The Department of Public Works and Infrastructure (DPWI) is responsible for coordinating and monitoring EPWP in all sectors. The DPWI manages the EPWP Incentive Grant Project and is responsible for the allocation of grants to public bodies to incentivise work created through a formula based on past performance on jobs created. The Incentive Grant is performance-based and significantly different from other conditional grant allocations and is paid per quantum of employment created for the EPWP target group and can be measured in person-days of work or Full-Time Equivalent jobs and this depends on the actual validated EPWP performance of the public body (van Wilgen and Wannenburgh, 2016; Vaughan, 2016; RSA: DPWI, 2019). The WfW Programme is a public works driven ecological restoration project for the clearing of alien plants and is the largest environmental programme within the EPWP. The WfW is one of the main initiatives aimed at providing work opportunities for South Africa's poor rural population, and is funded through the EPWP Incentive Grant Project based on past performance on jobs created, the number of accredited and non-accreted training

sessions achieved, as well as achievement of EPWP employment targets (McConnachie *et al.*, 2013; RSA: DPWI, 2018).

1.5 The South African Working for Water Programme

The high-level goal of WfW is to prevent, contain and reduce the density and distribution of established invasive alien plants to reduce their negative effects on the environment (Bek *et al*., 2017). The programme aims to improve the integrity of natural ecosystems; restore important ecosystems such as water, grassland, natural forest, and biodiversity; improve water purification and retention; prevent new invasive species from establishing; manage the impact of established IAS; and enhance the rehabilitation and maintenance of natural ecosystems and delivery of ecosystem services. In addition, one of the core mandates of the WfW system is the creation of work opportunities for the previously disadvantaged communities targeting women, youth, and people with disabilities; skill development; and strengthening support for Small Medium and Micro Enterprises (SMMEs) (van Wilge *et al*., 2012).

1.6 History of the Working for Water programme

The WfW was established in 1995 to control alien plant invasion thereby alleviating their impacts, principally on water resources. The programme's focuses on clearing alien invasive trees from conservation areas and river courses, and at the same time address poverty through the creation of work opportunities and development of human skills (Working for Water, 2007; van Wilgen and Wannenburgh; 2016; Angelstam *et al*., 2017; Martin *et al*., 2018; van Wilgen *et al*., (2020). The programme started with ten projects in six provinces with an operational budget of R25 million under the leadership of the then Deputy-Director General, Dr Guy Preston, in his capacity as Chair of the National Water Conservation Campaign and the late minister of the then Department of Water Affairs, Kader Asmal, and the vision was to create 20,000 jobs for 20 years in winning the war against invasive plants (van Wilgen *et al*., 2016a).

The programme budget grew to ZAR1,28 billion in 2013/2014 and to ZAR2 billion by 2017 (Ntshotsho *et al*., 2015; van Wilgen and Wannenburgh, 2016; van Wilgen, 2020). The programme currently has more than 300 clearing projects spread over all nine provinces in South Africa and some offshore islands and employs more than 20,000 people per annum (van Wilgen *et al*., 2020; Figure 1.2). The programme is presently under the administration of the Department of Forestry, Fisheries, and the Environment (DFFE) in the Environmental

Programmes Branch, Environmental Programmes' Chief Directorate, under the Non-Infrastructure Sub-directorate effective from 01 April 2023, formerly known as the Natural Resource Management Chief Directorate since 2011 and was previously under the administration of the then Department of Water Affairs and Forestry.

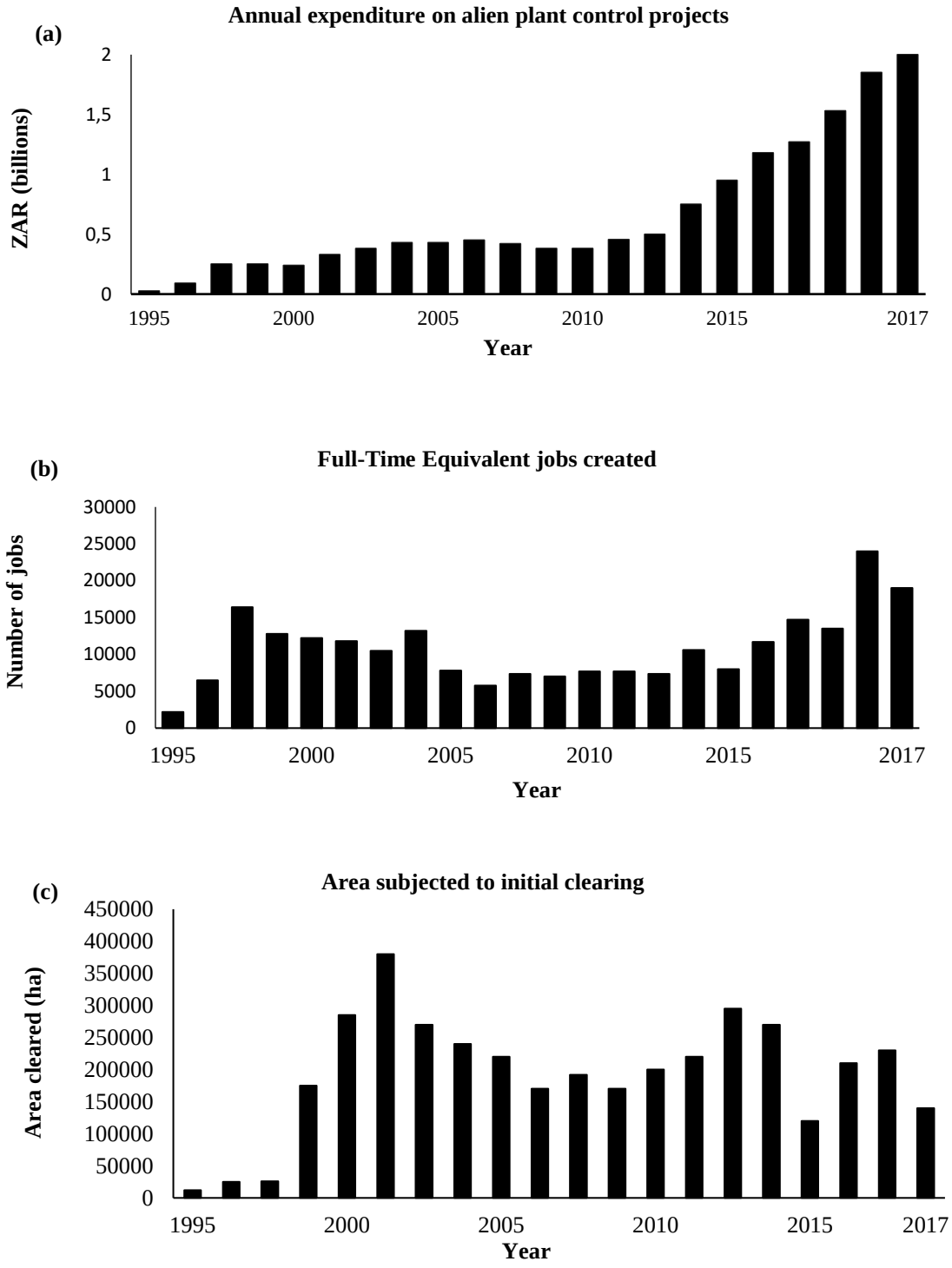

Figure 1.2: The contribution of the Working for Water programme to alien plant control in South Africa in terms of (a) the amount of money invested (ZAR unadjusted for inflation); (b) the number of Full-Time Equivalent jobs created (this number only includes jobs created for previously unemployed people as part of poverty alleviation efforts); and, (c) the area treated per annum in condensed hectares. Note that the apparent decrease in the area treated between

2013 and 2014 is due to a relaxation of the requirement to record areas treated (source: van Wilgen, 2020).

The WfW programme is part of the country's EPWP which is primarily aimed at the creation of job opportunities to alleviate poverty in South Africa (Angelstam *et al*., 2017), and the main funding comes from the government allocations and limited contributions from other sources including non-governmental organisations and private entities to enable the programme to clear IAPs and create employment among the rural poor while securing vital ecosystem services (McConnachie *et al*., 2013; van Wilgen and Wannenburgh, 2016; Hassan and Mahlathi, 2020). However, the funding is subjected to the achievement of targets such as the planned number of work opportunities, Full-Time Equivalent and ecosystem, rehabilitation, protection, and selection of priority areas (van Wilgen and Wannenburgh, 2016). The programme has cleared an average of about 200,000 condensed hectares and follow-up hectares of about 600,000 per year, which is the equivalent to three years of follow-up treatment and has achieved 2000-2300 Full-Time Equivalent jobs per annum (van Wilgen et al. 2020; Figure 2). However, WfW funding by the government is still regarded as insufficient to address the problem effectively (van Wilgen and Wannenburgh, 2016). Coetzee and Louw (2012) assert that the programme has made a substantial impact on the lives of many of the people it employs, but sceptical as to how successful it has been in terms of social upliftment.

1.7 Control methods implemented by Working for Water to manage invasive alien plants

Management and control of IAPs generally involve the primary control methods of chemical, mechanical, and biological control. The effectiveness of these management techniques is mainly dependent on environmental factors, the size of the management operation and the species under consideration. The fourth method that can be used is called integrated control which involves combining any of the three primary methods (Goolsby *et al*., 2020). Forms of integrated control have gained interest both globally and in South Africa because of their success with several woody invasive species (van Wilgen *et al*., 2020; Schaffner *et al.,* 2022).

1.7.1 Mechanical control method

Mechanical control entails the physical removal of the entire plant or removing the above-ground portions of a weed. The method uses control techniques such as hand pulling, digging, bark stripping, prescribed fire, harvesting, moving and ring barking (Minteer *et al*., 2021). It can be integrated with other control methods. The timing of this method can significantly influence its efficacy and the degree to which it may be integrated with biological control (Lake and Minteer, 2018). However, the use of a manual control method without chemicals can worsen the problem, and therefore this method can work well in some areas but can lead to unintended impacts on native species in other areas (Gagnon, 2020). According to Coetzee and Martin (2018), the method has been widely used, but rarely with great success and always at high costs. However, Minteer *et al*. (2021) asserts that mechanical methods such as hand pulling can be effective in small areas but are often time-consuming and labour-intensive. For example, a study that was conducted on the control of *Hakea sericea* Schrad. & J.C.Wendl. (Proteaceae) (Sweet Hakea) in the Western Cape Province, which included a combination of felling and burning, augmented by biological control, concluded that the initial mechanical clearing integrated with burning in the 1970s and 1980s by the Department of Forestry was responsible for reducing the density and extent of infestations (Elser *et al*., (2010).

1.7.2 Chemical control method

Chemical control entails the utilization of herbicides to suppress the invasive species (Yadav *et al*., 2016), it can be explicit to a cluster of plants, for example, broad-leaved species, or grasses without affecting non-target plants. This method is mainly used together with mechanical control. In this scenario, the herbicide is applied to stumps or to kill seedlings after felling or burning, which eventually impedes re-sprouting (Van Wilgen *et al*., 2001). The application rate, as in mechanical control, can also vary significantly from targeted individual seedlings and cut stumps to large foliar applications applied through aircraft. Unfortunately, the use of herbicide can have adverse impacts on the environment because they can affect or poison to non-target species. (de Castro, 2017; Tudi *et al*., 2021; Xu *et al*., 2022). Increasingly, the use of herbicides in South Africa is managed under the Fertilizer, Farm Feeds, Agricultural Remedies and Stock Remedies Act, while most of the countries have developed their pesticides laws and regulatory authorities (Ojemaye *et al*., 2020)

In South Africa, the use of herbicides for control of weeds and IAPs must be consistent with the provision in the NEMBA 10 Act of 2004 as well as the Fertilizers, Farm Feeds, Seeds and Remedies Act 36 of 1947 as they have the potential to negatively impact the environment and other living organisms since some of the active ingredients that are used to produce herbicides have a high toxicity level and half-life (i.e. the length of time it takes for 50% of the herbicide to break down to secondary compounds). For example, Picloram, a commonly used herbicide in South Africa has been shown to have a level of toxicity to mammals of 4012 for acute oral LD_{50} (mg/kg) and 2000 for dermal LD_{50} (mg/kg bw). It is moderately toxic to birds with an acute LD_{50} (mg/kg) of >1944, moderately toxic to honeybees with a contact acute 46-hour LD_{50} (>100), moderately toxic to fish with an acute h LC_{50} (mg/l) (8,8), not highly toxic to earthworms with an acute 14 day LC_{50} (mg/kg) (> 4,475), and it can last up to 82,2 days in the soil, and be released from the roots of treated plants into the soil, where non-target plant species may take it up and consequently die (van Zyl, 2016). Therefore, in South Africa, the use of herbicide requires a high level of training and users must be declared competent and have a valid Pest Control Operating License to be legally allowed to use herbicide in South Africa.

The Act further dictates that all intended clearing activities should be outlined in the control plans as per the guidelines required in terms of section 76 of NEMBA (Sieben *et al*., 2022). The laws in South Africa requires that registered herbicides are used in control programmes and adhere to guidelines for the preparation and application method, hence poor herbicide choices, applications and incorrect preparation methods may lead to ineffective clearing outcomes (van Zyl, 2016). In South Africa, chemical control is nearly always implemented when clearing IAPs.

1.7.3 Biological control method

Biological control involves the use of natural enemies to control a population of IAPs and relies on suitable host-specific natural enemies. The biological agents are sourced from the countries of origin of those IAPs to suppress the invasiveness of the target weed (Hill et al., 2020)McFadyen (1998) indicated that biological control has the potential to reduce target weed impacts while having little to no impact on the environment and other species. The method is perceived as the most environmentally friendly, cost-effective, safe, and self-sustainable method that can result in effective and permanent control of IAPs and is often associated with the alleviation of economic and ecological impacts of IAPS (Lake and Minteer, 2018; Minteer

et al., 2021; Zachariades *et al*., 2017). Biological control has been used in 130 countries as a valuable tool for the control of IAP species (Winston *et al*., 2014; Zachariades *et al*., 2017), and as a management tool in South Africa since 1913 to supplement chemical and mechanical control of problematic plants (Hillet al., 2020), and it is a proven, more responsible science as it was not always in the earliest forms of *ad hoc* biocontrol which were catastrophic for many endemic and indigenous species, such as using cats and mongooses to control rodents on islands, etc.

According to van Wilgen (2018), biological control has been used extensively in support of labour-intensive containment and control efforts in South Africa and remarkable success has been achieved in either controlling or reducing the invasive potential of many invasive plants (van Wilgen, 2018; Henderson, 2020). This method contributes significantly to the control of 34 of the 59 IAP species on which biological agents have been established in South Africa, wherein 14 of these target species are considered to be under complete under control without further need for any other control intervention (Zachariades *et al*., 2017). For example, a review of alien plant species such as *Sesbania punicea* Cav., *O. stricta*, *Lantana camara* L., (Lantana) and two species of invasive alien aquatic plants in Kruger National Park suggested that the reduction of populations of these species was due to biological control (van Wilgen *et al*., 2017). However, often biological control alone does not always provide adequate control and that necessitates the use of additional management techniques or the integration of other control methods (Lake and Minteer, 2018). It is also not an available option for most plant species, because there are closely related native species, of important crop species that the agent may not be sufficiently host-specific and in some cases the suitable agents cannot be found.

1.7.4 Integrated control method

The integrated control method involves a combination of at least two or three primary methods such as mechanical removal followed by applying herbicides (chemical method) and in some instances including biological control (Henderson, 2020). The integration of two or more control methods may be more effective than using one method in isolation and therefore the selection of techniques for integration and timing of treatments is vital for the successful implementation, particularly when applying biological control with other management tools. The timing of herbicide application, grazing, burning or mechanical removal must impact the target weed or plant with no adverse effects on biological agents (Lake and Minteer, 2018).

For example, in the Western Cape Province, the integration of biological with mechanical and/or chemical methods has drastically reduced populations of *Hakea* spp. And *Acacia* spp. (Esler *et al*., 2010; Moran and Hoffmann, 2011), and populations of *Lantana* spp. and *Opuntia* spp. in the Kruger National Park, Limpopo and Mpumalanga provinces (van Wilgen *et al*., 2017).

1.8 Implementation of the clearing of invasive alien plants project by the Working for Water programme

The WfW' s activities are managed and implemented at a provincial level, with additional units providing support for research, planning and reporting. The basic operating model involves the appointment of implementing agents or contractors to recruit workers from the previously disadvantaged local communities where the project is being implemented in accordance with EPWP guidelines. The implementing agents can be an irrigation board, conservation agency, municipalities, and forestry companies. The appointed contractors/ implementing agents are assigned demarcated areas and payments are made on achievement of agreed tasks and based on the contract specifications. These contracts have to be re-negotiated annually and the approval process at times takes longer than anticipated and may be time-consuming which eventually result in unnecessary delays (van Wilgen *et al*., 2022). For example, out of 156 proposed contracts for implementation in the 2021/2022 financial year (starting from 01 April), only 107 had been approved by end of October 2021, and as such led to the late start of operational activities, because contractors can only commence with clearing activities once an official order is issued (van Wilgen *et al*., 2022). WfW managers are responsible for drawing up of strategic plans and annual plans of operations (APO) for approval and securing funding based on operational targets such as hectares to be cleared and effort required expressed as person days (PDs), which is equivalent to one person being employed for a full eight-hour day's work (McConnachie *et al*., 2013; van Wilgen and Wannenburgh, 2016; Kraaij *et al*., 2017).

It is worth noting that the WfW project managers are required to do infield verifications in each management unit, collecting data on IAP species present, densities, age classes and appropriate treatment methods for capturing into the WfW information management systems (McConnachie *et al*., 2013; van Wilgen and Wannenburgh, 2016; Kraaij *et al*., 2017). The work contracts are generated through the WfW Information Management System (WIMS) and the effort requirement for each contract is automatically calculated using the WfW norms and

is used as the basis of an agreement between WfW and implementing agents (Neethling and Shuttleworth, 2013; Kraaij *et al*., 2017). Furthermore, the protocols require that a joint inspection by a WfW manager and the contractor be undertaken before the start of the contract, during implementation, and before the contract is signed-off for payment processing. It is a requirement that an invoice for all completed contracts should include timesheets with actual days worked on the contract, start and end date, and all actual expenses to be captured into the WIMS database (Kraaij *et al*., 2017; van Wilgen *et al*., 2022).

1.9 Working for Water programme success

The WfW programme has conducted control operations on 2,8 million hectares (ha) of IAPs, unfortunatly the outcomes are generally not understood due to lack of monitoring programmes (van Wilgenet al., 2020). The programme has created work opportunities for many historically disadvantaged people primarily focusing on women, youth and people with disabilities mainly rural areas where unemployment is high (Angelstam *et al*., 2017; Figure 2). According to van Wilgen *et al*. (2022), the WfW has successfully treated 27,275 km^2 over the past 25 years, and the extent and abundance of plant invasions have been reduced compared to if there had been no control activities implemented (McConnachie *et al*., 2016). The WfW is still regarded as a highly successful programme, and has raised awareness of the problem of biological invasions, secured substantial funding to address the issue, cleared invasive plants over extensive areas, and created much-needed employment (van Wilgen *et al*., 2022). Mukwada *et al*. (2016) stated that the removal of IAPs by WfW has been successful in some species and the success had been attributed to the project's multi-faceted and cross-disciplinary nature. However, the WfW has not been successful in its goal of reducing the overall impact of invasion within a reasonable timeframe and has only treated a relatively small fraction of South Africa's total alien plant cover (McConnachie *et al*., 2013). It is suggested that some IAPs might be spreading faster than the rate of clearing (van Wilgen, 2012, 2016b).

Beater *et al*. (2008) and van Wilgen *et al*. (2012) stated that despite enormous expenditure in clearing efforts in South Africa, only a small portion of infested areas have been cleared, and many studies have reported very little progress (less than 10%) in some areas prioritised for clearing since the inception of the programme in 1995. For example, McConnachie *et al*. (2012) investigated the clearing project in the northern Eastern Cape, and showed that there has been little reduction in total infestation since the inception of the project. In a separate example, in

an assessment conducted by Kraaij *et al.* (2017) on the effectiveness of IAP management in a large fynbos protected area in the Garden Route National Park in South Africa, they found that the quality of infield treatment application by WfW implementation teams was disappointing with no evidence of work done over a third of the assessed area, and deviation from acceptable standards of treatment application occurring over an additional 44% of the area. Similarly, McConnachie *et al.* (2012) found that the information recorded in the WfW-WIMS as treated in the Kouga (24% of the sites) and Krom (4% of the sites) catchments in the Eastern Cape were never treated.

An additional concern is regarding management techniques implemented by contracted teams. For example, Fill *et al*. (2017) argued that the reliance on manual and labour-intensive clearing aimed at maximising employment opportunities has reduced the efficiency levels resulting in a lack of progress towards the goals of reaching a maintenance level of IAP control. Similarly, van Wilgen *et al*. (2022) argued that the programme has lost focus and lacked inclusive vision of what, where, and/or when it intends to achieve goals, because of a lack of clarity in these goals, various structural issues which made control less effective, insufficient monitoring, and mismatch between annual plans of operation and reality which has contributed to insufficient funding. However, van Wilgen *et al.* (2022) further suggested that WfW can play a positive role in ensuring that IAPs are effectively controlled in well-defined priority areas, provided that a number of issues are effectively addressed by creating a more focused vision that spells out achievable goals; strategic actions based on conservation triage, focusing on clearly defined priority sites, improving planning and monitoring, and increasing operational effiecieny. In order to achieve these, the government should increase the level of funding, WfW should maximise the use of biological control, eradicate high-risk species where possible, and rationalise and intergrate value added projects. Failure to address those issues will result in widespread increases in the range and density of IAPs, including in priority areas.

1.10 Socio-economic benefits

The alleviation of poverty, particularly in rural areas, has been the main driver for the investment from the South African government's EPWP (van Wilgen and Wannenburgh, 2016; Angelstam *et al*., 2017). The Natural Resource Management programme including WfW has been highly successful in providing short to medium-term employment opportunities and a practical skill set for thousands of unskilled labourers (Giordano *et al*., 2012; Figure 2). The

WfW programme's secondary objective is to create work opportunities targeting designated groups including previously disadvantaged communities, with emphasis on women, youth and persons with disabilities (Hassan and Mahlathi, 2020), and to uplift livelihoods through employment in marginalised communities and socio-economic development (Angelstam *et al*., 2017). Since inception, the WfW projects have provided numerous jobs and training opportunities for approximately 20,000 people across the country on an annual basis (DEA, 2016; Mukwada *et al*., 2016). Mukwada *et al*. (2016) indicated that one of the most important social benefits generated by IAS is employment which has been a vital source of household income. A study in Mpumalanga Province in the Inkomati Catchment indicated that the investment in eradication of alien vegetation had both direct and indirect social benefits (Hassan and Mahlathi, 2020). However, the program has been criticised for not effectively selecting the poorest and neediest workers (Hope, 2006), and for its focus on short-term employment opportunities, lack of rigorous criteria for the selection of the projects and a relatively small fraction of WfW's total costs actually being spent on wages (McConnachie *et al*., 2012; McConnachie *et al*., 2013; van Wilgen and Wannenburgh, 2016). Unfortunately, of the three main goals of the WfW programme (Figure 3), the social benefits or failures are the least studied. The current study aims to assess if the goals of the WfW programme have been achieved in the northern Drakensberg escarpment, Mpumalanga Province, especially addressing the gap of knowledge on the social-economic impacts of the programme by exploring the perceptions of the WfW programme by employees and landowners.

1.11 Study area

The study area was located in the Thaba Chweu Local Municipality, Ehlanzeni District along the northern Drakensberg escarpment, Mpumalanga Province, South Africa, centred between the towns of Graskop (24.926498° S, 30.852588°E) and Pilgrim's Rest (24.8886201° S, 30.743250° E), lies between 560 m and 2023 m asl. The Mpumalanga Escarpment includes three of South Africa's biomes including Savannah, Grassland and Forest Biomes. Grassland Biome is the most prevalent biome in the study area (Ferrar and Lotter, 2007; Breman *et al*., 2019).

1.11.1 Vegetation

The area area is characterized by grassland vegetation that is interspersed with Afromontane forest (Maimela *et al*., 2022), and has an extraordinary diversity of plant species with an

estimated 4946 plant taxa occurring within the province (Emery *et al*., 2002). A recent review by Clark *et al.* (2022), revealed that the Limpopo-Mpumalanga-Eswatini escarpment has 496 endemic plant taxa which is the highest plant endemism recorded for a summer rainfall mountain area in southern Africa while the winter rainfall Cape Fold Mountains will still likely have higher diversity. The review further revealed that the transformation of the landscape such as conversion from mesic montane grassland to commercial forestry; the rampant spread of IAS; poaching of wild plant populations for horticulture and traditional use; mining; and bush encroachment by indigenous woody species, are the most challenging conservation concerns and therefore the remaining grassland should be the primary focus of protection and conservation stewardship efforts.

1.11.2 Land use

The primary land use activities in the area include forestry plantation, mining, agriculture and tourism-related activities. Other land use activities include business services, scattered settlement and small to medium scale farming, as well as old (decommissioned) mine shafts. (Giddy *et al.*, 2022; Kritzinger, 2022; Figure 1.3).

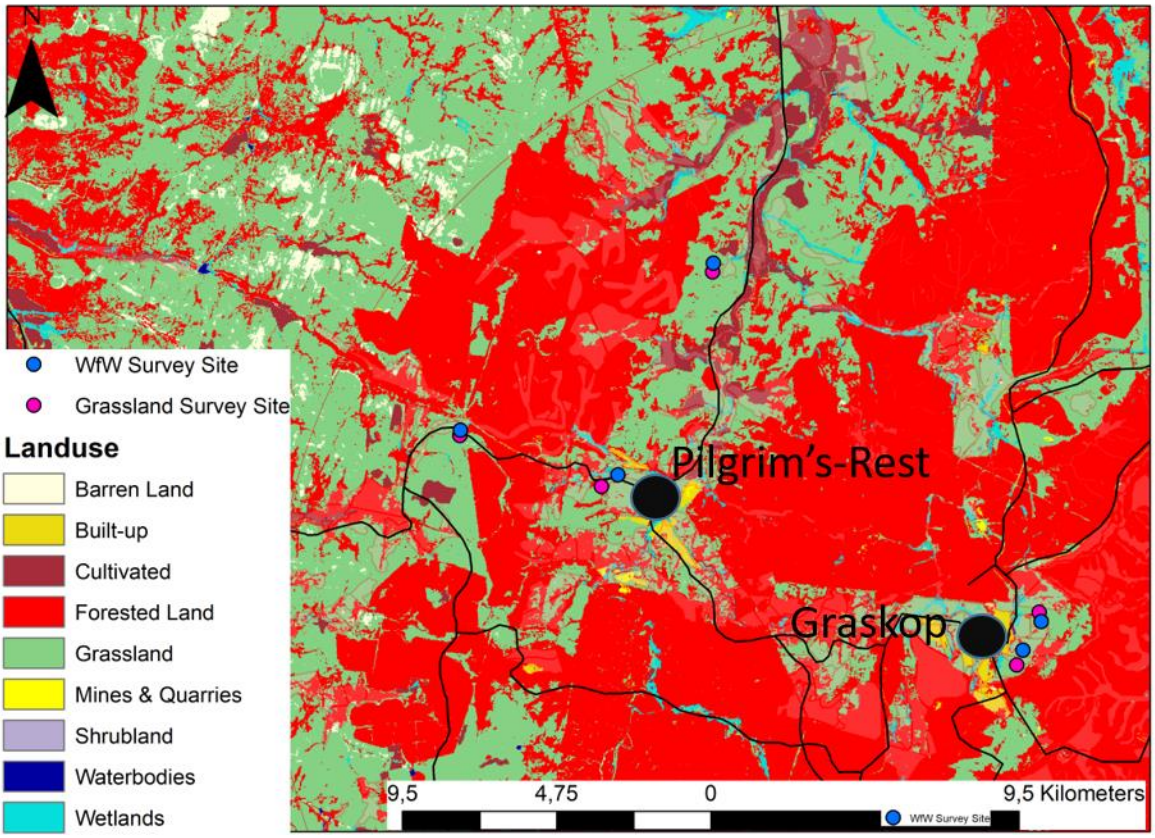

Figure 1.3: Land use activities along the northern Drakensberg escarpment. Smaller dots represent the study site for plant diversity surveys in this study with blue dots representing sites in Working for Water cleared areas, and pink dots representing the adjacent grassland sites outside of Working for Water areas. The large black dots represent the towns of Pilgrim's Rest and Graskop.

1.11.3 Climate

The Mpumalanga Escarpment is characterized by cool to moderate temperature (10-18 °C) with moderate to high rainfall (800-1 200 mm), and mean annual precipitation of than 1 000 mm (WRC, 2001). The study area is characterised by extreme relief and high elevation ranges of 560 m to 2,030 m above sea level (Lotter *et al*., 2014; Figure 1.4).

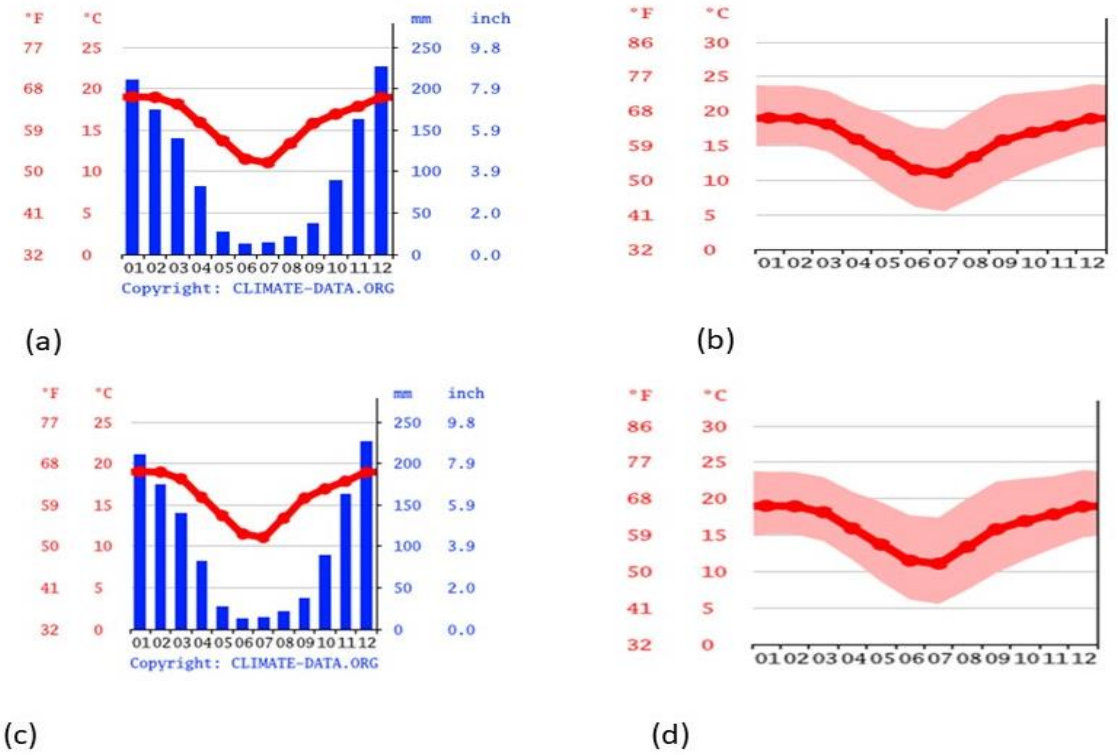

Figure 1.4: Average temperature and weather by month/ climate graphs for study areas. (a) Graskop climate graph/ weather by month (b) Graskop average temperature (c) Pilgrim's Rest climate graph/ weather by month (d) Pilgrim's Rest average temperature (Graphs taken from https://en.climate-data.org/africa/south-africa/mpumalanga/graskop-189588/).

1.11.4 Population

Thaba Chweu Local Municipality had a total population of 98,387 of which 81,6% are black African, 14,5% white, and 26% coloured with other population groups making up the remaining 1,2%. Of those aged 20 years and older, 4,5% have completed primary school only, 33,7% have secondary education, 30,7% have completed matric and 9,6% have some form of higher education. In 2011, the overall unemployment rate was at 20,49%, the youth unemployment was at 27,1%, and the growth rate between 2001 and 2011 was 1,86% (Stats Census, 2011). The unemployment rate had risen from 20,49% in the year 2011 to 24,2% in the year 2016 and 30,9% in 2020 (Thaba Chweu Local Municipality IDP, 2022-2027).

The population of Thaba Chweu Local Municipality had grown to 101,985 in 2016, because of changes in demarcation during 1996 and 2016, and in 2019 the projections for 2022 were standing at 121,966 due to migration and high unemployment rates across all the neighbouring provinces/ towns leading to people flocking into Thaba Chweu (Thaba Chweu Local Municipality IDP, 2022-2027). The main land use activities are forestry, agriculture, settlement, mining, business and tourism. A large number of employment opportunities come from the trade industry, followed by community service, agriculture, and forestry, and mining is the least contributing sector. Forestry and agriculture are the dominant sectors in the Graskop and Pilgrim's Rest towns and have been the main economic contributors (Thaba Chweu Local Municipality IDP, 2022-2027).

1.11.5 Water catchment area

The present study covers three quaternary catchments, namely: Graskop (X31A) and two in Pilgrim's Rest (B60A and B60B). These catchments have the highest relative importance and/ or priority within the Mpumalanga region as they have high water yields, contain areas which are rich in biodiversity that is considered irreplaceable, have high relative carrying capacity, and contain freshwater biodiversity priority areas and other ecosystem services (Forsyth *et al*., 2011). The northern Drakensberg escarpment comprises of two main river headwaters, namely Blyde River and Sabie River (Figure 1.5). Blyde River is a major tributary to Olifants River and it rises on the western slopes of the north-south trending Drakensberg Mountains and flows northwards towards the escarpment edge to the Blyde Dam, cascading down a steep series of rapids to its lower reaches, and flowing northwards to join Olifants River (Addo-Bediako and Malakane, 2020).

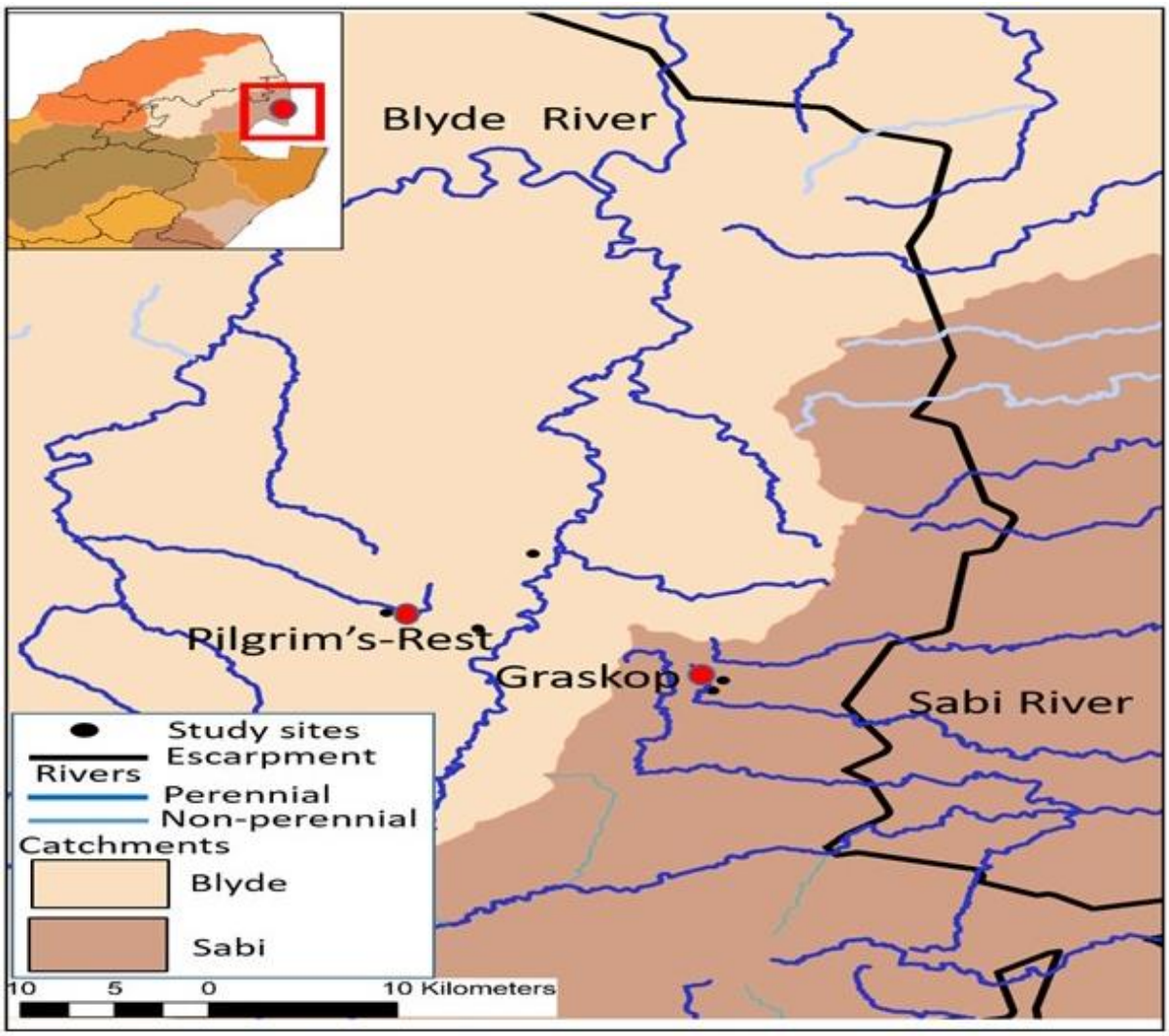

Figure 1.5: Major water catchments in the northern Drakensberg escarpment, Mpumulanga Province, South Africa.

The Blyde River sub-catchment is approximately 2000 km^2 in size and lies partly on the escarpment. As a result it experiences high rainfall with a mean annual precipitation of about 1000 mm. It is classified as a top-priority catchment and critical for downstream water security in the Mpumalanga Province (Forsyth *et al*., 2011; Nel *et al*., 2017; Addo-Bediako and Malakane, 2020). The Blyde River Catchment is a high-priority biodiversity and water resource area and plays a critical role in increasing water quality and quantity in the Olifants River while the Sabie River is a major tributary of the Icomati system, flowing eastwards from the Eastern Escarpment region of South Africa to the west 1600 m above see level (m asl), descending onto the low-relief Lowveld (400 m asl) and Lebombo zones (200 m asl) in the east (Heritage *et al*., 2015).

The Sabie River meets the Kruger National Park and flows through the coastal plains of Mozambique towards the Indian Ocean (Raven, 2004). The Sabie River Catchment is important ecologically and economically, supporting many different land users west of the Kruger National Park (Mallory *et al*., 2013). The Sabie Catchment system is recognised within various national and provincial plans and strategies, including the National Freshwater Ecosystem Priority Areas, the National Strategic Water Source Areas, the National WfW Prioritization, and the Mpumalanga Biodiversity Sector Plan (Forsyth *et al*., 2011; Nel *et al*., 2017; Le Maitre *et al*., 2018).

1.11.6 Invasive species

The WfW programme has been operating in the study area since 1995, and has performed initial and follow-up clearing of hundreds of hectares of IAPs including *A. dealbata, A. mearnsii, E. globulus, L. camara, Pinus palustris* Mill (Pinaceae), *P. radiata, Rubus cuneifolius* Bailey (Rosaceae) 9, *Solanum mauritianum* Roe (Solanaceae), *Populus alba* L. (), *Populus canescens* Smith (Salicaceae), *A. melanoxylon*. & Perr., *Sesbania punicea* Cav (Fabaceae). And many others as recorded in the WIMS Database. Most of these species have been observed in the study area and originate from the forestry industry, either as escapees or as a result of historic planting. The ecological functioning and biodiversity of this area are threatened by the invasion of IAPs which in turn threatens the various benefits derived by people from this ecosystem. (Figure 1.6).

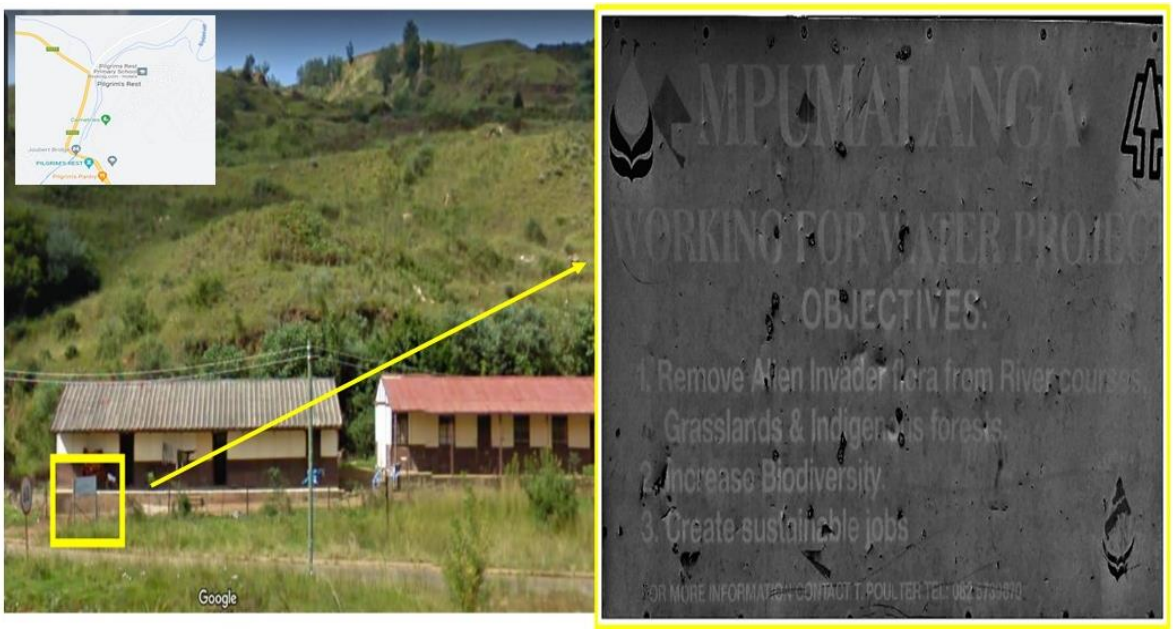

Figure 1.6: A sign board highlighting the objectives of the Working for Water programme. The sign board was erected outside the Pilgrim's Rest Secondary School (24.90466° S, 30.753996° E) in Pilgrim's Rest town (study area) when projects were first started in the area in 1995. The old sign reads as follows: "Mpumalanga Working for Water project objectives: 1. Remove Alien Invader flora from River courses, Grasslands and Indigenous forests. 2. Increase Biodiversity. 3. Create sustainable jobs."

1.12 Aim of the study

The aim of this study was to investigate the effectiveness of the WfW alien plant removal programme on the water courses, job creation and impact on native biodiversity along the northern Drakensberg escarpment, Mpumalanga, South Africa. The study assessed the impact of WfW on the livelihood of communities and the perceived benefits to the landowners where clearing had been conducted.

1.13 Objectives

In order to achieve the aims of this study, the following objectives were outlined:

- Determine the socio-economic benefits and effectiveness of the Working for Water programme as perceived by the communities in the northern Drakensberg escarpment.

- Determine the community knowledge of invasive alien plants and relevant legislations governing alien vegetation control.
- Determine whether the WfW is meeting set employment targets.
- Determine the perceptions of impacts of invasive alien plants by communities and landowners.
- Determine the level of satisfaction by landowners where clearing work had been conducted and highlight future improvements in the implementation of WfW.

- Determine the impact of clearing of invasive alien plants on native biodiversity along the northern Drakensberg escarpment.
    - Determine impact on species diversity on areas cleared by WfW programme and adjacent natural grassland (referred to as Open Veld).
    - Determine the species composition between paired plots and the effect of clearing across serveral grassland habitats and sites.

The data chapters are presented in draft manuscript format and as a result some repitation are unavaoidable.

Chapter 2: Socio-economic benefits and effectiveness of the Working for Wateprogamme as perceived by communities in the northern Drakensberg escarpment

2.1 Introduction

In addition to managing the spread of invasive alien plants (IAPs), the Working for Water's (WfW) secondary objective is to provide job opportunities, training and economic empowerment to the marginalized sectors of South African society, mainly in rural areas where unemployment is widespread (McConnachie *et al*., 2013; Ntshotsho *et al*., 2015). Since its inception, the programme has had remarkable success in securing substantial funding from the South African government to reduce the high level of unemployment, given the enormous challenges facing the country in the post-apartheid era (see chapter 1; van Wilgen and Wannenburg, 2016; van Wilgen *et al*., 2022), and the ability of the WfW to meet job creation targets, leading to the rapid rise and sustainability of funding (van Wilgen and Wannenburgh, 2016).

The WfW programme as a labour-intensive project is expected to contribute to the creation of short to medium-term work opportunities in line with Expanded Public Works Programmes (EPWP) policies and guidelines (McConnachie *et al*., 2013). According to van Wilgen *et al.* (2022) (see Chapter 1 for further information), the WfW control operations resulted in 107,554 Full-Time Equivalents jobs between 1998 and 2020, with a mean of 4,676 full-time jobs per year, distributed between 58% women, 65% youth and 2% of people living with disabilities (RSA: DPIW, 2019). On average, participants received 120,517 days of training between 2011 and 2020 which equates to approximately 25 days per Full-Time Equivalent job per year. This training included skills directly essential for the work such as WfW induction, contractor development, plant identification, herbicide application, health and safety, and first aid, as well as broad social development skills such as personal financial management, diversity management, peer educator and others (van Wilgen *et al*., 2022).

Hassan and Mahlathi (2020) argued that the bulk of previous studies investigating the WfW programme have not accounted for the social benefits from labour employment and cost of invested capital funds. However, some studies have investigated the contribution of WfW to the communities. For instance, van Wilgen and Wannenburgh (2016) found that the WfW programme has created between 2000 and 23,000 fulltime equivalent jobs per year supported

by Byrne *et al.* (2020) who indicated that the programme has created more than 20,000 jobs per year over two decades. However, van Wilgen *et al*. (2022) states that, despite these impressive figures, few studies have attempted to quantify the degree to which WfW's social objective has been achieved.

In South Africa, private landowners are legally obliged to control IAPs on their land under the Conservation of Agricultural Act (1983) and the National Environmental Management: Biodiversity Act (2004). In 1995, the government sought to address the problem of listed invasive alien species (IAS) by providing both private and state landowners with assistance to clear IAS (van Wilgen and Wannenburg, 2016; van Wilgen *et al*., 2022). The WfW's general policy states that private landowners will maintain sites free from re-invasion after WfW has completed one initial and two follow-up treatments (McConnachie *et al.*, 2013). However, it has infrequently been investigated what the landowners' opinion of the invasive species on their property was, what their experience working with WfW contractors have been, and the overall benefits by landowners where clearing has been implemented.

The aims of this study were to (a) determine socio-economic benefits experienced by employees of WfW living along the northern Drakensberg escarpment and (b) to determine the perceived effectiveness of IAP management interventions within the northern Drakensberg escarpment by landowners where WfW clearing projects have been implemented.

2.2 Material and Methods

2.2.1 Study sites

The study was conducted in Matibidi, Moremela, Leroro villages, and Graskop and Pilgrim's Rest towns in Thaba Chweu Local Municipality in the Mpumalanga Province, South Africa (Figure 2.1). The study area is predominantly rural where the main economic sectors are forestry plantation, agriculture, tourism, mining and business services (Giddy *et al*., 2022). Notably, Thaba Chweu Local Municipality is one of the major tourist attraction areas in South Africa (Thaba Chweu Local Municipality IDP, 2020/2021), and mining and forestry are the largest sectors in this area. The economic potential in the study area is dependent on its natural resource base which consists of forests, minerals, unique attractiveness for tourism and to an extent its human resources. However, there is low active involvement of the previously

disadvantaged communities in commercial and tourism development and there are minimal economic activites in rural areas (Tshandu, 2010).

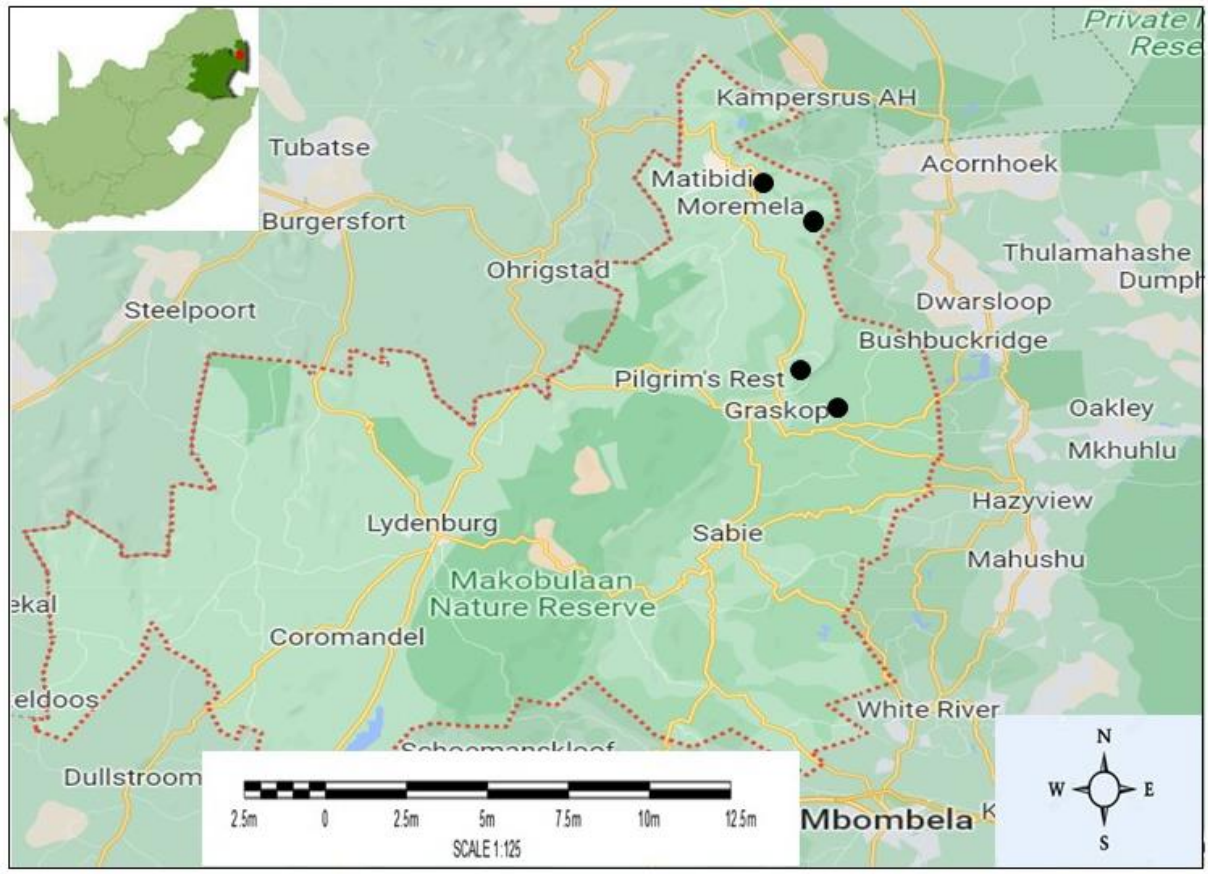

Figure 2.1: Map showing the Thaba Chewu Local Municipality, Mpumalanga Province, South Africa, and the locations where the participants completed research questionnaires – black dots (Source: Google maps, AfriGIS, 2023).

2.3 Data collection and Ethics

Data for contractors and workers were collected using semi-structured narrative questionnaires which contained both open-ended and close-ended questions. The research questionnaires and Informed Ethics Consent were approved by the General/ Human Research Ethics Committee (GHREC) of the University of the Free State (reference number UFS-HSD2021/1102/21). Consent from interveiwees was always obtained in writing. The questionnaires for contractors and workers (called participants) were distributed during two events: Compensation for occupational injuries and disease training on the 25th November 2021 in Graskop, and Workplace Risk Assessment training on the 26th November 2021 in Bushbuckridge. Additional

questionnaires were also given to employees of the WfW programme who were not attending the training session. Participants who worked in the WfW were randomly chosen and questionnaires were returned back by December 2021.

The participants' questionnaires were distributed to 80 workers employed by the WfW programme and consisted of three main sections, namely; participants' particulars to determine if the employment targets were in line with the WfW and EPWP guidelines; secondly, participants' knowledge of invasive species and their impacts in order to understand if participants understood the necessity of removing IAPs as this plays a critical role in the work that the WfW programme has been doing over the years; and thirdly, general questions regarding their opinion of the WfW programme in order to determine if the programme has made any significant impact on the environment and the livelihood of the community living along the northern Drakensberg escarpment (See Appendix 1 for further information).

Similarly, the data for landowners were collected using semi-structured narrative questionnaires which contained both open-ended and close-ended questions. Consent from the interviewees was obtained in writing. The questionnaires were distributed randomly to the landowners where WfW IAPs clearing has been conducted. The details of the landowners were obtained from completed clearing assistance forms and arrangement to visit their properties were made telephonically. As some landowners could not be contacted, some farm visits were made following physical addresses they provided in the completed clearing assistance forms in order to collect the questionnaires. The majority of landowners did not complete the questionnaires immediately and in these cases, landowners were requested to inform the researcher once the questionnaires had been completed so that they could be collected or received electronically through email.

The landowner questionnaires were distrubuted to more than 20 landowners and consisted of four main sections, namely; details of their property in order to determine where the clearing of IAPs actually happened; secondly, knowledge of IAPs and their impacts in order to understand if landowners are aware of the IAPs and their impacts on the environment and livelihoods; thirdly, the level of satisfication with the work that the WfW programme has conducted on their property and the investment made as the programme uses public funds for its operations, hence it is necessary to understand if the work was considered value for money; and fourthly, to determine if the Department of Forestry, Fisheries and the Environment should continue to implement the WfW programme and what improvements (if any) that landowners

would like to see being implemented in order to holistically address the problem of IAPs. The landowner questionaires were completed between January 2022 and November 2022. For further information on questions and questionnaire structure, both questionnaires can be found in Appendix 2.

The researcher informed participants and landowners of the aim and purpose of the study before they answered the questionnaires. Most importantly, they were informed of their rights to participate in the study including any intention to withdraw from participation and that there were no risks involved in participating in the study. The researcher observed all COVID-19 protocols and POPIA act legislative requirements.

2.4 Data analysis

Descriptive statistics were used to summarize responses from questionnaires while qualitative answers were summarized to assess the perceived benefits of the WfW programme. In order to ensure logical, meaningful and efficient data analysis, a computer-assisted Google survey form or tool was created online and all responses were captured by the researcher as per the completed questionnaires to aid in summarizing the responses from the questionnaires. The data for participants and landowners are stored online (see Appendix 2).

2.5 Results

2.5.1 Working for Water participant questionnaires

Overall, 81% (n=80) of the participants responded to the questionnaires. The age of the respondents ranged from 18 to 65 years, and comprised of 20% people between 18-20 years, 29% between 21 to 30 years of age, 31% between 31 to 40 years of age, 14% between 41 to 50 years of age, and 6% above the age of 50 years. Both genders were represented with 69% of respondents being female and 30% male. Regarding marital status, 88% of the participants were single, 9% married and 3% divorced.

With regard to educational background, 16.9 % of participants possesed a basic education (Grade R-7), 59% had a level of secondary school education (Grade 8-12), 22% had basic qualifications, and 3% had postgraduate qualifications. Family size ranged from one individual to eleven persons per household with an average of five people per household. The participants

indicated that within their household their maximum household income was between R0-R5000, which was mainly from the WfW funding and partly from temporary work opportunities in the area.

2.5.1.1 Level of knowledge of invasive alien plants

The level of knowledge of IAPs varied across participants, with 46% of the respondents indicating that they had a good knowledge of IAPs, 34% with a very good knowledge of IAPs, and 20% of the respondents indicated that they had an excellent knowledge on IAPs (Figure 2.2). None of the participants chose the lowest category of a fair knowledge of IAPs.

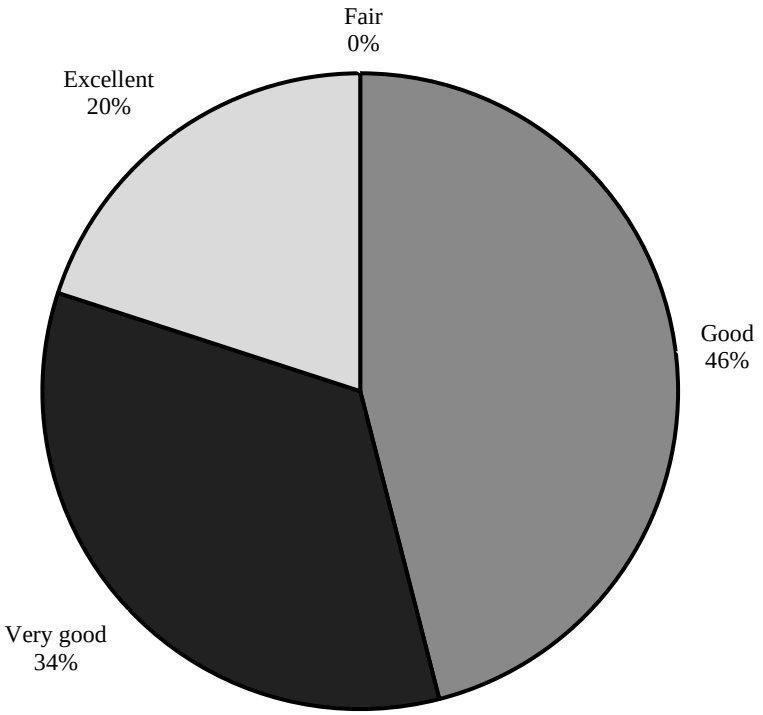

Figure 2.2: The percentage responses for four categories on the participants' knowledge of invasive alien plants ranging from fair to excellent knowledge.

Most (86%) respondents indicated that they are aware of IAPs, and believe that IAPs are a major problem, 6% indicated that IAPs are not a major problem, and 8% indicated that they are not sure if these plants are a major problem or not.

2.5.1.2 Knowledge of legislations that govern invasive alien vegetation and control

All participants acknowledged that they were aware of the National Environmental Biodiversity Act 10 of 2004, Conservation of Agricultural Resource Act 43 of 1983 and National Water Act 36 of 1998, general legislation governing invasive alien vegetation control and management. Responses indicated that 43% of the participants had a good knowledge of legislations that govern invasive alien vegetation control and management, 35% indicated that they have very good knowledge, 12% indicated that they have excellent knowledge, whereas 9% of the respondents indicated they had fair knowledge (Figure 2.3).

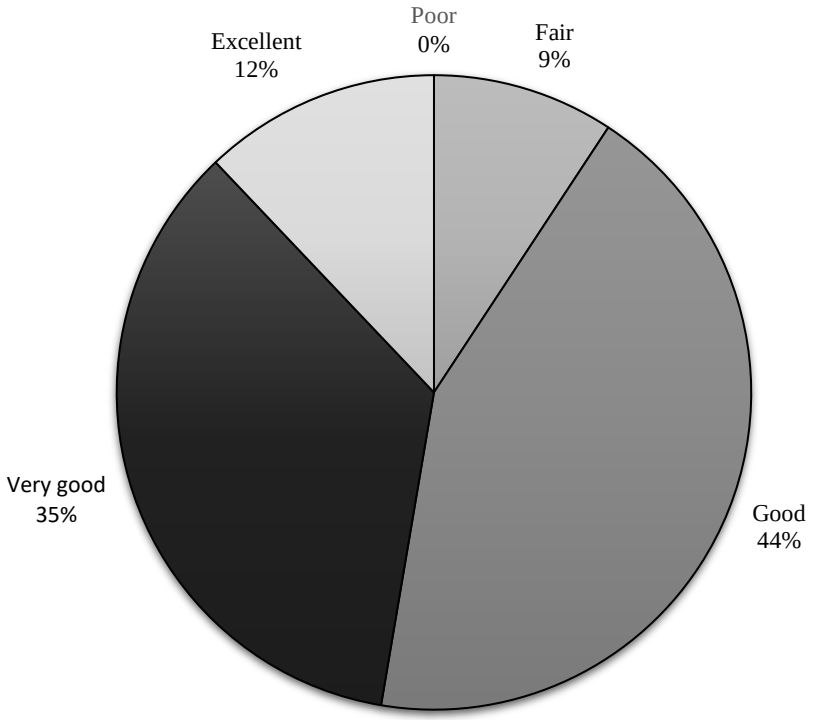

Figure 2.3: The percentage responses for five categories on the participants' knowledge of legislations governing invasive alien vegetation control and management.

2.5.1.3 International studies on invasive alien plants

The respondents were asked to indicate their sentiments towards "*International studies which have suggested that Invasive Alien Plants have several negative impacts on the environment*". The following statements were put forward (a) IAPs alter the fire regime of the natural vegetation; (b) IAPs harbour vermin (rats, mice, snakes, etc); (c) IAPs reduce native

biodiversity; (d) IAPs create impenetrable thickets that impede human and animal movement; (e) IAPs reduce the yields of farming land by encroaching on cultivated land; and (f) IAPs reduce the grazing land available to livestock. The respondents were asked to either indicate that they strongly disagree (SD), disagree (D), neutral (N), agree (A), or strongly agree (SA) with each of the above statements. Most (64%) of the respondents strongly agreed with the sentiment that IAPs alter the fire regime of the natural vegetation, 50% strongly agreed that IAPs harbour vermin, 61% strongly agreed that IAPs reduce native biodiversity, 54% agreed that IAPs create impenetrable thickets that impede human and animal movement, 58% strongly agreed IAPs reduce the yields of farming land by encroaching on cultivated land, and 61% strongly agreed that IAPs reduce the grazing land available to livestock (Table 2.1).

Table 2.1: Sentiments regarding international studies on invasive alien plants by participants (strongly disagree (SD), disagree (D), neutral (N), agree (A), strongly agree (SA)).

Sentiments	**SD**	**D**	**N**	**A**	**SA**
a) IAPs alter the fire regime of the natural vegetation	2	0	0	34	64
b) IAPs harbour vermin (rats, mice, snakes, etc)	2	0	3	45	50
c) IAPs reduce native biodiversity	0	3	5	31	61
d) IAPs create impenetrable thickets that impede human and animal movement	2	0	5	54	39
e) IAPs reduce the yields of farming land by encroaching on cultivated land	0	2	2	38	58
f) IAPs reduce the grazing land available to livestock	2	2%	0	35	61

2.5.1.4 Major threats of invasive alien plants along the northern Drakensberg

The respondents were further asked to agree or disagree with whether IAPs in the northern Drakensberg escarpment posed a threat based on the following statements: (a) causing damage to infrastructure such as roads, dams, etc; (b) reducing biodiversity (plants and animals); (c) invading river courses and catchment areas; (d) outcompeting native species; (e) reducing grazing area and interfering with grazing activities; and (f) reducing land productivity. The respondents were asked to either indicate that they strongly disagree (SD), disagree (D), neutral (N), agree (A), strongly agree (SA) with each of the above statements. Similarly, most (60%) of the respondents agreed that IAPs have potential to cause damage on infrastructure, 65% agreed that IAPs have potential to reduce biodiversity, 56% agreed that IAPs have potential to invade river courses and catchment areas, 53% indicated that IAPs have potential to outcompete native species, 63% indicated that IAPs have potential to reduce grazing area and interfere with grazing activities, and 52% indicated that IAPs have the potential to reduce land productivity. In addition, the respondents made further comments wherein they indicated that IAPs kill indigenous plants, consume more water, reduce farming yields, encroach cultivated land, and are detrimental to the environment and therefore it's imperative to remove them before they cause irreparable damage to the environment (Table 2.2).

Table 2.2: Major threats of invasive alien plants in the northern Drakensberg escarpment (strongly disagree (SD), disagree (D), neutral (N), agree (A), strongly agree (SA)).

Statements	**SD**	**D**	**N**	**A**	**SA**
a) IAPs have potential to cause damage on infrastructure	0	2	0	60	38
b) IAPs have potential to reduce biodiversity	0	0	0	65	35
c) IAPs have potential to invade river course and catchment areas	0	0	0	56	44
d) IAPs has potential to outcompete native species	0	0	2	53	45

e) IAPs has potential to reduce grazing area and interfere with grazing activities	0	3	0	63	34
f) IAPs has a potential to reduce land productivity	0	2	0	52	46

2.5.1.5 Ecological benefits along the northern Drakensberg escarpment due to clearing of invasive alien plants by Working for Water

Most (70%) of the respondents indicated that stream flow and water security had increased, and 25% indicated that biodiveristy had been restored, as a result of clearing of IAPs by WfW programme along the northern Drakensberg escarpment, whilst 5% of the respondents indicated "other" non-specified benefits (Figure 2.4).

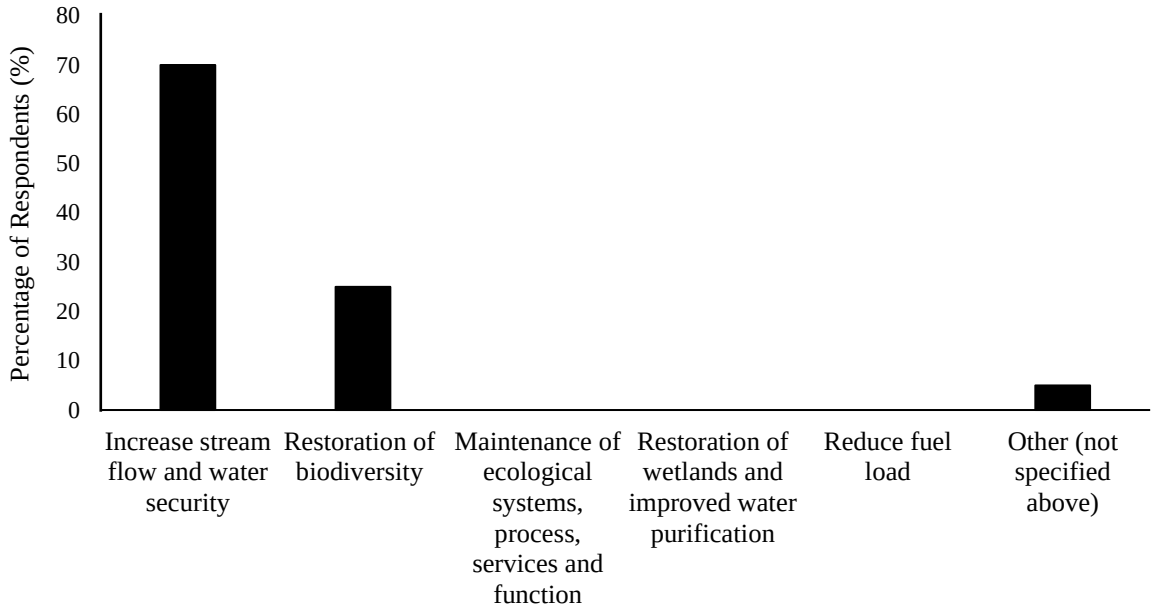

Figure 2.4: Ecological benefits along the northern Drakensberg escarpment as a result of clearing of invasive alien plants by Working for Water.

2.5.1.6 Advantages of invasive alien plants

Despite negative impacts associated with IAPs, the presence of these plants have certain advantages to the local communities in the northern Drakensberg escarpment such as provison of firewood, building and fencing material such as timber and poles, habitat and nesting sites for birds, medicine, and for production of mats, twine, rope, clothes, paper and many other uses for the benefit of the local community and general economy. The respondents were asked to either indicate that they strongly disagree (SD), disagree (D), neutral (N), agree (A), or strongly agree (SA) with each of the above benefits. Almost all of the respondents indicated that they agreed (54%) or strongly agreed (43%) with the sentiment that IAPs provide firewood for local communities. However, 1% had a neutral view, 1% disagreed and 1% strongly disagreed with this sentiment. With regard to provison of building materials, 63% indicated that they strongly agreed, 36% agreed and only 1% disagreed with this sentiment. For the statement that IAPs provide habitat and nesting sites for birds, 36% and 67% indicated that they agreed and strongly agreed with the sentiment respectively. Regarding the statement of IAPs providing medicine, 49% indicated that they strongly agreed, 49% agreed and only 2% disagreed with the statement. Lastly, 62% and 38 % of the respondents agreed or strongly agreed respectively that IAPs can be used for production of mats, twine, rope, cloth and paper (Table 3).

Table 3: Advantages of invasive alien plants (strongly disagree (SD), disagree (D), neutral (N), agree (A), strongly agree (SA)).

Statements	**SD**	**D**	**N**	**A**	**SA**
a) IAPs provide firewood to local community	1	1	1	54	43
b) IAPs provide building material such as timber and poles	0	1	0	36	63
c) IAPs provide habitat and nesting sites for birds	0	0	0	33	67
d) IAPs provide medicine	0	2	0	49	49

e) IAPs can be used for production of mats, twine, rope, cloth and paper	0	0	0	38	62

2.5.1.7 Involvement of respondents in the Working for Water programme

The respondents had been involved in the WfW programme in different capacities. The findings indicated that 28% of the respondents were involved as Heath and Safety representatives (either as a First Aider or Health and Safety representative in the programme), 23% were involved as Herbicide applicators, 21% were involved as Service Providers or Contractors, 20% as General workers, and 8% as Supervisors in the programme (Figure 2.5).

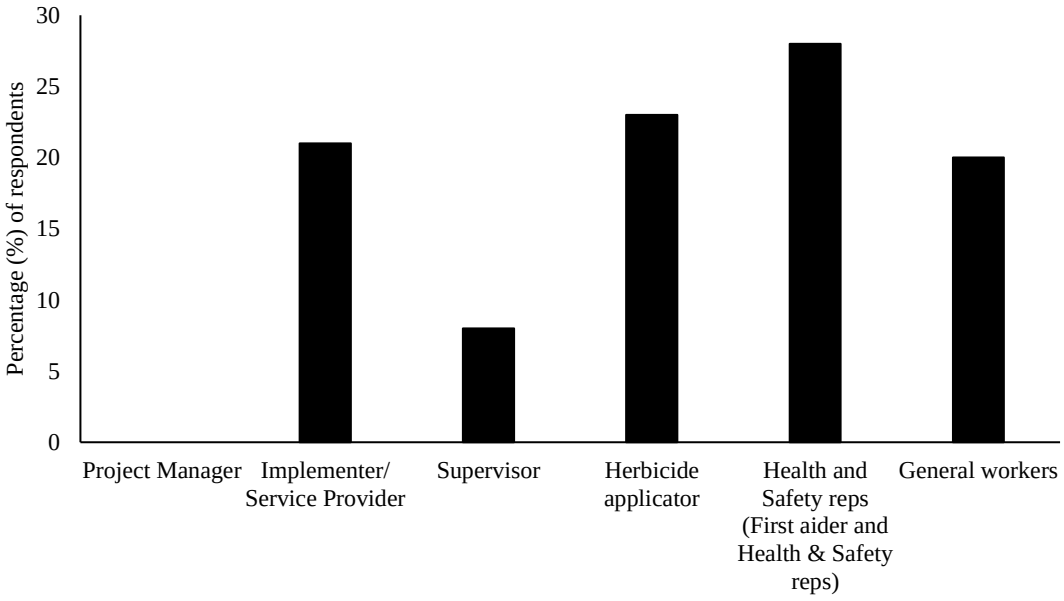

Figure 2.5: Capacity of participants who have been involved in the Working for Water programme in different catagories

The repondents provided further information on how often they worked for the WfW programme, and 60% of the respondents indicated “other”, which simply meant that the period that they worked was perhaps not specified or they did not want to divulge this information, while 29% of the respondents indicated that they worked in the WfW programme once in a given year, and 11% of the respondents indicated that they worked once every six months.

2.5.1.8 Socio-economic benefits of the Working for Water programme by communities living in the northern Drakensberg escarpment

In this study, 91% of the respondents indicated that the programme had benefited communities living in the northern Drakensberg escarpment while 9% indicated that they did not benefit from the existence of the WfW programme in the area. Of those who indicated that they had benefited, 48% indicated that they acquired knowledge and skills, 27% indicated that they benefited through employment opportunities, 22% had benefited through water provision and improved grazing area, and 3% indicated that their standard of living had improved as a result of clearing of IAPs along the northern Drakensberg (Figure 2.6).

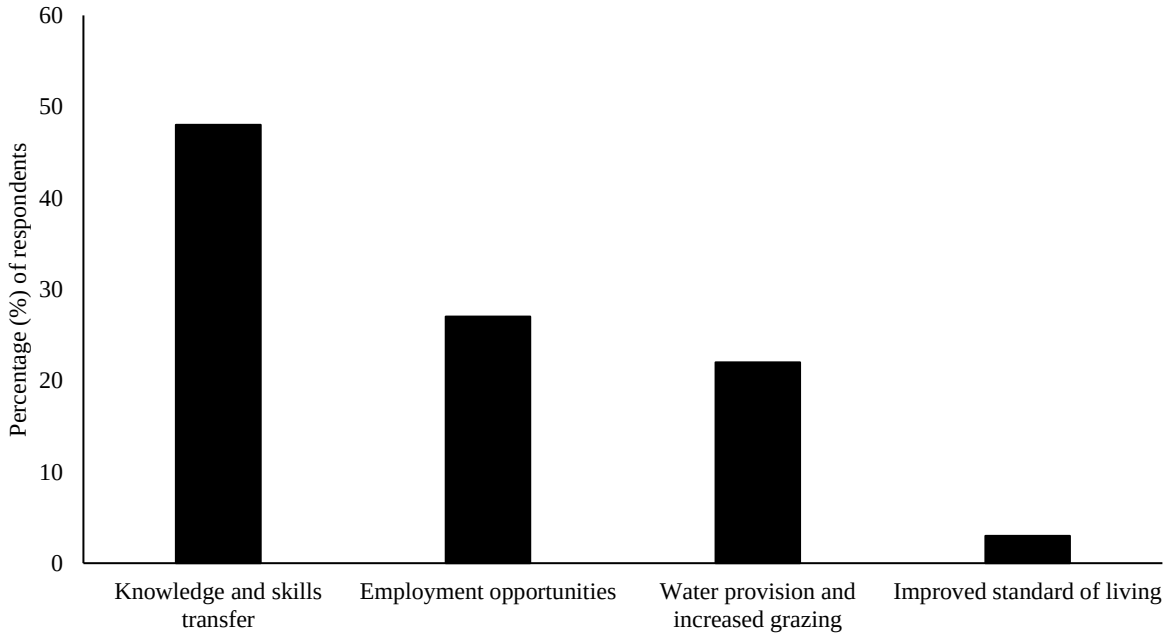

Figure 2.6: Socio-economic benefits experienced by the community living along the northern Drakensberg escarpment.

The respondents indicated that the delays in bidding processes and issuing of order numbers had affected them in different ways, wherein 39% indicated that these delays made it difficult to support their families, 25% indicated that the delays lead to loss of follow-up work, 18% indicated that the delays lead to a loss of income and skilled workers, and 18% did not specify or indicate their views in this regard (Figure 2.7).

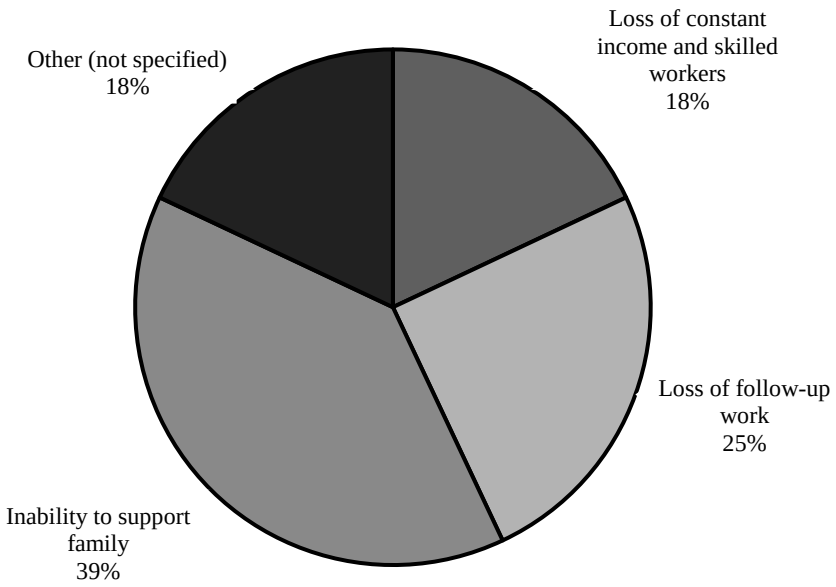

Figure 2.7: The effects of delay in bidding processes and issuing of order numbers on Working for Water participants and other institutions directly funded by the progrmme. Black colur represent other catergories not listed, dark grey coluor represent loss of income and skills, medium grey represent inability to support families by participants and light grey represent loss of follow-up clearing work because of intermittent funding .

The delay in bidding processes and issuing of order numbers also affected the implementation of the WfW clearing programme along the northern Drakensberg escarpment wherein 42% of respondents indicated that the delays had allowed IAPs to regrow, 13% indicated that delays enabled IAPs to seed, 29% indicated that delays had resulted in the loss of trained workers, and 3% stated that the delays had led to loss of equipment and resources required to conduct work. The remaining 13% did not indicate their views (Figure 2.8).

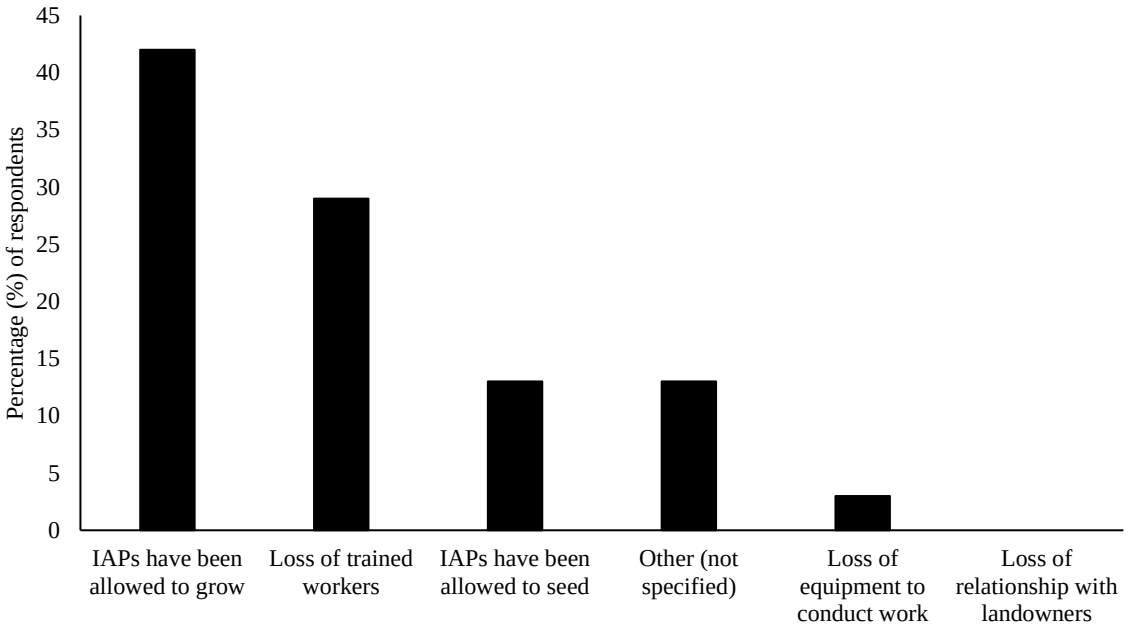

Figure 2.8: Effects of delay in bidding processes and issuing of order numbers in the implementation of Working for Water programme. Black bars represent the degree of effects as result of intermittent funding of WfW.

The participants were asked to make suggestions to ensure improvement in the implementation of the WfW programme and the following suggestions were listed for respondents to indicate their view: signing of long term contracts with service providers, employing participants permanently, decent wages, danger allowance, collaboration with landowners and key stakeholders, provision of funds, and empowering local communities. In this regard, 21% stated that the WfW programme should enter into long term contracts with service providers; 64% are in support of permanent employment; 4% support decent wages and danger allowance; and 3% were in support of collaboration with landowners and key stakeholders, as well as funding local communities, while 1% did not give any suggestion regarding improvement in the implementation of the WfW programme (Figure 2.9).

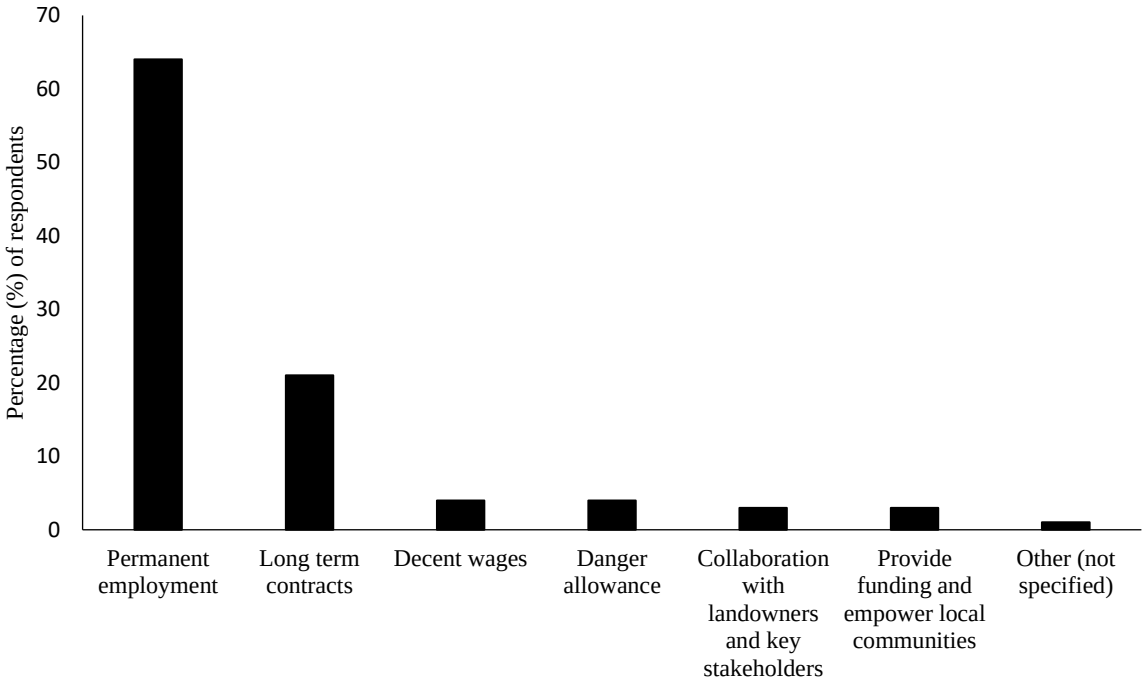

Figure 2.9: Suggestions of participants on the improvement in the implementation of Working for Water programme. The bars represent percentage of improvement in the implementation of WfW.

2.5.2 Landowner questionnaires

2.5.2.1 General knowledge of invasive alien plants by landowners

Ten landowners responded to the distributed questionnaires. All respondents indicated that the presence of IAPs is a major problem in their properties and also indicated that *A. mearnsii* , *Eucalyptus* spp. Labill species, *L. camara* , *P. alba*, *P.* × *canescens* Aiton **(**both Salicaceae), *R. cuneifolius* and *S. mauritianum* were some of the worst IAPs that are found on their properties. The landowners were asked to state their sentiments regarding to the main problems of IAPs such as alteration of environmental conditions, reduction of grazing and land productivity, displacement of native, useful species and changing ecosystems, reduction of stream flow and water availability, damage to infrastructure, disturbance of ecological processes, services and functioning, loss of native vegetation, and erosion and soil degradation. In this regard, 60% of the respondents indicated that IAPs cause alteration of environmental conditions on their properties while 40% of the respondents indicated that IAPs were not a major problem on their properties. Most (80%) of the respondents indicated that the IAPs

reduced grazing, land productivity, displaced native, useful species and changed ecosystems, and reduced stream flow and water availability on their properties. Half of the landowners indicated that the presence of IAPs caused damage to infrastructure as a result of increased fire intensity or frequency and 60% indicated that the presence of IAPs disturbed ecological processes, functioning and services on their properties. Furthemore, 20% stated that the presence of IAPs caused a loss of native vegetation on their properties, and 10% indicated that the presence of IAPs caused severe erosion and degradation of soil on their properties.

When landowners were asked if they were aware of the WfW programme and the work that had been conducted on their properties; all indicated that they were aware of the WfW programme and work that had been conducted on their properties. Furthermore, the landowners were asked to indicate if they were aware of the National Environmental Biodiversity Act 10 of 2004, Conservation of Agricultural Resource Act 43 of 1983 and National Water Act 36 of 1998 of which they all indicated that they were aware of these legislations relating to the management of IAPs in South Africa. Landowners were also asked to expand on their responses and they indicated that these legislations gave guidance on the management of alien species, whereas others indicated that they regulated and protected natural ecosystems and biodiversity to the benefit of all.

2.5.2.2 Type of land use, hectares cleared, experience with Working for Water and level of satisfaction about the work that the Working for Water programme has done on landowners properties

Landowners were asked to indicate the type of land use of their property, hectares of invasive species cleared, experience with WfW and level of satisfication about work conducted by the programme on their properties. The types of land use activities listed to choose from were forestry plantation, livestock farming, farming in general, conservation and woodland indigenous forestry management. The ratings were from 1-10 regarding experience with WfW and their level of satisfication where 1-3 was extremely dissatified, 4-6 satisfied and 6-10 extremely satisfied. In this regard, more landowners indicated that they were extremely satisfied (scale 7-10) with their experience with the programme, two landowners indicating that they were satisfied (scale 3-6), whilst the remaining two indicated that they were extremely dissatisfied (scale 1-3) (Table 2.4). Similarly, when asked about their level of satisfaction about the work that has been conducted on their properties by the WfW teams, more landowners

indicated that they were satisfied (scale 4-6) with the work conducted by WfW teams, three landowners indicated that they were extremely satisfied (scale 7-10), whilst the remaining three landowners indicated that they were extremely dissatisfied (scale 1-3) (Table 2.4). The landowners were requested to elaborate on their ratings and some of the landowners stated that the objectives of the WfW programme are good, but implementation has been poor and the period between treatments has been too long and sometimes only one treatment was done. Others indicated that they had a good working relationship with WfW staff, were extremely satisfied with the work done by WfW contractors, were happy that the infestation levels of IAPs were brought down significantly, while others indicated that IAPs grew back quickly and needed timeous follow up clearing to contain further spread.

Table 2.4: Experience with Working for Water programme by landowners and level of satisfication about clearing work that has been conducted by Working for Water on their properties.

Landowner	Type of land use	Hectares cleared	Experience with WfW (0=poor-10=excellent)	Level of satisfication (0=poor-10=excellent)
1	Livestock	unsure	6	7
2	Livestock	5	8	8
3	Farming	5	3	3
4	Farming	10	4	6
5	Farming	50	5	4
6	Forestry plantation	180	3	6
7	Forestry plantation	500	7	4
8	Conservation	800	5	6

9	Conservation	2000	10	10
10	Woodland Indigenous Forestry Management	±8000	8	8

2.5.2.3 Competence of Working for Water clearing teams

The landowners were asked to rate competencies of the WfW clearing teams who worked on their properties, where 1-3 was low level of competence, 4-7 moderate competance and 7-10 competence. In this regard, 40% of the landowners indicated the WfW clearing teams were highly competent, 40% indicated that the teams were competent, and 20% indicated that the teams' competence was low (Figure 2.10).

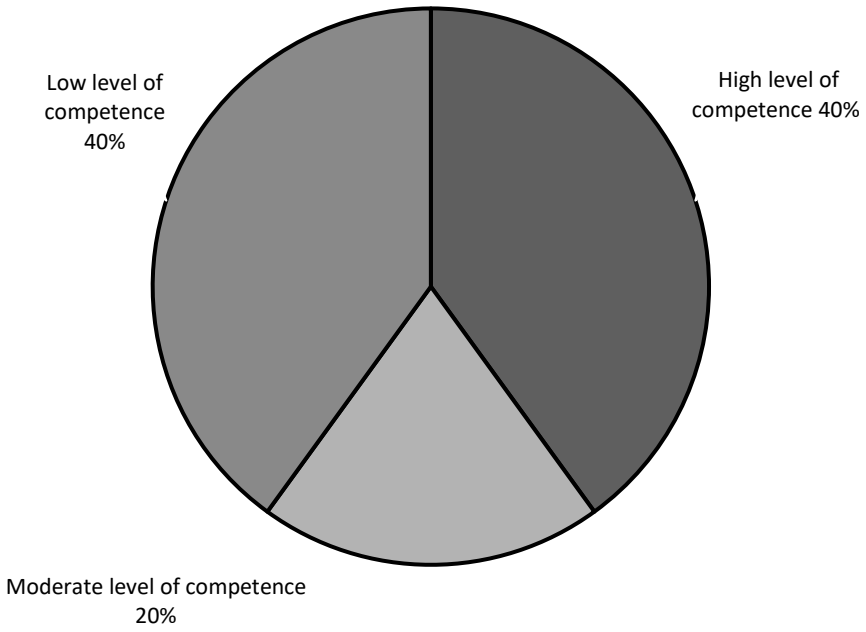

Figure 2.10: Competence of Working for Water clearing teams along the northern Drakensberg escarpment. Different colours in the chart represent the level of competatance.

2.5.2.4 Status of invasive alien plants as a result of the Working for Water clearing programme

The landowners were asked to indicate if they had seen any reduction of IAPs on their properties due to clearing by WfW teams. More (60%) landowners indicated that they had seen some reduction. Furthermore, landowners were asked to estimate the amount of reduction as a percentage of the original invaded area. In this regard, 90% landowners indicated that they had seen reduction of IAPs on their properties ranging from 20 to 80%.

2.5.2.5 Impact of clearing of invasive alien plants by WfW programme on restoration and/or preservation of ecosystem functions and services

The landowners were asked to indicate if the clearing of IAPs by the WfW programme had contributed to restoration and/or preservation of ecosystem functioning and services based on the following statements which stated that clearing of IAPs increased stream flow and water availability, increased grazing land, increased land productivity, restored ecosystem functioning and services. More landowners (70%) indicated that clearing of IAPs had increased stream flow and water availability, and 50% of the landowners stated that grazing area land productivity had increased, and ecosystem function and services had been restored (Figure 2.11).

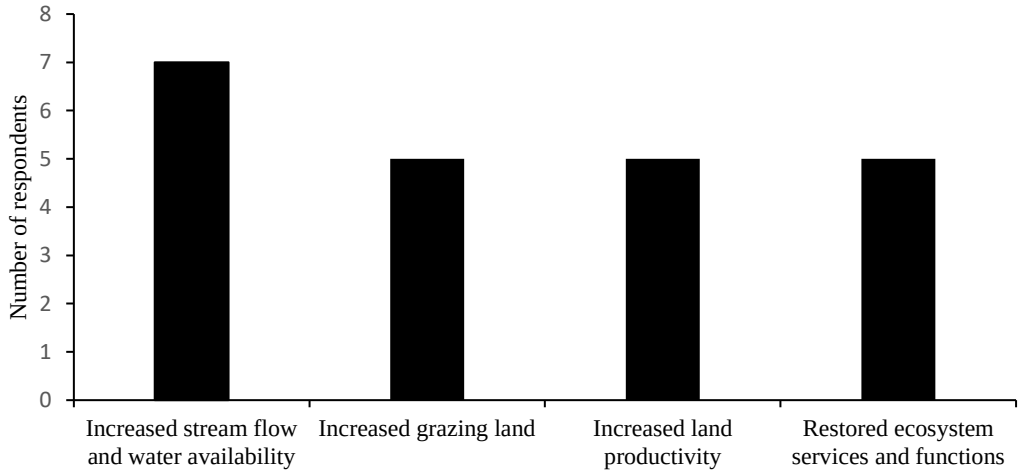

Figure 2.11: Impact of clearing of invasive alien plants by Working for Water programme. The bars in the graph represent the degree of impact as a result of clearing by WfW.

2.5.2.6 Working for Water Programme implemetations and future improvements

The landowners were asked if the Department of Forestry, Fisheries and the Environment (DFFE) should continue to implement the WfW programme, and they all indicated that the WfW programme should continue to be implemented to manage IAPs in the country, since the problem already exists and many landowners and managers cannot afford the cost involved with clearing IAPs. They also indicated that WfW should streamline implementation processes to avoid unnecessary stoppages of teams and ensure continuous treatments of follow up areas.

Landowners were asked to give suggestions for what could be done to ensure improvement in the implementation of the WfW programme based on the following suggestions: increase funding, long term contracts with service providers (three years and more), improve education and awareness about IAPs, and ensure compliance and enforce legislative frameworks (NEMBA and other relevant legislations). All respondents suggested that funding for the implementation of WfW should be improved to ensure that the programme achieves its objectives without any hinderance, 60% of the landowners suggested that WfW should enter into long term contracts with service providers (contractors) and ensure improvement of IAPs awareness and education, and 40% of the landowners suggested that WfW should ensure enforcement and compliance with legislation regarding IAPs in South Africa.

2.6 Discussion

This study revealed that, for the participants in the WfW programme in the northern Drakensberg escarpment, 59% of employees were young people between the age of 18 and 30 years, and 69% of employees were women. This confirms that the WfW programme has come very close to reaching targets for youth employment, and has complied with the set employment requirements regarding women (Bek *et al*., 2017).

This study further revealed that the majority of the respondents were knowledgeable about IAPs, their impacts and the need to control and manage them, as well as the legislative framework governing IAPs. The respondents demonstrated good understanding of major threats of IAPs along the northern Drakensberg escarpment, but also advantages of those IAPs, concluding that IAPs do have certain advantages for local communities, such as provison of firewood, building and fencing material such as timber and poles, habitat and nesting sites for birds, medicine, and can be used for the production of mats, twine, rope, clothes, paper and

many other uses for the benefit of the local community and economy. This shows that the training provided by WfW is instructive and informative ensuring contractors are aware of the reasons for the work they are conducting. The benefits associated with IAPs is a continual conundrum in South Africa where many rural households have become reliant on invasive species for daily needs. This conundrum was further explored in a study by Ngorima and Shackleton (2019) which aimed to assess the perceptions and livelihood uses of the *A. dealbata,* by local communities at three localities in the montane grasslands of the Eastern Cape, South Africa. The assessment was done using a mixture of random household interviews, focus group deliberations and participatory instruments. The study found a dualistic role of *A. dealbata* in local livelihoods. In addition, *A. dealbata* was extensively used for medicine, forage and firewood (100% of households), tools (77%) and construction timber (73%), with minimal use for traditional medicine and forage. The cumulative value of roughly ZAR 2,870 (± USD224) per household per year (across all households) represents a substantial cash saving to households, majority of whom are relatively poor by national and international measures. Similarly, the increasing extent of *A. dealbata* (93% said it was increasing) worsens local household vulnerability, although reported a declines in cultivated areas, crop yields and forage production, and allegedly higher risks of crime. This quandry is well summarized by the substantial majority of respondents (84%) not wanting higher extents and densities of *A. dealbata*, but an equally high majority not wanting its total removal from local landscapes. Most respondents hated *A. dealbata* in fields, close to homesteads or along primary access routes, and were more tolerant of it away from such sites. Institutional and use dynamics have differed over several decades in response to the changing extent and densities of *A. dealbata* and the wider socio-economic and political perspectives. The study findings indicated that greater efforts are required to comprehend perceptions and uses of IAPs by the people who reside with them and potentially direct such understanding where required into more spatially and temporally contextualised response strategies.

Most (97%) of the participants stated that WfW programme had improved their living condition, while the remaining 3% indicated that the programme had not improved their living conditions. Furthermore, when exploring the reasons for stating that the programme had improved living conditions, 72% of the respondents indicated that the programme had improved their living conditions through improved knowledge and skills and most importantly the training opportunities that they had attended while working in the programme, 13% indicated that the programme had improved their household income, 10% indicated that

working in the programme had improved their chances of getting work opportunities in other sectors, and 5% of the respondents indicated that the programme had improved their living conditions in terms of access to clean water, food, shelter, electricity and many other improvements. This clearly indicated that the WfW programme has made a meaningful impact to the communities who mainly depend on WfW funding for their livelihood along the northern Drakensberg escarpment. However, short term contracts and intermittent funding have significant implications for the communities now relying on the funding. However, some of the respondents indicated that the manner in which the programme is presently being implemented, such as delays in the bidding process and issuing of order numbers before they can commence work, had affected employees and contractors negatively and in different ways, including loss of income, inability to support their families as most of them largely depend on WfW funding, loss of skilled labourers, loss of follow-up work and allowing IAPs to regrow.

The responses to the questionnaires suggest that WfW are meeting their employment targets. Of note, however, was the heavy reliance of families from rural areas on WfW as most respondents had large household sizes and no other forms of income. Delays in funding are catastophic, having significant impacts on communities as the study showed that WfW employees could no longer support their families who had become reliant on the programme.

With regards to perceptions of the WfW programme by landowners, this study revealed that the clearing assistance by WfW projects has had financial and economic benefits to the landowners on whose land clearing has been implemented. The presence of IAPs have a serious impact on their properties as these plants alter the natural environment, displace native and useful species, reduce stream flow and water availablity, reduce grazing area, and cause soil erosion and land degradation. The landowners indicated that they are well aware of IAPs on their properties and the clearing work that has been conducted by the WfW programme. In addition, landowners are aware of the legislative frameworks governing IAPs in South Africa and they are of the view that these regulatory prescripts should be implemented to protect natural ecosystems. They argued that the legislations help landowners and users to regulate their weeding programmes, and manage weed infestation on their properties. However, some landowners argued that implementation of clearing assistance was inconsistant with the WfW policies wherein some instances only intial treatment was conducted and no follow-up work was conducted, while others argued that were follow-up treatment was done, the time between

treatments had allowed species to regrow and new alien species to establish through secondary invasions.

Unfortunately, limted landowner surveys were conducted due to the difficulty of finding landowners in the Graskop and Pilgrim's Rest area as many farms were dissolved to accommodate large scale foresty or involved in land redistribution programmes, meaning large areas were owned by Government. However, the limited questionnaires suggest landowners recognise the problems associated with IAPs and the need to manage them but also that they are not financially able to do so themselves. They also suggest that in majority of landowners are happy with WfW implementation and the work they do but think the quality could be improved.

The WfW programme currently operates IAP clearing projects that are spread across all nine provinces in South Africa, and as result, studies in different regions may result in different responses. However we believe a number of the responses will hold true for many rural regions of South Africa. The WfW projects in the northern Drakensberg escarpment have significatly contributed to the creation of work opportunities and skills transfer to the marginalised communities as most of the participants indicated that their source of income is mainly from the WfW projects and any disruption due to delay in tendering and issuing of order numbers affected their livelihood. It is therefore appropriate to ensure improvement in the implementation, ensure long-term employment opportunities and skills development according to need, and maximise conservation efforts aimed at restoring natural ecosystems. In this study, most of the participants indicated that the local community had benefited from the existence of WfW programme in the area in many ways, such as employment opportunities, improved water supply and grazing area, and standard of living.

It is worth noting that there are other programmes that provide employment and skills development in the conservation sector in South Africa and these includes programmes such as Working for Wetlands (WfWet), which was initially managed as a sub-programme of WfW and aims to prevent and reduce degradation of wetlands, and Working on Fire (WoF), which is an environmental initiative aimed at assisting with veld and forest fire management while providing employment opportunities and skills development. In addition, Working for Ecosystems (WfEco), Working for Forestry (WfF) and Value Added Industries (VAI) provide further work opportunities and skills development (Angelstam *et al*. 2017). The employment of workers within the EPWP is regulated by the Basic Conditions of Employment Act of 1997,

Ministerial determination 4: Expanded Public Works Programme, which set out employment targets of 60% women, 55% youth, and 2% of people with disabilities for all sectors that are participating in the EPWP, and is expected to comply with these requirements. van Wilgen *et al.* (2022) argues that few studies have attempted to quantify the degree to which WfW's social objectives have been achieved and it was this lack of clarity regarding the intended outcomes and absence of monitoring of the programme's social achievement which prompted this study in order to fully understand the impact of the programmes on the lives of the employees who have worked in the WfW programme.

In this study, there were some limitations especially with regard to obtaining sufficient landowner questionnaires. Despite extensive efforts to find landowners over two years, getting landowners to complete and return questionnaires was particularly challenging. It is therefore essential to address challenges relating to landowners' cooperation as they are the beneficiaries of these studies but often seemed uninterested in engaging with the topic. This may be because of lack of awareness or not seeing any value in participating in the study. It is a pity as they are instrumental for providing possible solutions that are aimed at ecosystem restoration. This is one of the first studies in the WfW system that has aimed to investigate the perceptions of landowners to WfW clearing programmes. It is suggested that the study be expanded and rolled out to other regions to ensure that the WfW and all relevant stakeholders are consulted in order to make informed decisions to improve implementation of clearing projects as it takes into consideration people who are directly affected by the project, principally landowners and workers. Notably, there are no WfW activities on farms which have been subjected to land reform/ restitution since 2019. The WfW recently finalised a new tender which will accommodate these farms. In addition, there are minimal activties on plantation farms that have been transferred to the land restitution beneficiaries but under the custodianship of the Department of Public Works and Infrastructure.

2.7 Conclusion

The results of this study indicated that investment by the WfW programme in the creation of work opportunities for the previously disadvantaged communities in the study area is economically and socially viable, and the communities along the northern Drakensberg escarpment have benefited through knowledge and skill transfer, water provision, improved grazing capacity, and through employment opportunities and future job prospects as a result of

the training that they have received. However, the inconsistency in the implementation of the programme, including delays in bidding processes, delays in issuing of order numbers, and short term work opportunities, have a negative impact on the livelihoods of the project participants as this affects their ability to support their families because of loss of income, as some of them indicated that they work once in six months whereas others indicated that they had not worked for an entire finacial year. This is really dire for those families especially when this is the only form of income. The study revealed that the work opportunities that are being created by the WfW programme do not necessarily address poverty and unemployment and therefore it is recommended that the WfW programme should invest in longer-term work opportunities or employ participants on a permanent basis to create stability in the programme and sustainable income in order to support livelihoods. This will have the duel benefit of creating institutional knowledge within the programme and allow transfer of ideas between contractors and landowners. For example, contractors can develop relationships with landowners allowing easier access to invasions but also contractors will become more accostomed to working in the environment and the weeds therein.

Chapter 3: Responses of plant communities to invasive alien plan-tremoval on the northern Drakensberg escarpment, South Africa

3.1 Introduction

The WfW programme is implemented nationwide, across all provinces to manage and control IAPs, which are a major threat to the functioning of ecosystems services and biodiversity to enhance the sustainable use and conservation of natural resources. The management of IAPs aims to restore and rehabilitate ecosystems to promote or maintain the ecological intergrity of ecosystems, their functioning and provision of ecosystem services such as water flow, water security, soil fertility and improve land productivity. The extent of invasion by IAPs pose a significant threat to biodiversity, water security and associated livelihoods, therefore important to protect, restore and manage catchment areas. However, the success of the programme has not been effectivly determined. Here we aimed to investigate if ecosytem recovery has occurred after clearing operations.

South Africa has a long history of invasive alien plant (IAP) management with the government investing approximately ZAR1 billion (~$70 million) annually, primarily through the Working for Water (WfW) programme (Zengeya and Wilson, 2020). Since initiation in 1995, the programme has grown and successfully cleared significant areas infested with IAP's (Hobbs, 2004, van Wilgen *et al*., 2020). However, long-term studies in grasslands and savannas revealed that after a decade of clearing, invasions had not been reduced, and the focus has been shifted from dealing with single species to a wide variety of IAPs (Beater *et al*., 2008). More recently, van Wilgen *et al*. (2022) reviewed the cost, extent and effectiveness of the management of plant invasions by the WfW, concluding that "The effectiveness of control operations has not been monitored regularly, but a few studies at local scales have found reductions in alien plant cover, and it is likely that "Working for Water" has had a role in limiting invasion." The main goal of the clearing efforts was to reverse the negative impacts of IAPs through restoration of ecosystem structure and functioning. The WfW system primarily relies on a key assumption focussing on ecosystem recovery; that target ecosystems, mostly riparian, would "self-repair" once the main stressor (dense stands of invasive alien trees) had been removed (van Wilgen *et al*., 1998; Esler *et al*., 2008; Morris *et al*., 2008). Of the few localised studies identified by van Wilgen *et al*. (2022), that have investigated recovery post

WfW clearing, very few have been in mountain systems, but rather focussing on riparian and aquatic systems (See references within van Wilgen *et al.,* 2022).

The Eastern Great Escarpment as defined by Clark *et al*. (2011) (Sneeuberg to Wolkberg) in Mpumalanga Province is a critical water source with two river catchments, Blyde and Sabie Rivers, which serve as a source of water to the rural communities and is classified as the most significant ecological system in South Africa (DWAF, 1997; Addo-Bediako and Malakane, 2020; Lusunzi *et al*., 2021, Chapter 1). The Sabie River Catchment, which is part of the Wolkberg Centre of Floristic Endemism, has 163 red-listed plant species and several threatened birds (including the critically endangered *Hirundo atrocaerulea* (Blue swallow), as well as numerous reptiles, amphibians, mammals, and a rich aquatic fauna (Matthews *et al*., 1993; Cowling and Hilton-Taylor, 1994; Allen *et al*., 1997; Nel *et al*., 1999). Unfortunately, this important biodiversity hotspot and water source for South Africa has been invaded by several woody and herbaceous plant species, threatening water provisioning, a critical ecosystem service. The dominant IAPs in this biome include *A. mearnsii*, *Pinus patula* Miller (Pinaceae), *Populus* spp. , *Acacia melanoxylon* R.Br. (Fabaceae), *Eucalyptus* spp. , and *R. cuneifolius*. Invasive species in combination with habitat destruction, mining and illegal harvesting of native plants are considered the main threats to native plant biodiversity in the region (Clarke *et al*., 2002). For example, Le Maite *et al*. (2016) study on the estimates of impacts of IAPs on water flows in South Africa revealed that invasions by *A mearnsii*, *Eucalptus* spp. and *Salix* spp. had resulted in substantial reduction on a volume basis in the Grassland Biome whislt *Pinus* spp had large impacts on Fynbos Biome. Furthermore, study in Pakistan showed that in a greenhouse experiment *Eucalyptus camaldulensis* used three times more water as compared to native trees (Zahid *et al*., 2010). In a separate study conducted by Ruwanza et al. (2015) found that allelophathic substances released by *Eucalyptus* spp. had negative impacts on the germination and growth of native riparian trees.

Invasive alien clearance on the Mpumalanga Escarpment (subset of the Limpop Mpumalanga-Eswatini Escarpment) was formally initiated through the WfW programme in 1995, through contracts targeting dominant IAPs. Management was mainly through mechanical and chemical means including felling, ring barking and foliar application of approved herbicides on seedlings. Follow-up treatments have been conducted at the same sites targeting either the initial target species or secondary invasive alien species since 1995. Given the long history of IAPs clearance on the Mpumalanga Escarpment , this study aimed at providing quantitative

data on the impact of these interventions on ecosystem recovery. In particular, the study sought: a) to assess the effect of invasive alien removal on subsequent plant community assembly; b) to determine the recovery of native vegetation following the removal of dense alien invasions. These assessments will objectively inform future WfW interventions with particular focus on its objective to restore ecosystem structure.

3.2 Material and Methods

3.2.1 Study sites

The study was conducted on the eastern edge of the Drakensberg mountains in Mpumalanga Province, South Africa (refered to as the Mpumalanga Escarpment ; latitude 24.822463°S and longitude 30.740213°E) near the towns of Pilgrim's Rest and Graskop. The escarpment has an elevation of more than 1,900 m above mean sea level (m asl) to the west while the lowveld to the north and east has an average alititude of about 500 m asl (Makhubela *et al*., 2021). The escarpment encompasses the headwaters of the Blyde River and Sabie River, at elevation ranges between 560 and 2,030 m asl (Lotter *et al*., 2014; Maimela *et al*., 2022). The area experiences hot summer temperatures averaging mid 30^{o}C and frequently exceeding 40^{o} C, while winter seasons are mild to cool and generally frost-free (Maimela *et al*. 2022). The study area receives moderate to annual high rainfall (800–1,200 mm), and mean annual precipitation of more than 1000 mm (WRC 2001). Native vegetation on the escarpment is dominated by grasslands and associated life-forms and these are interspersed with Afromontane forest (Clark *et al*., 2022). The forest patches host a variety of forest-dependent trees, including some species considered rare, insufficiently known, or listed under the Red Data List of South African Plants (Lötter and Beck, 2004). The sites were all located in the Thaba Chweu Local Municipality (for more information see Chapter 1).

3.2.2 Selection of study sites

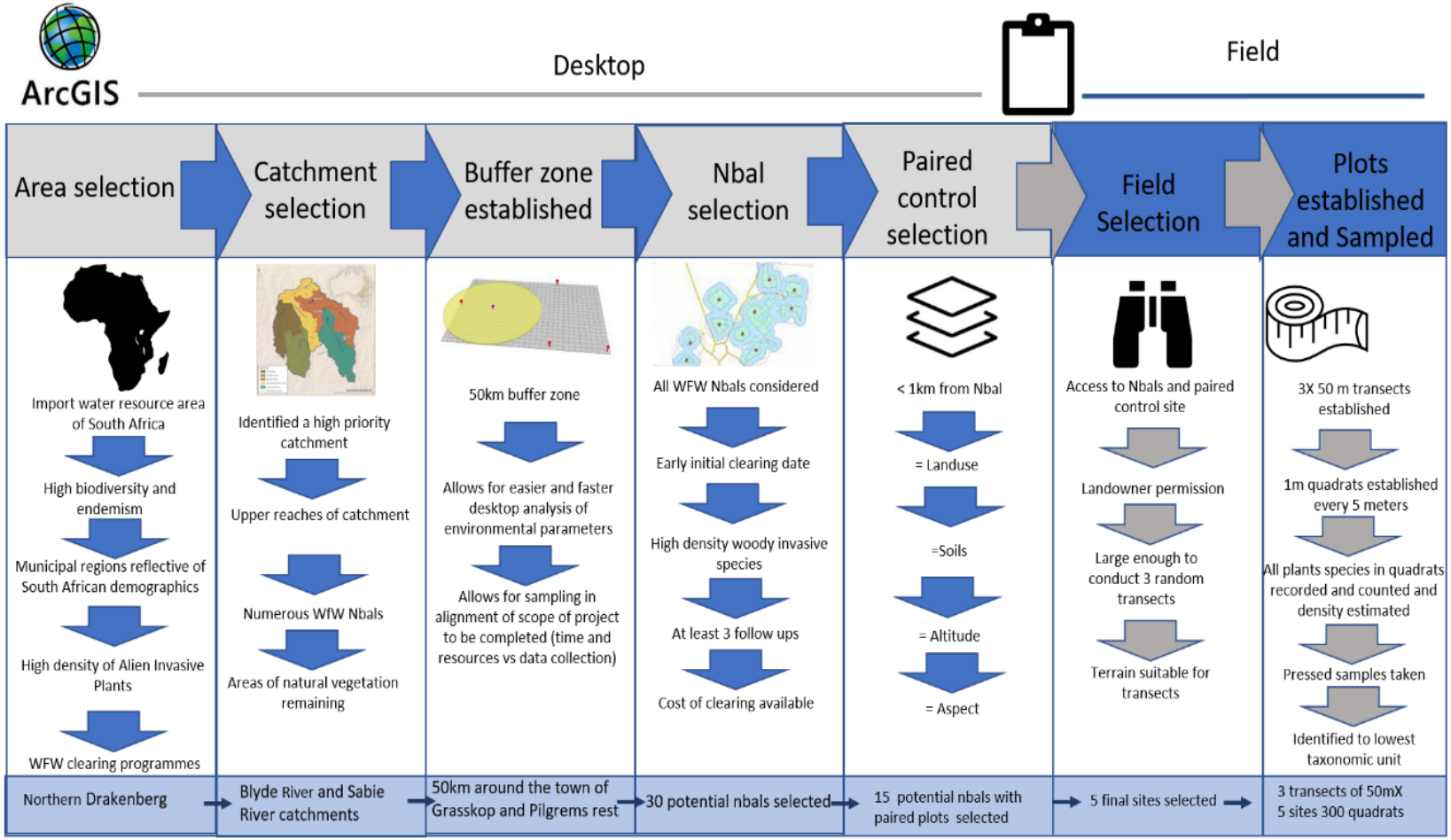

Figure 3.1: The workflow of methods to determine final study sites. The schematic above the table shows which sections which were conducted as desktop studies and the sections which were conducted in the field. The first column “”Area selection” shows the steps take to select the the

study area; Column 2 “Catchment selection” shows the steps taken to select the study catchments; The columns 3-5 “Buffer zone stablished, Nbal selection and paired plot selection” shows the desktop methods used to select the actual plots where the studies were conducted. The final two collums indicate the steps of the fild work.

Desktop investigations using freely available environmental data layers (Table 3.1) in ArcGIS 10.7 (ESRI 2021) were initially used to identify and select possible study sites. Field surveys were then conducted to confirm study site suitability and to collect vegetation data. The first step in site selection was to choose which catchments to work in. The Blyde River and Sabie River Catchments were selected in the northern Drakensberg escarpment (Figure 1.5, chapter 1; Table 3.1). These catchments were prioritised as they have considerably high biodiversity and endemism, and ranked as the highest priority catchments critical for downstream water security in the Mpumalanga Province (DWA, 1997; Forsth *et al*., 2001; Le Maitre *et al*., 2002; Lusinzi *et al*., 2021). Once the catchments were selected, the national landcover dataset was then overlayed on the catchments to select out grassland areas (Table 3.1, Figure 3.1). Once these were selected, the Natural Biological Alien (Nbal) data layer, which refers to a spatial polygon of a site that contains alien plant invasions, delianeted for the purposes of awarding contract to clear the site or WfW Water Information Management System database (WIMS) data which was overlayed to determine areas where WfW clearing had been conducted in the grassland areas. (Figure 3.2). The WfW Nbal data layer was started in 1999 and is how the programme records its clearing initiative, and the following data are recorded for each Nbal : the species involved, the area treated (which was captured spatially at a scale of at least 1:50,000), the density class of the infestation (seven density classes were used, based on aerial canopy cover; the classes were: 0.1–1%, 1–5%, 6–25%, 26–50%, 51–75%, 76–99% and 100%), workload (expressed in persondays per hectare) and contract value (money spent on direct clearing operations, including direct supervision, labour, equipment, protective clothing, transport, and administration costs incurred by the contractor). The cost of chemicals was included in overheads (see below). For this study, the Nbals were refined to Nbals which had significant woody invasive species (*A. mearnsii, A. melanoxylon*, *P. patula* or *E. grandis and E. saligna*) and herbaceous species (*S. mauritianum and R. cuneifolius*) and having been cleared more than 10 years ago. Priority was given to older sites, including sites cleared in 1995. It was then possible to select study sites in grasslands in the Blyde and Sabie Catchments where clearing had occurred, but also areas nearby (<1 km) where clearing had not occurred. Approximately 30 study sites were then selected with uncleared areas (paired control sites) nearby <1 km away for further investigation.

In order to confirm paired control (uncleared) sites were similar to selected cleared study sites, elevation, aspect and soil type (See Table 3.1) were then overlayed to ensure points selected

within cleared sites and adjacent veld shared the same abiotic attributes. Finally, the South African national road layers were then overlayed to determine access to the sites.

Once a number of sites had been selected using desktop analysis, sites were physically visited to check if they were suitable (i.e., if accessible and if landowner permission could be obtained). The sites were refined down to five suitable sites within the Blyde and Sabie Catchments (Figure 3.3), namely: Graskop 1 and 2, Robbers Pass, Pilgrim's Rest and Blyde River Catchment. It is worth noting that the Working for Water Project manager, Obed Mugane, was also consulted during the initiation of the project. Mr Mugane had been working for WfW projects in the area since the project initiation in 1995 and has personally worked in a number of the Nbals selected for this study and was able to provide excellent insight into the historical clearing especially for Nbals created pre-1999.

Table 3.1: Environmental and climatic data layers used for the selection of study sites.

Data layer	Source	URI/Reference
WFW Polygons	WIMS/WFW	www.wfw.org.za
Water Catchments	Strategic Water Source Area	http://www.sasdi.net/metaview.aspx?uuid=fcb6dd66c2efb525b80933c8eb53b6f1
Land use	DEA E1434 Land-Cover South African National Land-Cover 2018	https://www.dffe.gov.za/projectsprogrammes/egis_landcover_datasets
Soils	Soil and Terrain Database for Southern Africa (SOTERSAF)	https://data.isric.org/geonetwork/srv/api/records/3571c1f3-159d-442c-b324-0af53d03f12e
Altitude	South African Atlas of Agrohydrology and Climatology	Schulze, R.E. 1997. South African Atlas of Agrohydrology and Climatology. University of Natal. Pietermaritzburg.
Aspect	South African Atlas of Agrohydrology and Climatology	Schulze, R.E. 1997. South African Atlas of Agrohydrology and Climatology. University of Natal. Pietermaritzburg.
Roads	South Africa Road systems	https://www.igismap.com/south-africa-shapefile-download-boundary-line-polygon/

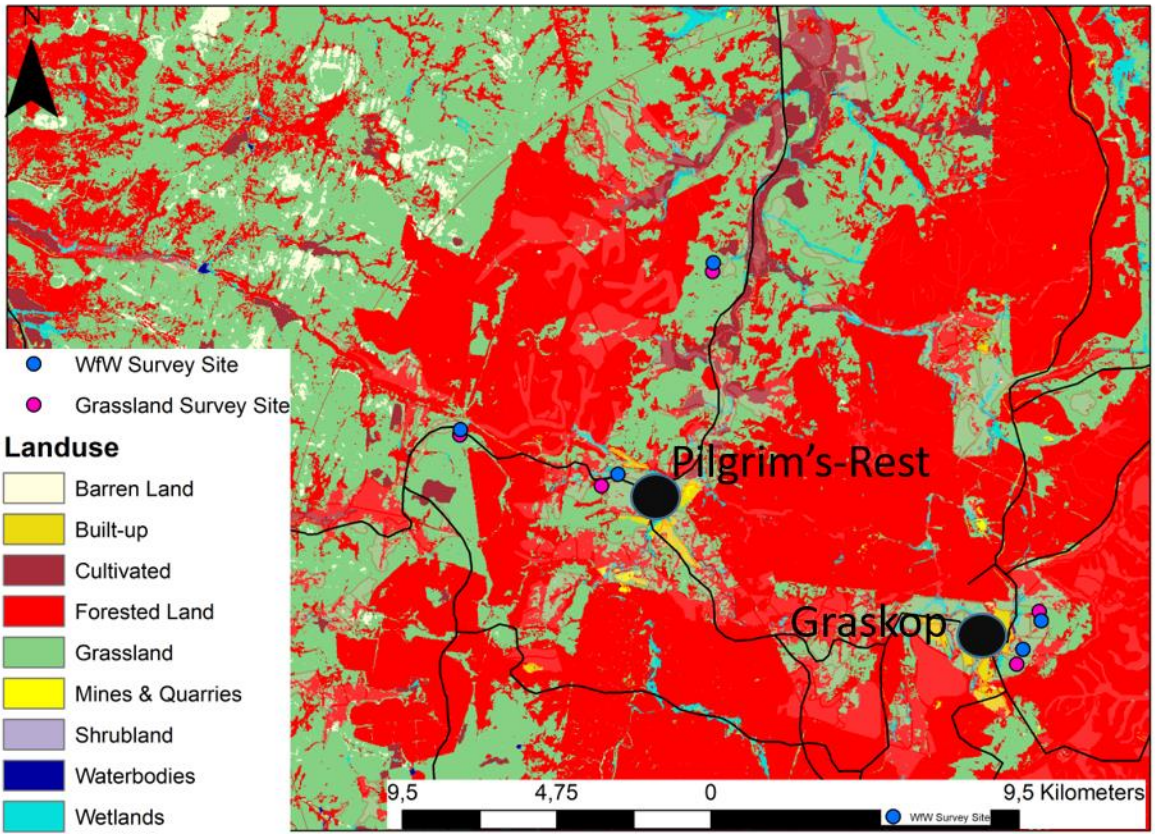

Figure 3.2: Map showing landuse activities in the Pilgirm's Rest and Graskop study sites. Blue dots indicate study site while pink dots indicate paired control sites.

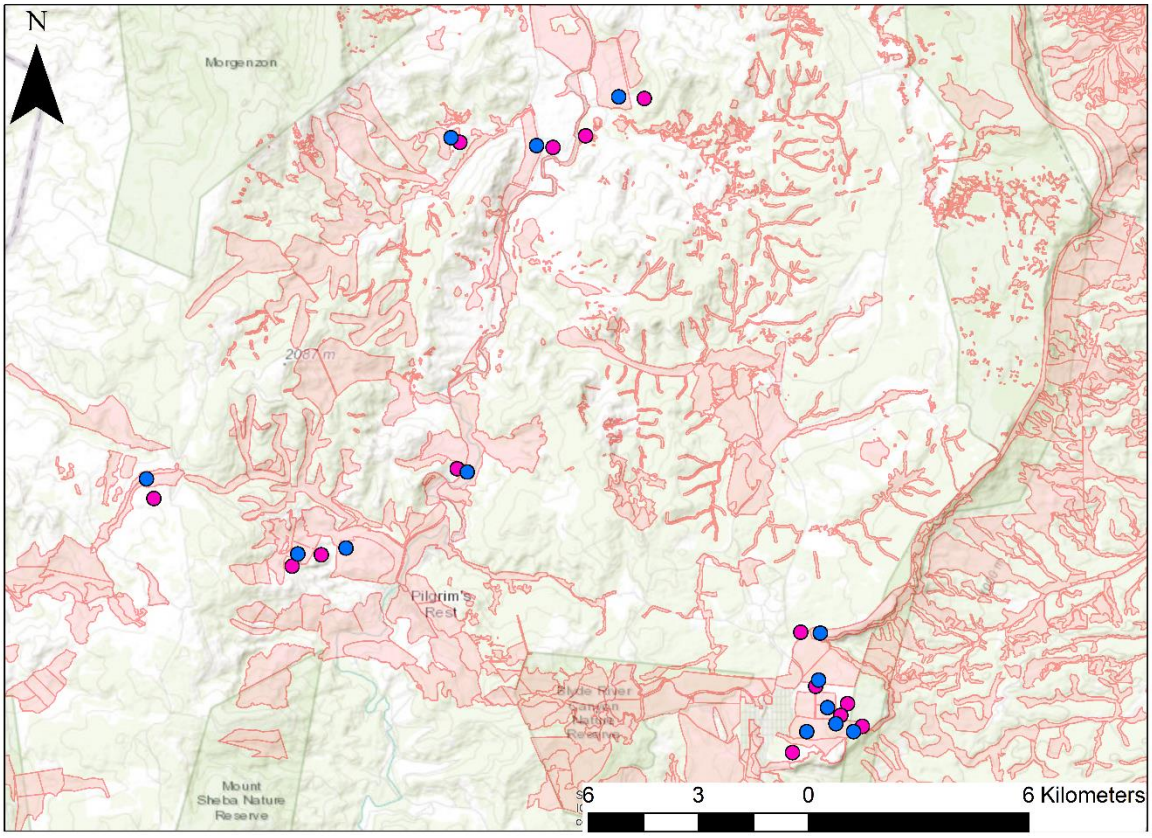

Figure 3.3: Map showing selected sampled sites in Pilgrim's Rest and Graskop; red colours indicate the Working for water: The Natural Biological Alien (Nbal) data layer.

3.2.3 Site characteristics

3.2.3.1 Graskop (B60B102957 & B60B102959)

Graskop site was located in the Graskop Conservancy on the eastern side of the town of Graskop (24.926498°S-30.854504°E & 24.933716°S-30.852588°E). The sites were located at an elevation ranging from 1,442 to 1,736 m.a.s.l. The sites were dominated by Grassland vegetation with patches of forest and the dominant soil is Lithic leptosols (Figure 3. 4). It was reported that initial clearing started in the conservancy between 1995-2000 (Mugane Pers. comm). In this study two Nbals (B60B102957 & B60B102959) were selected from the Conservancy area. Work was conducted with permission of the Local Conservancy Manager.

The Nbal number B60B102957 was cleared by WfW in 2013, and the dominant species was *A. melanoxylon.* The total clearing cost at this Nbal was ZAR 92,537.41 according to the WfW WIMS database (Table 3.2, site 1). The second Nbal B60B102959 was cleared between 2013

and 2018 and the total clearing cost was ZAR 876,542.56 (Table 3.2, site 2).. The dominant species varied per treatment stage in this Nbal. The dominant species on initial treatment was *A. mearnsii;* on the first follow-up treatment it was *A. melanoxylon;* and *R. cuneifolius* on the second and third follow-up treatments. The other species which were treated at different clearing stages were *E. saligna, Canna indica* L. (Cannaceae), *Cortaderia selloana* Schult. & Schult. F (Poaceae), *Lilium formosanum* E.H. Wilson (Liliaceae). Treament in this regard refers to the removal of invasive alien plants through mechanical, chemical, bioliogical and intergreated clearing method with the aim of restoring invaded area to under control or its original states.

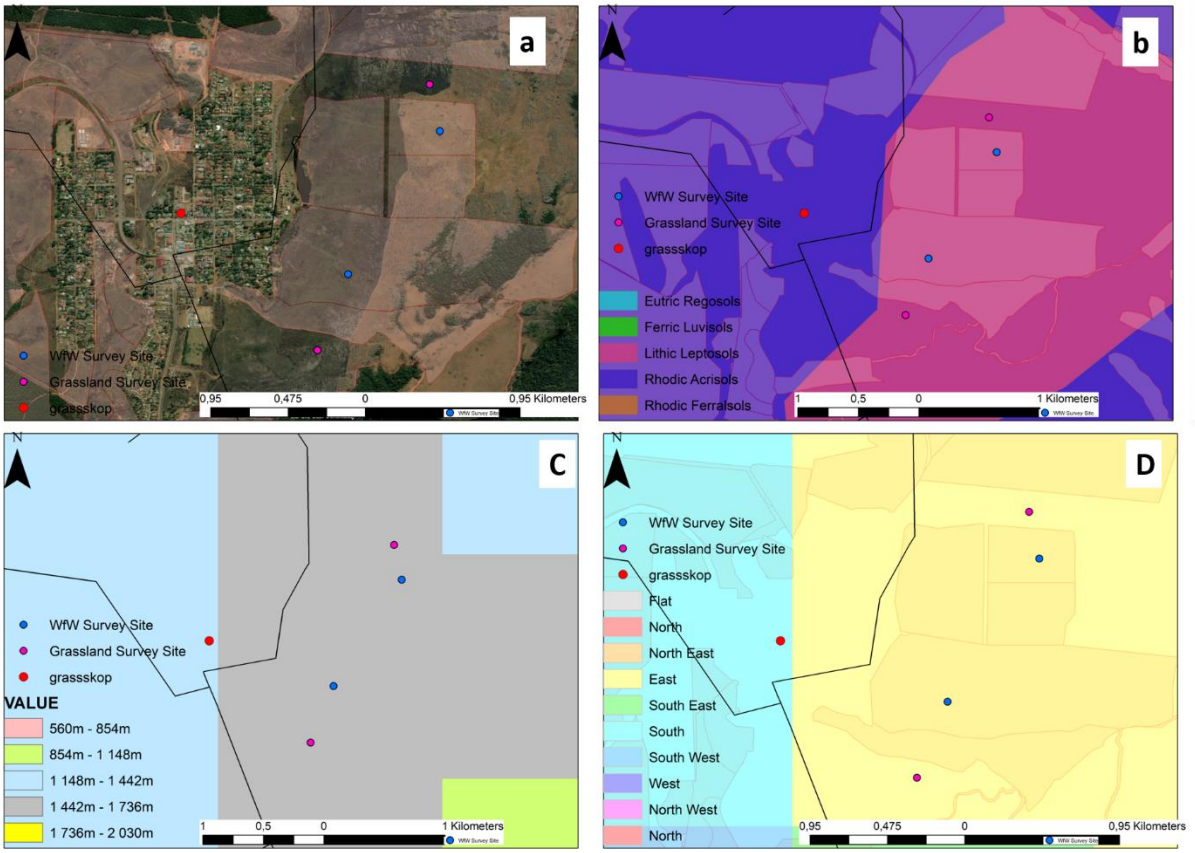

Figure 3.4: Graskop (a) sampled sites inside and outside WfW nbals, (b) soil type, (c) altitude, and (d) aspect. Blue dots represent cleared plots (treatment) and pink dots are the paired veldt controls.

Table 3.2: Sampled sites where WfW have conducted clearing work between 2002 and 2018. Treatment refers to the number of clearing of IAPs by WfW team per site or mapped polygon.

Site 1: Graskop (87.45 ha)			
Date	Treatment	Dominant species	Cost (Rands)
2013	1	*Acacia melanoxylon*	92537,41
		Total	**92537,41**

Site 2: Graskop (355.53 ha)			
Date	Treatment	Dominant species	Cost (Rands)
2013	1	*Acacia mearnsii*	143895,63
2015	2	*Acacia melanoxylon*	226354
2016	3	*Rubus cuneifolius*	224776
2018	4	*Rubus cuneifolius*	281516,9
		Total	**876542,56**

Site 3: Robbers Pass (54.81 ha)			
Date	Treatment	Dominant species	Cost (Rands)
2002	1	*Acacia melanoxylon*	8146,59
2002	2	*Acacia mearnsii*	14522,24
2006	3	*Acacia mearnsii*	46,39
2014	4	*Acacia melanoxylon*	22037,65
2017	5	*Acacia melanoxylon*	31440,06
		Total	**76 194,92**

Site 4: Pilgrim's Rest (325.04 ha)			
Date	Treatment	Dominant species	Cost (Rands)
1995		*Eucalyptus grandis*	NA
2002	1	*Acacia mearnsii*	22545,76
2003	2	*Acacia mearnsii*	35603,37
2003	3	*Acacia mearnsii*	25361,87
2004	4	*Acacia mearnsii*	21912,53
2009	5	*Solanum mauritianum*	28872,62
2013	6	*Rubus cuneifolius*	61949,25
2015	7	*Acacia melanoxylon*	238982,57
2016	8	*Acacia mearnsii*	147749,73
		Total	**582977,70**

Site 5: Blyde River Catchment (3.15 ha)			
Date	Treatment	Dominant species	Cost (Rands)
2006	1	*Acacia mearnsii*	1734,89
		Total	**1734,89**

3.2.3.2 Robbers Pass (B60F100066)

The Robbers Pass site was located along the R33 road between the town of Ohrigstad and Pilgrim's Rest (24.873232°S-30.694438°E). The site was located at an elevation ranging from 1,736 to 2,030 masl. The sites were dominated by Grassland vegetation with patches of forest and the dominant soil was Rhodic Acrisols (Figure 3.5). According WIMS the WfW programme conducted one initial and three follow-up treatments at this Nbal between 2002 and 2017. The dominant species on initial treatment was *A. melanoxylon* whilst on the first and second follow-up treatments it was *A. mearnsii,* and again *A. melanoxylon* on third and fourth follow-up treatments. The other species which were treated at different clearing stages were *A. melanoxylon, P. patula, S. mauritianum,* and *Eucalyptus spp*. The total clearing cost at this Nbal was ZAR 76,194.92 (Table 3.2, site 3).

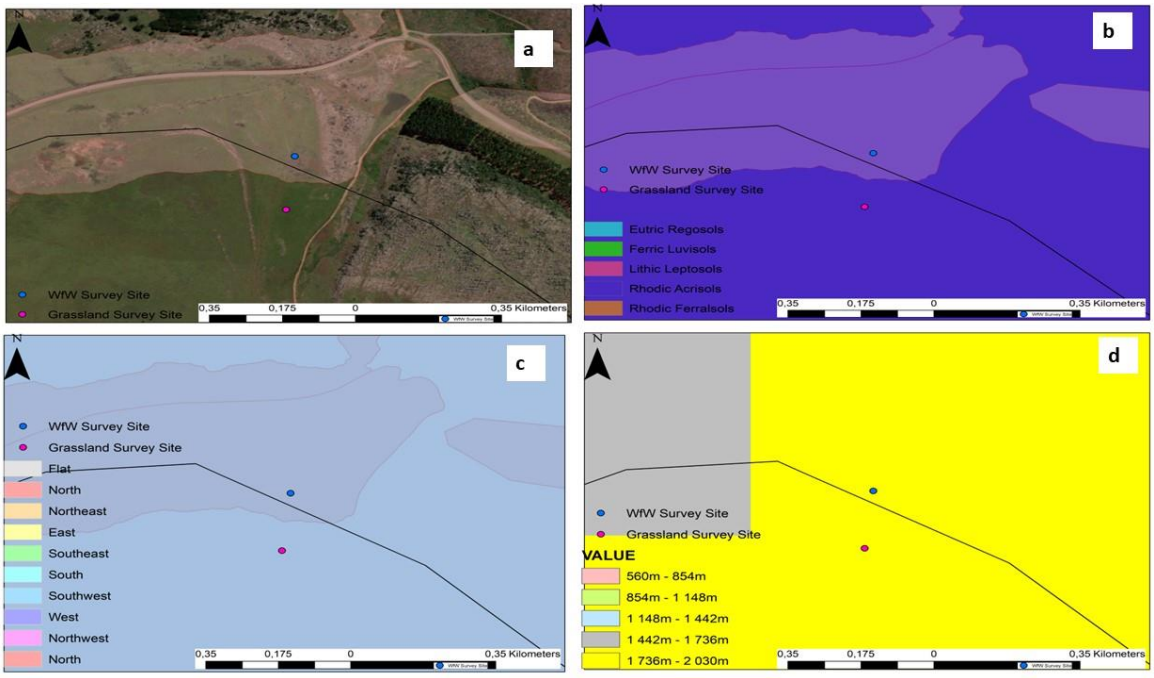

Figure 3.5: Robbers Pass (a) sampled sites inside and outside WfW nbals, (b) soil type, (c) altitude, and (d) aspect. Blue dots represent cleared plots (treatment) and pink dots are the paired veldt controls.

3.2.3.3 Pilgrim's Rest site (B60F100180)

The Pilgrim's Rest site was located on the outskirts of Pilgrim's Rest town, near the Pilgrim's Rest Golf Club (24.8886201°S-30.743250°E). The sites were located at an elevation ranging from 1,148 to 1,442 masl. The sites were dominated by Grassland vegetation and the dominant soil was Rhodic Acrisols (Figure 3.6). According to Mugane (2021) this was one of the first sites cleared of *E. grandis* by WfW in 1995 (Table 3.2 site 4). Since initial clearing the WfW programme has conducted a "new" initial clearing and seven follow-up treatments at this nbal between 2002 and 2016. The dominant species on initial, first follow-up, second follow-up and third follow-up treatments was *A. mearnsii;* on the fourth follow-up treatment it was *S. mauritianum; R. cuneifolius* on the fifth follow-up treatment; *A. melanoxylon* on the sixth treatment; and again *A. mearnsii* on the seventh treatment. The total clearing cost was ZAR 582,977.70 at this Nbal.

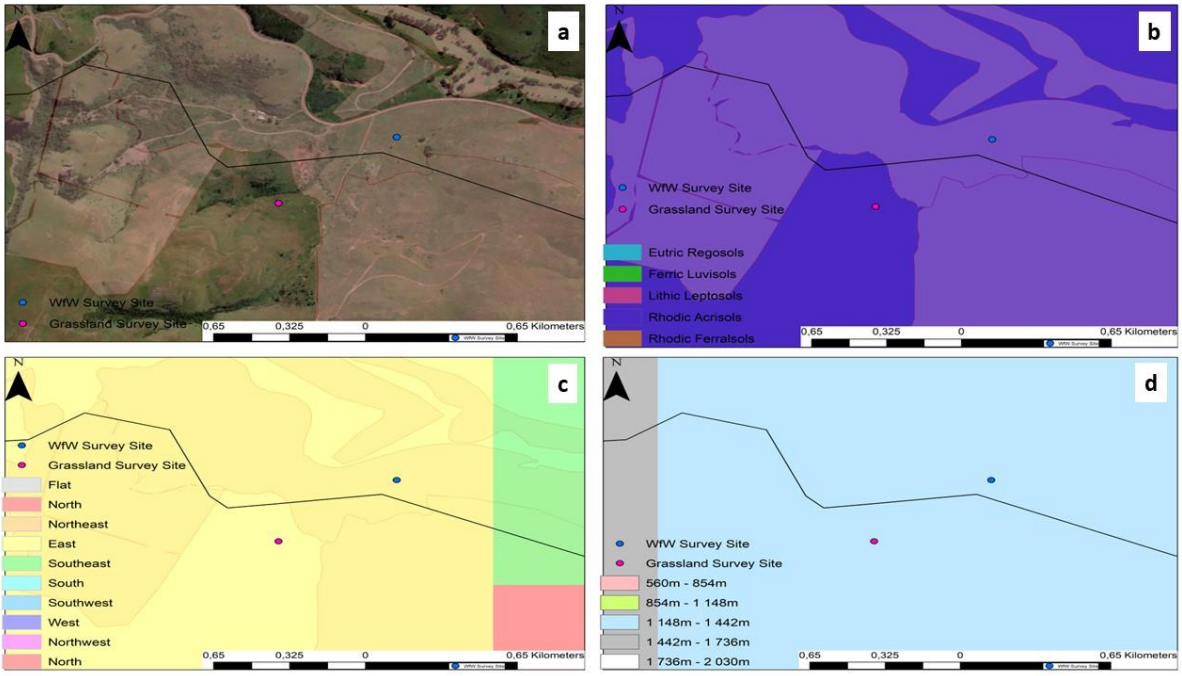

Figure 3.6: Pilgrim's Rest (a) sampled sites inside and outside WfW nbals, (b) soil type, (c) altitude, and (d) aspect. Blue dots represent cleared plots (treatment) and pink dots are the paired veldt controls.

3.2.3.4 Blyde river catchment B60B102383

The Blyde River catchment site was located on the western side of the Blyde River along the Vaalhoek road in the northern Drakensberg (24.826949°S-30.764385°E). The sites were located at an elevation ranging from 1,148 to 1,442 m asl. The sites were dominated by Grassland and the dominant soil was Lithic leptosols (Figure 3.7). Working for Water conducted one initial treatment at this Nbal in 2013 and there were no further records of follow-up treatments according to the WIMS database. The dominant species was *A. mearnsii* and the other species were *S. mauritianum, R. cuneifolius, and E. saligna* (Table 3.2 site 5). The overall clearing cost was ZAR 1,734.89 according to the WfW WIMS database.

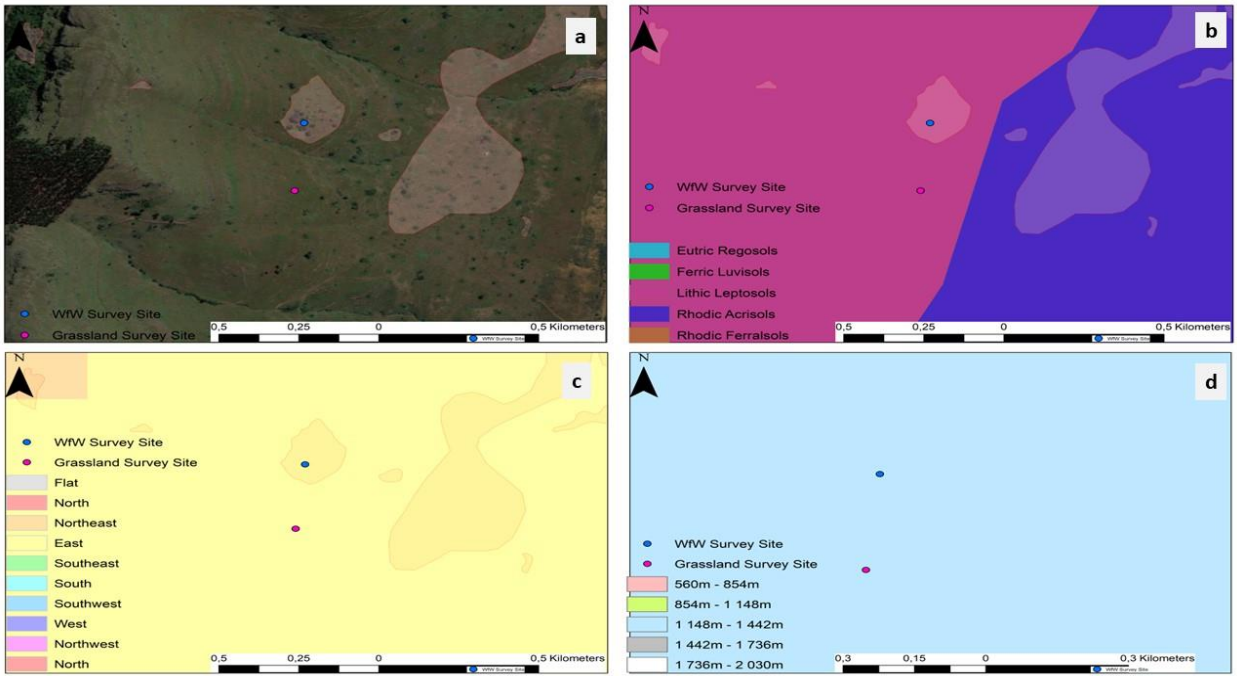

Figure 3.7: Blyde River Catchment (a) sampled sites inside and outside WfW nbals, (b) soil type, (c) altitude, and (d) aspect. Blue dots represent cleared plots (treatment) and pink dots are the paired veld controls.

3.2.4 Vegetation community assembly

Surveys to determine vegetation composition were conducted between 31 January and 07 April 2022. This period coincides with the flowering stage for most of the plants, making identification easier. A belt transect method, where sampling was done at 4 m intervals over a 50m transect was used to estimate vegetation composition and cover. At each 4 m interval, a 1

m×1 m quadrat was placed on the ground (total of 11 quadrats per transect) and percentage cover of the different vegetation forms (each species) was estimated. The transects were replicated thrice in both cleared plots and uninvaded open veld with a distance of 50 m between the transects. Thus, a total of 30 transects were sampled at the 5 sites (Figure 3.8). Plant species were collected on the first encounter and pressed for identification and storage. All specimens were taken to the University of Free State's Qwaqwa Herbarium where they were identified by Botanists using reference specimens and the vegetation of Southern Africa handbook (Werger, 1998). Furthermore, Prof V R Clark, head of Afromontane Research Unity in the Unversity of Free State was consulted to confirm identification as well as identify unknown speciemens (Appendix 6). Unfortunately because of a high number of species in the region, and lack of available taxanomic experts, a number of species remained unidentified. The specimens are stored at the same facility. Some limitations were encoutered during the survey and this include number of treatments conducted by WfW and clearing costs varied significantly between sites making it difficult to make comparisons between sites. In addition, the dominant initial invasive species varied per Nbal. The density and abundance of woody invasive species which had originally invaded the sites, and when they were initially cleared, was also challenging to determine making comparisons difficult. Finally no invaded controls we availible, it is assumed based on many other studies that the invasion pre-release would have been dense monocultures with low species diversity associated

Figure 3.8: Pictures taken during vegetation surveys along the Eastern Eascarpment during this study.

3.3 Data Analysis

Data analysis was carried out in STATISTICA, version 13.2 (Statsoft Inc., Tulsa, Oklahoma) and R software version 4.2.1 (R Development Core Team 2022). Vegetation data from areas cleared under the WfW programme and adjacent natural grassland (referred to as Open Veld) were first tested for sampling saturation using the '*accumcomp*' function of the '*vegan*' package in R at 95% confidence interval. Since the species accumulation curves reached asymptotes, further analyses were conducted (Figure 3.9). Shannon-Weiner (H') diversity indices were then computed for each plot across all sites, checked for normality using the Shapiro-Wilk test and subjected to two-way analysis of variance (ANOVA) with Shannon-Weiner index as the response variable. Statistically different groups were separated using the Tukey-Kramer post-hoc test. Non-metric multidimensional scaling (NMDS), an indirect gradient analysis approach which produces an ordination based on a distance or dissimilarity matrix, was used to visualize vegetation dissimilarity between cleared plots and open veld in a 2-dimensional space. The NMDS was performed in R using the '*vegan*' package and the Bray-Curtis dissimilarity was applied to compute distances between the two vegetation communities for each site (Oksanen *et al*., 2019). Since the NMDS does not quantify the variation between communities, permutational multivariate analysis of variance (PERMANOVA) was then used to test for differences in vegetation community composition between the cleared plots and adjacent open veld. Furthermore, the contribution of individual species to dissimilarity between plots were calculated using similarity percentages (SIMPER). Finally, to test for variation in species composition between the paired plots, the data were tested for the assumption of homogeneity of multivariate dispersion (Anderson, 2006). All analyses were carried out per site due to variability in elevation, aspect, and soils across the five locations.

3.4 Results

Species accumulation curves showed that at all sites the curve was reaching its asymptote therefore indicating sufficient sampling had been conducted. Potentially further sampling could have been conducted at the second Graskop site (Figure 3.9). The species accumulation curves also clearly indicated far higher species numbers at all sites in the open veld compared to the previously cleared Nbals. This, howoever, was not the case for Graskop 1 but this richness in number of species at this site was primarily due to high numbers of secondary invasive aliens which had colonized the cleared Nbal.

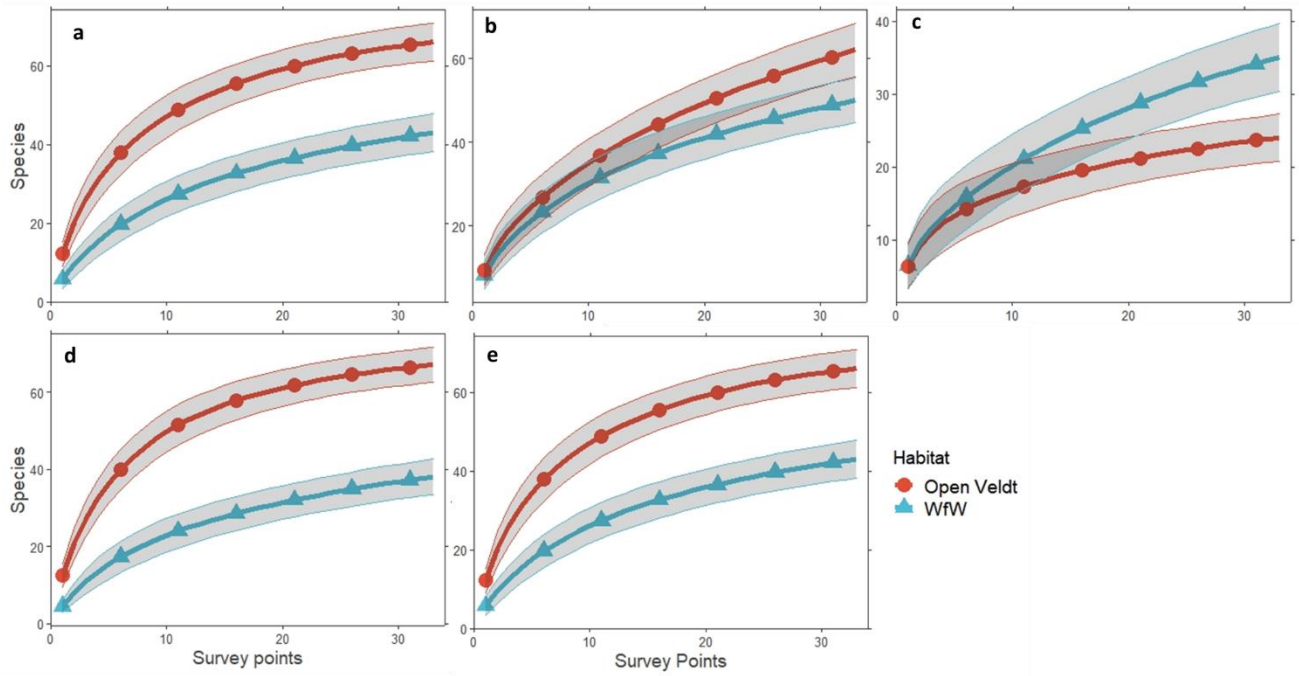

Figure 3.9: Species accumulation curves for Robbers' Pass (a), Graskop 1 (b), Graskop 2 (c), Blyde River Catchment (d) and Pilgrim's Rest (e).

There was at difference in species diversity across habitats and sites, however significant difference was in Robbers Pass and Blyde River Catchment sites (Figure 3.10). Generally, cleared sites had lower diversity as compared to natural veld. Results showed a significant interaction effect between site and habitat (Table 3.3) and post-hoc test results showed that species diversity was significantly lower in cleared sites at Blyde River Catchment and Robbers Pass. Graskop 2 had significantly lower species diversity, both in natural and cleared habitats.

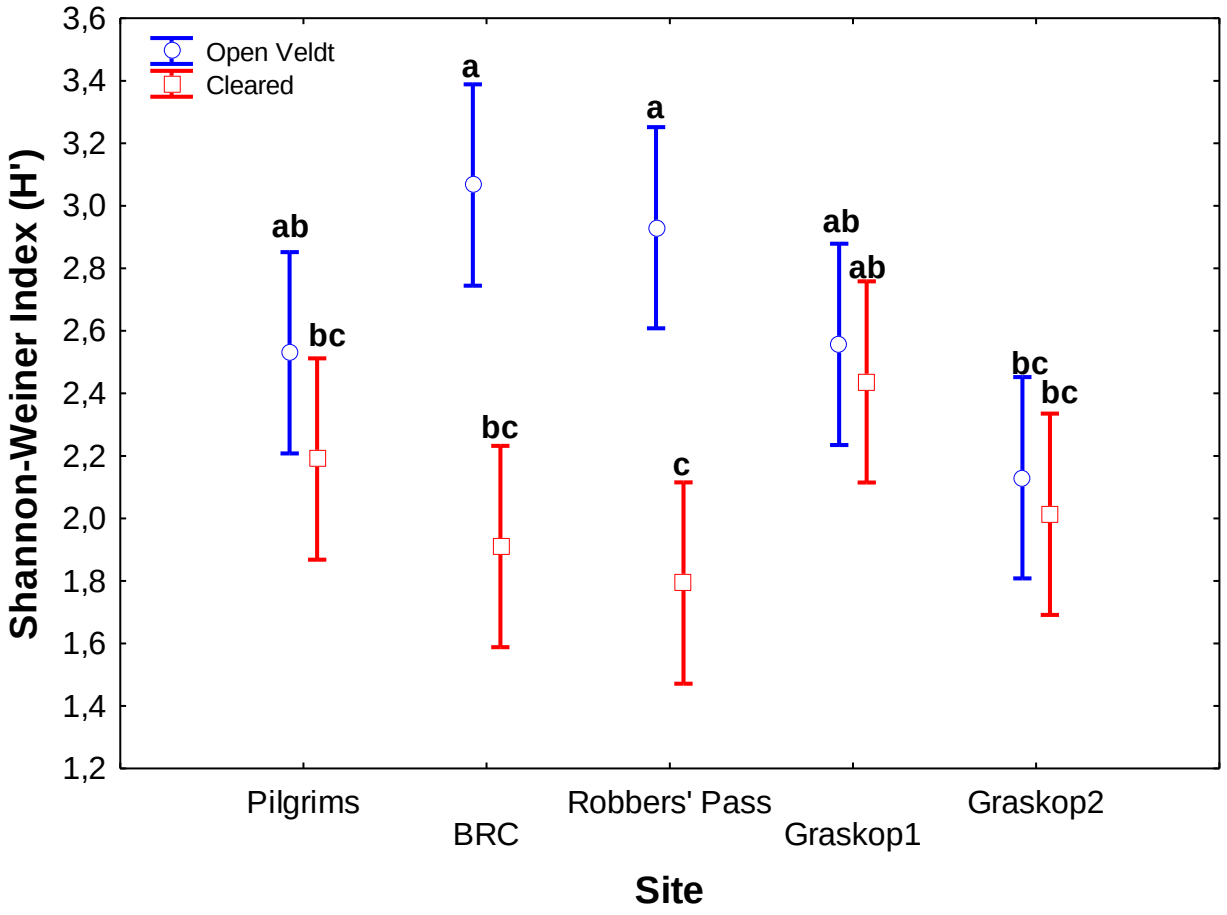

Figure 3.10: Vegetation species diversity indices (Shannon-Weiner; mean ± 95% confidence interval) at cleared and natural grassland. (BRC = Blyde River Catchment).

Table 3.3: Summary of ANOVA for differences in vegetation diversity between treatments and sites

Source	**Sum of Squares**	**DF**	**MS**	**F**	***p***
Intercept	166.4750	1	166.4750	2329.733	*<0.001*
Site	0.7092	4	0.1773	2.481	*0.077*
Habitat	2.4711	1	2.4711	34.581	*<0.001*
Site*Habitat	1.6892	4	0.4223	5.910	*0.003*
Error	1.4291	20	0.0715		

The NMDS plots showed that vegetation community assembly differed between cleared plots and open veld across all sites (Figure 3.11). However, there were more species shared between the two habitats at Blyde River Catchment and Pilgrim's Rest as the plots showed was minimal separation. Although there was a significant habitat effect across all sites ($p<0.005$), the PERMANOVA tests showed that this explained between 11% (Blyde River Catchment) and 34% (Robbers Pass) of variation in vegetation communities observed (Table 8). The SIMPER

analyses further showed that grasses such as *Eragrostis curvula* and *Loudetia simplex* were among those which contributed to more than 50% of community dissimilarities (Table 3.5). However, their occurrence was not associated with habitat as their abundances in both cleared and open veld varied with sites. The native species composition across the sites were mainly grasses, herbaceous plants, shrubs, sedges, ferns, forbs, and woody plants whilst IAPs composed mainly of *A. mearnsii* across all sites (Table 3.6).

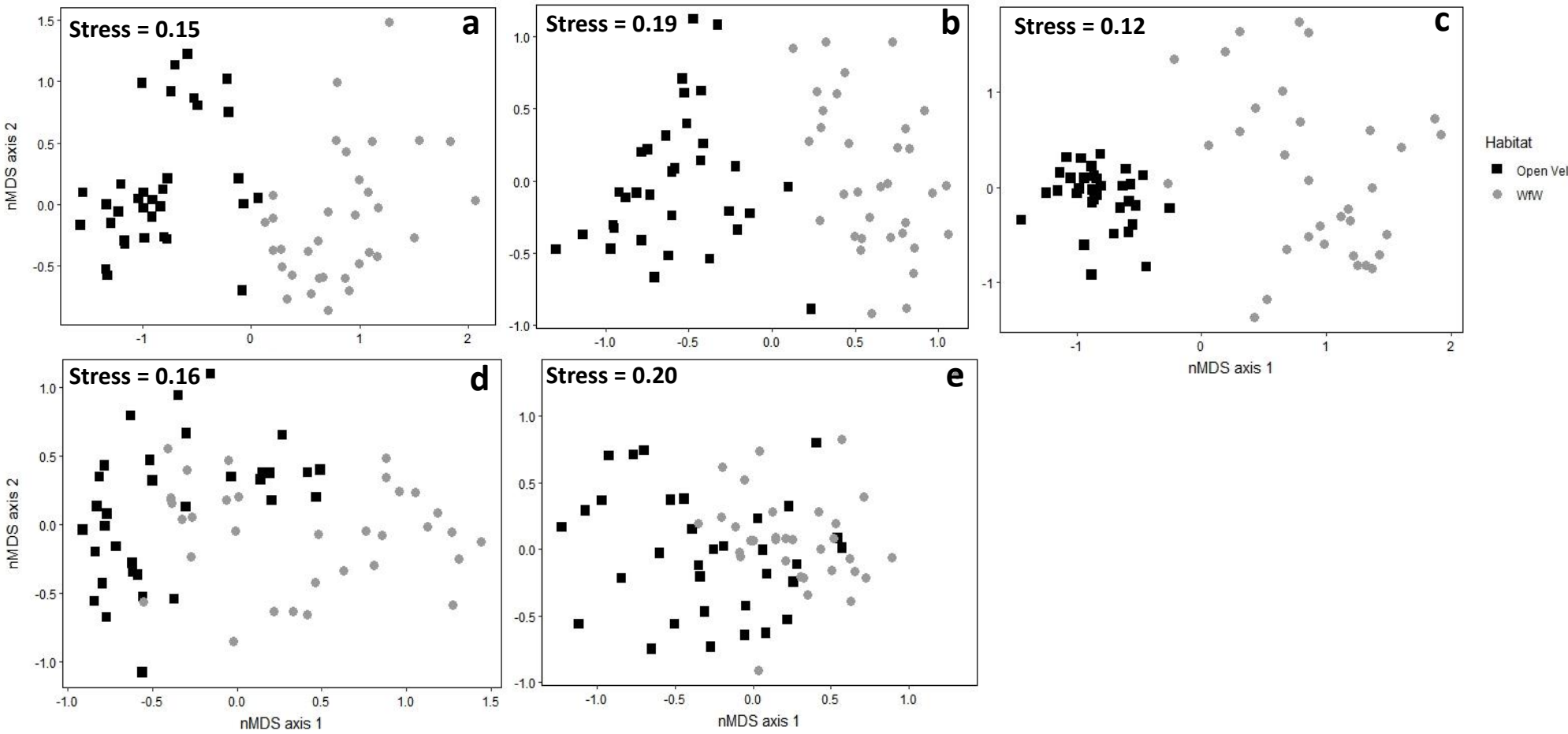

Figure 3.11: Two-dimensional nonmetric multidimensional scaling (NMDS) plots for vegetation species composition in cleared plots and adjacent natural vegetation based on Bray-Curtis distance for Robbers Pass (a), Graskop 1 (b), Graskop 2 (c), Blyde River Catchment (d) and Pilgrim's Rest (e).

Table 3.4: Summary of permutational multivariate analysis of variance (PERMANOVA) results for vegetation dissimilarities between cleared plots and open veld. Bold p-values indicate significant differences.

Site	**Source**	**DF**	**SS**	**R^2**	**F**	***p-value*(>F)**
Robbers Pass	Habitat	1	7.26	0.34	32.96	**0.001**
	Residual	64	14.1	0.66		
	Total	65	21.36	1		
Graskop 1	Habitat	1	5.45	0.25	21.84	**0.001**
	Residual	64	15.97	0.75		
	Total	65	21.42	1		
Graskop 2	Habitat	1	2.38	0.16	12.61	**0.001**
	Residual	64	12.07	0.84		
	Total	65	12.45	1		
Pilgrim's Rest	Habitat	1	1.28	0.17	7.23	**0.001**
	Residual	35	6.21	0.83		
	Total	36	7.49	1		
Blyde River Catchment	Habitat	1	1.06	0.11	4.35	**0.002**
	Residual	35	8.57	0.89		
	Total	36	9.63	1		

Table 3.5: Vegetation species contributing more than 50% dissimilarities per site. Bold p-values indicate significant differences in species abundances between plots.

Site	Species	Average	SD	Ratio	Average WfW	Average OV	Cumulative Sum	*p-value*
Robbers Pass	*Cyperus ficinia*	0.20	0.11	1.81	0.00	28.42	0.21	**0.001**
	Eragrostis curvula	0.17	0.11	1.48	27.94	2.00	0.35	**0.001**
	Trachypogon spicatus	0.08	0.08	0.96	5.94	11.61	0.48	**0.028**
	Cenchrus clandestinus	0.04	0.11	0.38	7.03	0.00	0.53	1.000
	Small Eragrostis	0.04	0.05	0.77	2.70	4.70	0.57	**0.001**
Graskop 1	*Restio* spp	0.12	0.09	1.25	6.00	24.15	0.13	**0.001**
	Loudetia simplex	0.11	0.09	1.22	20.24	0.00	0.25	**0.001**
	Grass K	0.06	0.08	0.77	4.24	10.52	0.32	**0.045**
	Loudetia spp	0.06	0.09	0.72	0.00	11.97	0.39	**0.001**
	Rhynchospora brownii	0.06	0.06	0.97	7.55	8.88	0.46	0.901
	Aureo nitens	0.06	0.07	0.83	11.06	0.15	0.52	**0.001**
Graskop 2	*Loudetia* spp	0.14	0.13	1.14	6.67	26.30	0.21	**0.001**
	Sedge 14	0.10	0.09	1.12	14.15	11.58	0.35	0.416
	Grass K	0.09	0.06	1.52	16.42	10.61	0.48	**0.004**
	Grass U	0.08	0.05	1.65	16.70	10.15	0.60	**0.001**
	Grass R	0.06	0.04	1.45	6.61	10.61	0.69	**0.002**
	Forb	0.05	0.04	1.06	8.30	1.18	0.75	**0.001**
Pilgrim's Rest	*Eragrostis curvula*	0.12	0.09	1.37	19.85	33.24	0.18	**0.001**
	Eragrostis racemosa	0.09	0.08	1.12	16.21	11.85	0.32	0.365
	Paspalum notatum	0.05	0.08	0.66	1.30	8.45	0.40	**0.001**
	Loudetia simplex	0.05	0.06	0.92	3.09	8.03	0.48	**0.018**
	Lippia species	0.03	0.05	0.60	5.30	0.00	0.53	**0.001**
	Forb A	0.02	0.02	1.00	3.79	0.15	0.57	**0.001**
	Oxalis spp	0.02	0.02	0.78	2.94	0.09	0.59	**0.001**
	Pseudogeranium	0.02	0.05	0.36	1.82	0.76	0.62	0.412
	Eragrostis capensis	0.02	0.05	0.33	2.58	0.00	0.64	0.073

	Polygala	0.02	0.05	0.30	1.33	1.36	0.66	0.671
	Tristachya leucothrix	0.01	0.02	0.61	1.18	1.52	0.69	0.423
	Indigofera	0.01	0.01	1.12	1.12	2.12	0.70	**0.019**
	Shrub A	0.01	0.03	0.34	0.61	1.09	0.72	0.467
	Aster 6	0.01	0.02	0.43	1.15	0.45	0.73	0.113
	Sedge 2	0.01	0.02	0.38	0.91	0.76	0.75	**0.007**
Blyde River Catchment	*Eragrostis curvula*	0.16	0.20	0.81	0.00	24.55	0.16	**0.028**
	Loudetia simplex	0.15	0.09	1.63	18.09	2.09	0.31	**0.001**
	Monocymbium ceresiiforme	0.06	0.06	0.88	6.94	0.00	0.37	**0.001**
	Culpurnia aurea	0.03	0.08	0.44	0.06	5.03	0.41	0.999
	Themeda triandra	0.03	0.06	0.53	2.30	2.58	0.44	0.938
	Cyperus finicia	0.03	0.04	0.65	3.42	0.00	0.47	**0.001**
	Acalypha glabrata	0.03	0.03	0.88	3.12	0.00	0.49	**0.001**
	Bidens pilosa	0.03	0.05	0.50	0.00	3.24	0.52	0.909

Table 3.6: IAPs composition across sites along the northern Drakensberg escarpment.

Site	Area (Ha)	Initial Target (Species)	Number of Target Species	Year	Follow-up Treatments	Mean H'	Total cost (ZAR)
Pilgrim's Rest	325.04	*Acacia mearnsii*	4	2002	7	2.19	582977.7
Blyde River Catchment	3.15	*Acacia mearnsii*	1	2006	0	1.91	1734.89
Robbers' Pass	54.81	*Acacia melanoxylon*	2	2002	4	1.79	76194.92
Graskop 1	87.45	*Acacia mearnsii*	1	2013	0	2.44	92537.41
Graskop 2	355.53	*Acacia mearnsii*	3	2013	3	2.01	876542.56

3.5 Discussion

This study conducted vegetation surveys at five sites, each site included a cleared WfW Nbal and a unmanaged open veld control along the eastern edge of the Drakensberg mountains in Mpumalanga Province. Two of those sites were located in the Graskop conservancy, and one at each of Robbers Pass outside Pilgrim's Rest, Blyde River Catchment, and on the outskirts of Pilgrim's Rest town. The number of treatments conducted by WfW and clearing costs varied significantly between sites making it difficult to make comparisons between sites. In addition, the dominant initial invasive species varied per Nbal.. The study plots included sites that were invaded by *Acacia* spp., *Eucalyptus* spp.and *Pinus* spp. only because there were the only species which had been identified during vegetation survey whilst species such as *Lantana* spp., *Populus* spp., *Solunum* spp., and others were not included as there were seen during the survey. The limitations of the study was that the invaded sites were not sampled because of there were no invaded uncelared sites in the study area as the sites have been cleared before since the inception of the WfW programme.

In general, there were less species recorded in previously invaded sites and plant communities differed significantly between previously invaded areas and uninvaded open veld sites. This study is among the few dedicated to the assessment of the ecosystem recovery goal of the WfW programme, particularly in terrestrial ecosystems. Several studies have outlined challenges of ecosystem recovery following the removal of IAPs. For instance, Ruwanza (2001) assessed passive ecosystem restoration following *E. grandis* removal in South Africa and found ecosystems rarely recover to their original state following IAP removal. Recovery is affected by several interacting factors, which are linked to invasion history and intensity, the lack of native species in the soil-stored seed bank, and dry summer conditions hampering seedling establishment and recovery on sites cleared of dense stands of alien trees. For example a recent study by Galloway *et al*. (2017) showed that areas under 30-year old pine plantations had high native species and growth form density (number of species/growth forms per unit area) and similar plant density (number of individuals per unit area) to reference fynbos areas. While areas under 50-year old pine plantations had significantly lower native species, growth form density, and plant density, than reference fynbos sites and were dominated by alien species. In comparison, Morris *et al*. (2008), who investigated the response of riparian community structure to clearing of IAPs in the Kruger National Park, found that the density of IAPs were

significantly reduced relative to before clearing and the overall densities of indigenous species increased after clearing, which was consistent with the finding of this study.

Unfortunately, it was not within the time frames or scope of this study to determine the structure of invasive species in comparison to native species in the previously cleared Nbals. However, from the number of repeat clearings and observations it was apparent that alien plants are a component of both the previously cleared sites and the control veld, although to a lesser extent. In two sites, Robbers Pass and Blyde river catchment, the initially cleared dominant invasive was still present in the Nbal. Other studies have also indicated that only 7% of closed-stands in riparian invasion have been cleared since 1995, further indicating the difficulty in the eradication of invasive alien species (Marais and Wannenburgh, 2008). This outcome has financial implications on the programme as repeated treatments over the same area significantly increases the cost of the interventions. It is worth noting that the financial expenditure was not factored into the study despite being mentioned, and might make for an interesting analysis.

Although the cleared study sites evaluated were heterogenous, they were different to the natural veld indicating a change in community composition and therefore a potential loss of biodiversity and change in ecosystem functioning. Conservation of mountains is key to successful biodiversity conservation (Noroozi *et al*., 2018; Callisto *et al*., 2019). The Limpopo–Mpumalanga–Eswatini Escarpment (LMEE) where our study site lies, has recently been shown to contain has 496 endemic plant taxa, of the 4,657 other taxa associated with the area (Clark *et al*., 2022). The endemis plant taxa in the Drakensberg Mountain Centre (DMC) is higher and presumable the richest concetration of montane in southern Africa apart from the Core Greater Cape Floristic Region (2020). Interestingly, most of the endemics identified by Clark *et al.* (2022) of conservation concern occurred in Grassland (68,4%). Unfortunately only 10,4% of the LMEE is under formal conservation. This highlights the plight of the remaining grassland fragments and the importance of management (i.e. removal of invasive species). Even with management, however, it seems species recovery has been slow and not returning to unmanaged levels. It was not within the scope of this study to identify key species or species listed as threatened in and outside of the cleared Nbals. However while conducting the surveys, it was noticeable that some less common species such as many of the grassland orchids were less frequent in the cleared sites. This is concerning as this suggests the changed habitat may

be experiencing unrepairable damage to the plant diversity within the region and precious endemic species are potentially being driven to extinction.

The results of this study therefore suggest that the presence of IAPs is transforming grassland vegetation, probably through alteration of micro-climatics and notable the degree of recovery after clearing found to be at a very low pace and could be as a result of disturbance of ecological process by IAPs. The transformation of ecosystems is probably mainly because of canopy characteristics which reduce temperature and light availability for understory communities, while creating habitats with novel microclimates in the process (Chikowore *et al*., 2021). Over a long time, this results in local extinctions and a loss of biodiversity. The second most significant change in ecosystem services is a reduction in range condition, and therefore grazing capacity, as the previously invaded sites had reduced grass species and an increased presence of forbs. This was similar to several studies which have also linked the reduction in grazing capacity to IAS invasions locally and globally (Ndhove *et al.*, 2011; Yapi *et al.*, 2019).

van Wilgen *et al*. (2022) suggests that the recovery of biodiversity and ecosystem functioning are important goals for alien plant control, but few studies monitor recovery, especially in montane grasslands. Here we suggest that biodiversity might not naturally return to original levels. Holmes *et al*. (2020), who recently reviewed available information on post management recovery, concluded that ecosystem recovery may require restoration interventions beyond controlling invasions.

Chapter 4: General discussion, recommendations, and conclusions

4.1 Introduction

In recent years, the number of successful biological invasions has continued to rise despite increasing global conservation efforts (Pagad *et al.*, 2015), often resulting in substantial impacts to ecosystems (Vilà *et al.*, 2010, 2011). In 1995, the South African government initiated the Working for Water (WfW) programme, which had three main objectives: (1) remove alien invaders from river courses, grasslands, and indigenous forests; (2) increase biodiversity, and (3) create sustainable jobs. This study aimed to investigate the success of these ambitious objectives in the northern Drakensberg escarpment, Mpumalanga province, South Africa.

The first objective of this study described in Chapter 2 was to determine the socio-economic benefits and effectiveness of WfW programmes as perceived by the communities in the northern Drakensberg escarpment. The main findings of this study showed that both participants (current contractors and workers employed by the WfW programme) and landowners (respondents who have had the WfW programme working on their properties) have a good knowledge of IAPs, related legislations that govern IAPs in South Africa, and the negative impacts of IAPs on biodiversity and livelihoods. Interestingly, a recent study investigating the general public's knowledge of IAPs in Europe, South Africa and South America showed that South Africans had significantly greater knowledge of IAPs and the regulations governing them than the other countries investigated (Gervazoni *et al.*, 2023), which may be a result of the WfW programme. Despite the negative impacts, participants asserted that IAPs still provide certain benefits such as provision of firewood for local communities, building and fencing materials, habitat and nesting for birds, and resources for the production of mats, twine, rope and paper. The study also revealed that employment opportunities created by WfW had significantly contributed to rural communities' livelihoods, but short-term contracts and intermittent funding have significant implications for the communities who rely on these jobs for their livelihood.

The objectives of Chapter 3 were to determine the impact of clearing of IAPs on the plant communities in the northern Drakensberg escarpment. The chapter describes a series of field surveys conducted to determine species abundance and diversity inside and outside WfW Nbals. Vegetation surveys were conducted at sites previously cleared by WfW teams and

adjacent paired sites (uncleared control sites). The surveys showed that there were differences in plant communities between cleared and uncleared plots at four of the five sites surveyed and that the cleared sites had lower plant diversity than adjacent natural veld (uncleared sites). It is concluded that the presence of IAPs lowers biodiversity in the landscape, and clearing of IAPs by WfW has significantly contributed to restoration of native vegetation, but full recovery has not yet been achieved.

4.2 The impacts of intermittent funding on the Working for Water Programme

The dual incentive of job creation within the WfW programme, particularly in rural areas, has been a successful motivation for investment from government's Expanded Public Works Programme (Angelstam *et al.,* 2017) and led to growth in funding (van Wilgen and Wannenburgh, 2016) and therefore the support of increasing numbers of people (Chapter 1). However, the long-term impact of these investments needs to be considered and what occurs when there are delays in contracts or termination of the programme.

The study found that most of the participants appreciate the work opportunities that are being created by the WfW programme as they largely depend on the income earned through the programme (often being the only form of income for entire households). Thus, any complications in processes have significant impacts not just on the individual but on the livelihoods of families and communities. For example, delays in bidding processes and subsequent issuing of order numbers (particularly in 2020-2021, during the time of this study) meant that many participants went for an entire year without funding and therefore they were unable to support their families who rely exclusively on the WfW income. These delays were across the whole of South Africa and not just in the study site. Thus, it is possible that close to 20 000 of the most marginalised of our communities, primarily women, youth and people with disabilities were impacted by the delays.

A second impact of delays in the funding process, also highlighted by the respondents of the questionnaires, was that the delays allowed IAPs to regrow in areas which were supposed to be receiving follow-up clearing. Follow-up clearing is significantly cheaper and easier than initial clearing. However, with the funding delays, WfW Nbals that were supposed to be receiving funding for follow-up had reverted to a scenario closer to initial clearing and thus funding, when provided, was insufficient to conduct proper clearing. In addition, it was noticed

that some species (primarily wattle species) were able to flower and seed during the funding delays, further setting back clearing initiatives.

Finally, the delays in funding resulted in a loss of capacity and equipment. Many programmes rely on the institutional knowledge of contractors to the areas in which they work (for example relationships with landowners and how to access certain regions) (pers obs.). The funding delays meant that some contractors, who were able to, sought other employment opportunities, sometimes leaving with equipment. Replacement of equipment and personnel takes time, training, and money, further delaying clearing operations. This study concluded that there were erratic and interrupted flow of funds which had negatively affected the overall objectives of the WfW. In addition, slow recovery of native vegetation was observed at all sampled sites with remnants of IAPs which may have been followed up if there was a continuous and interrupted flow of funds and proper planning.

These are important findings and warrant further investigation. A few suggestions to improve the study are provided below:

- The study should at the very least be expanded to other areas if not to all biomes or provinces to determine the overall impact on communities benefiting from the programme.
- There are various levels of employment within the WfW programme from monthly contractors to managers who are employed on a full-time basis, therefore it would be important to separate these in the questionnaires and analyses when investigating the contributions of employment to rural communities.
- Better determination of the time spent working in the programme by interviewees is needed as it was difficult to determine from the questionnaires as many respondents could not remember how long they had worked for the programme.
- It was also challenging to determine specifically how the programme had improved living conditions for participants from the questionnaires. Therefore, a quantitative measure of improved livelihood status would have contributed to this study.

Results from this study in addition to similar larger scale studies will ensure that proper management decisions can be made and implemented to ensure continuous improvement of the programme.

4.3 The importance of landowner engagement

South African legislation requires landowners to control listed invasive alien species on their properties under the Conservation of Agricultural Resource Act (1983) and the National Environmental Management Biodiversity Act (2004) (McConnachie *et al*., 2013). This legislation and creation of the national framework for invasive exotic plants through the WfW programme have significantly increased awareness about IAPs in South Africa (Atyosi *et al*., 2019). However, the government realised that landowners were not necessarily responsible for the introduction of the species in the first place, and as a result, the central government sought to address the shortfalls by providing both private and state land owners with clearing assistance in the form of teams of workers who can clear IAPs (van Wilgen *et al*., 2022), and at the same time creating employment opportunities for previously disadvantaged communities, skills development and strengthening support for SMMEs (van Wilgen *et al.*, 2012; van Wilgen *et al*., 2022).

The views of landowners regarding the WfW programme are an important aspect in the implementation of WfW programme as they are one of the primary benefactors of the programme. However, it was difficult to work with landowners as many did not cooperate at all whilst others had to be persuaded to complete the questionnaires. The relationship between landowners and WfW teams is paramount to the success of the programme. This will allow the WfW programme to adjust and develop from feedback. This could work both ways with WfW practitioners being able to provide information to landowners about the legislation governing invasive species, current management best practice and forcible improvement in the implementation of the WfW programme.

Some suggestions to improve interactions with landowners include:

- The study should also be attempted in many other areas where WfW clearing has been implemented and maybe there will be better landowner engagement.
- More quantitative results would have been helpful in placing actual figures to described benefits.
- A system where clearing will only occur if landowners are willing to provide some form of feedback could be implemented by WfW.

4.4 Restoration

Invasive Alien Plants affect the structure and function of ecosystems, while clearing efforts often result in further disturbances depending on the duration and severity of invasion (Holmes *et al.,* 2006; Beater *et al*., 2008). This study revealed that IAPs are transforming grasslands in the northern Drakensberg escarpment, and this comes as no surprise since IAPs are known to have detrimental effects on biodiversity (Wilcove *et al*., 1998; Walker and Steffen, 1999), second only to habitat destruction (Walker and Steffen, 1999; Latimer *et al*., 2004).

The study showed that despite areas being cleared for over ~25 years many important native species have not returned, and the communities remain different. Therefore, it has to be assumed that species recovery in this study area might not occur without some form of additional management. Therefore, restoration actions to accelerate native vegetation recovery and ensure monitoring of the cleared sites could be considered. Restoration has received increasing acknowledgement over the last few years and technology and knowledge are really developing (Esler *et al*., 2008; Homes *et al*., 2020; Froeschlin *et al*., 2022; Lewis *et al*., 2023). However, active restoration is not a common component of the WfW clearing programmes and has never been attempted in the study area. Active restoration should be considered by the WfW Programmes as this could ensure they reach their primary goals of protecting and preserving biodiversity. We believe this might not even have to be part of the WfW programme and could be a partnership with companies or organisations who may already have the infrastructure to do this and who may be willing to contribute. For example, Forestry and large agricultural companies such as ZZ2 who are both working in the regions and doing aspects of grassland conservation, could partner with WfW programmes to contribute to the goals of WfW.

4.5 Habitat destruction in the Northern Drakensberg escarpment

IAPs still threaten the remaining grassland habitats in the northern Drakensberg escarpment. However, it is clear that invasive species invading the grassland remnants is a minor threat compared to the large-scale habitat destruction from commercial forestry and mining occurring in the region. Habitat destruction is regarded as the main threat to biodiversity (Sala *et al*., 2000) and causes massive and rapid losses of community structure and biodiversity (Charles and Dukes, 2007; Kehoe *et al*., 2020; Zina *et al*., 2020; Farahat *et al*., 2021). This is supported by Clark *et al*. (2022), who recently suggested that the conversion of mesic montane grassland

to commercial forestry is one of the main conservation concerns in the Eastern Great Escarpment.

Current land use in the study area has led to significant habitat transformation and effective reduction in grasslands. The dominant species being planted are *Pinus* species which are known to impact water availability, ecosystem functioning, and fire hazards (van Wilgen *et al*., 2022) and have long term impacts on the environment even once removed (Figure 4.1).

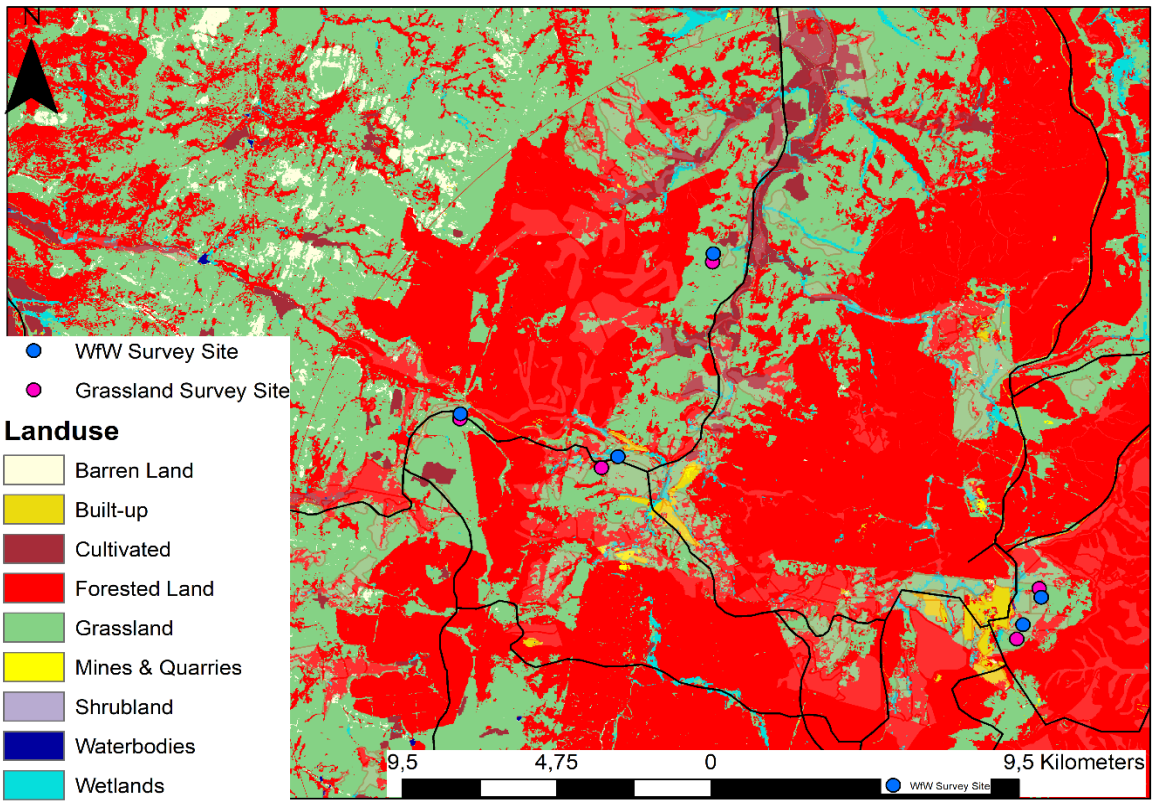

Figure 4.1: Land use in the study area clearly shows significant habitat destruction in the region (Red denotes forestry; Yellow denotes mines and Quarries).

Mining in Mpumalanga accounts for 83% of South Africa's coal production. The impacts of mining are not only limited to the direct degradation of the mining area but also the resulting air, soil, and water pollution, all of which can be catastrophic for biodiversity conservation. There are 239 operating mines and 788 derelict and ownerless mines in Mpumalanga. In addition, 76% of Mpumalanga's grasslands have been "targeted" by mining and prospecting applications (Zhuwakinyu, 2016). For example, in the study region, two opencast mines have been proposed, to be located directly adjacent to the Blyde River. The first would measure ca. 3.5 x 1.2 km and the second ca. 2.0 x 0.7 km, both on very steep mountain slopes surrounding the town of Pilgrim's Rest (Batho Earth and SED SEIA, 2020). Mines are poorly regulated in

Mpumalanga and the impacts on the remaining fragments of grassland cannot be underestimated (Zhuwakinyu, 2016).

Therefore, the only way to conserve these remaining grasslands is through conservation efforts. Van Wyk and Smith (2001) accurately highlight that the Grassland Biome has not captured the public and policy imagination for conservation efforts to the same extent as forest, and this has resulted in open habitats in the Limpopo-Mpumalanga-Eswatini Escarpment receiving little to no conservation efforts. We argue that the conservation of the Grassland Biome in the escarpment should be given high priority to ensure effective conservation as it has been noted that many state-owned conservation areas are not receiving appropriate conservation management. Therefore, the remaining Grassland should be the primary focus of protection and conservation to prevent total loss of endemic plant species.

4.5 Recommendations

Funding for research

Given that this study is one of only a few directly-funded Department of Forestry, Fisheries and the Environment's WfW projects (MSc funded student), it is recommended that this should be a larger component of the WfW programme as the results will assist with the improvements in the implementation of the WfW programme and also provide valuable long-term capacity. If similar studies are funded, it would be beneficial to consider other regions of South Africa where the WfW programme has been implemented as it provides valuable baseline data about program the programme in the region but also educates the researcher and interviewed contractors about alien plant invasions, management and the impacts of the WfW programme.

To this regard, even if further students are not funded, quantitative, long-term, post management evaluations and assessments of cleared sites should be done, across all regions where clearing programmes are being implemented to effectively determine the impact of IAP clearing on native vegetation. Based on these results, WfW should develop long-term clearing management plans with clear and realistic goals for all priority areas, and progress towards those goals should be routinely monitored to ensure continued improvement. It is recommended that the WfW programme should contribute to research focussed on the perceived socio-economic benefits of the programme to try and make it as impactful and sustainable as possible.

Additional training

From personal observation, field work, as well as responses from questionnaires, there is a need for more targeted training for field operators regarding identification of invasive species, estimating densities and adapting management strategies being implemented to ensure that they are working optimally in each scenario. For example, during a discussion with an experienced WfW Project Coordinator who has been with the WfW programme since 1995, he highlighted that training on determining density and species identifications used to be conducted on a regular basis within the WfW programme. The Project Coordinator further stated that he had been trained in conducting quadrat surveys of IAPs to accurately determine species composition and density in targeted clearing areas and thus could accurately determine the amount of resources needed in areas for management. However, this is no longer applied as WfW induction, and Plant identification, Health and Safety, First aid, Herbicide applications, and compulsory pre-medical examinations are the main areas that require further training. A second example, when visiting a site of *Rubus cuneifolius* Pursh (Rosaceae) that was recorded as recently cleared near the town of Graskop, it was revealed that the supposed cleared stands were unmanaged as a result of incorrect herbicide dosage or negligence from the contractor. These inconsistencies in the implementation of clearing plans, lack of post clearing maintenance by contractors and landowners, and lack of monitoring and clearing assessment by WfW, allows IAPs to regrow and end up costing the WfW programme not only financially but also in reputation.

Advertisement

We believe positive advertising of success stories should be conducted. Failures of clearing programmes are often reported, however, here we showed a number of cleared Nbals remaining clear of dominant invasive species. These data should be published and advertised. Signage could be implemented where there has been successful clearing near popular travel routes to promote WfW public perceptions. For example, one of the sites from this study was in the Graskop Conservancy which receives high tourist numbers and many local residents walk in the conservancy daily. This conservancy used to be dominated by invasive Acacias, however, now a large percentage is free of woody invasive species and is a beautiful mountain grassland. A sign board highlighting the WfW success and the involvement of the local community to prevent re-invasions at the entrance to the conservancy would contribute significantly to the programme (Figure 4.2). This might in turn promote better landowner/WfW engagement.

Figure 4.2: Mountain grassland from the Graskop conservancy, a previously invaded site at Nbal B60B102957 and B60B102959.

Sustainable jobs

The creation of sustainable job opportunities is one of the objectives of the WfW programme, and the findings of this study indicate that WfW has not succeeded in creating sustainable work opportunities due to short-term contracts and intermittent funding which have significant implications for the communities who rely on WfW for their livelihood. This study recommends that quantitative, long-term evaluations and assessments of the impacts of the funding models on communities be undertaken to address inefficiencies in the WfW programme. If sustainable funding is available, WfW should prioritise long-term contracts to ensure stability within the WfW operations, and ensure that available funds should be used economically, effectively, and efficiently.

Compliance

Finally, government should ensure that both private and state landowners comply with legislations regarding management and control of IAPs in South Africa, provide necessary support in terms of clearing assistance, and ensure more effective and frequent follow-up clearing to control alien plant regeneration. This should include the integration of biological control methods into chemical and mechanical control methods as well as active restoration after clearing to ensure full restoration of sites.

4.8 Conclusions

This study is one the few studies which have investigated the impact of the WfW clearing programme on rural communities over the last 20 years. The results of the study concluded that WfW has been highly beneficial for providing employment opportunities and practical skills to the unemployed communities, however, those work opportunities were mainly short-term employment and were inconsistent with the notion of the 'creation of sustainable work opportunities' objective as the WfW programme remained the only employment for many participants.

This study concludes that the process of appointing service providers (contractors) and subsequent issuing of official order numbers for contractors to commence work sometimes takes a long time and there is limited communication during this period. This has a negative impact on the communities who rely on WfW funding for their livelihoods, and their perceptions of the programme. The study further concludes that clearing assistance by WfW programme has contributed significantly to the restoration of habitat and sites in the landscape and in most scenarios many of the dominant invasive species which were cleared have not returned.

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Appendices

Appendix 1: Categories 1a, 1b, 2 and 3 listed Invasive Species, in terms of which certain restricted activities are prohibited in terms of section 71A (1); exempted in terms of section 71(3); required a permit in terms of section 71(1) of the NEMBA AIS, 2020.

Restricted Activities as defined in the Act	**Category 1a**	**Category 1b**	**Category 2**	**Category 3**
Importing into the Republic, including introducing from the sea, any specimen of a listed invasive species.	Prohibited	Prohibited	Permit Required	Prohibited
Having in possession or exercising physical control over any specimen of a listed invasive species.	Exempted	Exempted	Permit Required	Exempted
Growing, breeding or in any other way propagating any specimen of a listed invasive species or causing it to multiply.	Prohibited	Prohibited	Permit Required	Prohibited
Conveying, moving or otherwise translocating any specimen of a listed invasive species	Prohibited	Prohibited	Permit Required	Prohibited
Selling or otherwise trading in, buying, receiving, giving, donating or accepting as a gift, or in any way acquiring or	Prohibited	Prohibited	Permit Required	Prohibited

disposing of any specimen of a listed invasive species.				
Restricted Activities as defined in Regulation 6	**Category 1a**	**Category 1b**	**Category 2**	**Category 3**
Spreading or allowing the spread of any specimen of a listed invasive species.	Prohibited	Prohibited	Permit Required	Prohibited
Releasing any specimen of a listed invasive species	Prohibited	Prohibited	Permit Required	Prohibited
The transfer or release of a specimen of a listed invasive fresh-water species from one discrete catchment system in which it occurs, to another discrete catchment system in which it does not occur; or, from within a part of a discrete catchment system where it does occur to another part where it does not occur as a result of a natural or artificial barrier.	Prohibited	Prohibited	Permit Required	Prohibited
Discharging of or disposing into any waterway or the ocean, water from an aquarium, tank or other receptacle that has been used to keep a specimen of an alien or a listed invasive species.	Prohibited	Prohibited	Permit Required	Prohibited

Catch and release of a specimen of a listed invasive fresh-water fish or listed invasive fresh-water invertebrate species.	Prohibited	See Notice 3	See Notice 3	See Notice 3
The introduction of a specimen of an alien or a listed invasive species to off-shore islands	Prohibited	Prohibited	Prohibited	Prohibited
The release of a specimen of a listed invasive fresh-water fish species, or of a listed invasive fresh-water invertebrate species, into a discrete catchment system in which it already occurs.	See Notice 3	See Notice 3	See Notice 3	See Notice 3

Appendix 2 : Landowner and Participants questionnaires. The data is stored online and can be accessed through the following links.

https://docs.google.com/forms/d/1Kzo33QUGI9IZubURkcPsv3Z8S2quQ8TA1ae2cPESNF4/edit?ts=63e1e8b6#responses

https://docs.google.com/forms/d/1c0Y2B5LKo4RXujYPQEoz8Yr_PY7wWBC0Wyo5W2KLHmY/edit?ts=633464f4

Annexure 1: Working for Water participants questionnaire

My name is Nthambeleni Bologo, a postgraduate student at the University of Free State (QwaQwa campus) registered for Master of Science in Botany. I am under the supervision of Dr Sandy-Lynn Steenhuisen (Head and Senior Lecturer: Plant Science, Facility of Agriculture and Natural Science, University of Free State) and Dr Grant Martin (Deputy Director, Centre for Biological control, Department of Zoology and Entomology, Rhodes University. The research is about the impact of the invasive alien plant species clearing programme on socio-economic benefits and plant biodiversity in the northern Drakensberg escarpment, South Africa and seeks to understand the effects of clearing programme on biodiversity, and the socio-economic benefits along the northern Drakensberg escarpment.

Instruction: Please put a tick [√] in the box next to the answer of your choice or write in the space provided as the case may be.

PART A: DEMOGRAPHIC STATUS

1.Gender

Male ☐ Female ☐

2. Marital status

☐ Single ☐ Married ☐ Divorced ☐ Never married

3. Age group

☐ 18-20 ☐ 21-30 ☐ 31-40 ☐ 41-50 ☐ 50 and above

4. Size of Family (Number)_____

5. Employment status (Tick)

Full time Employed ☐ Unemployed ☐ Temporary Employed ☐

6. Household income

☐ R0-R5000.00 ☐ R5001.00-R10 000.00 ☐ R10 001.00- R20 000.00

☐ R20 001.00-R30 000.00 ☐ R30 000.00 and above.

7. Educational qualification

☐ Basic education (Grade 9-7) ☐ High education (Grade 8-12) ☐ Undergraduate

☐ Postgraduate ☐ beyond PG (specify)_____

SECTION B: GENERAL QUESTIONS ON INVASIVE ALIEN PLANTS

8. What is of your level of knowledge on Invasive Alien plants?

Level of knowledge on IAPs	Please tick appropriate box
Poor	
Fair	
Good	
Very Good	
Excellent	

9. What is your level of knowledge of legislations which govern Invasive alien vegetation control and management?

Level of knowledge of legislations which govern Invasive alien vegetation control and management?	Please tick appropriate box
Poor	

Fair	
Good	
Very Good	
Excellent	

10. Are you aware of the impact of Invasive Alien Plants? Please tick appropriate box

Yes		No	

11. Do you think Invasive Alien Plants are major are a major problem in the northern Drakensberg?

a) Yes, it is a major problem	
b) It is not a major problem	
c) It is not a problem	
d) Not sure	

12. "International studies have suggested that Invasive Alien Plants (IAPs) have the following negative impacts on the environment": Please indicate what your sentiments towards the following statements are.

[- SD = Strongly disagree, D = Disagree, N = Neutral, A = Agree & SA = Strongly agree]*

Statement	SD *	D	N	A	SA
a) The IAP alter the fire regime of the natural vegetation (changes the fire season).					
b) The plant harbours vermin (rats, mice, snakes etc).					
c) IAP' reduce native Biodiversity.					

d) IAPS create impenetrable thickets that impede human and animal movement.					
e) IAPs reduces the yields of farming land by encroaching on cultivated land.					
f) IAPs reduces the grazing land available to livestock.					

13. What do you think are the major threats of Invasive Alien Plants within the northern Drakensberg? Please indicate what your sentiments towards the following statements are with regard to the above

[- SD = Strongly disagree, D = Disagree, N = Neutral, A = Agree & SA = Strongly agree]*

Statement	SD*	D	N	A	SA
a) IAPs have a potential to cause damage on infrastructure such as roads, dams					
b) IAPs have a potential to reduce biodiversity (plants and insects).					
c) IAPs have potential to invader river course and catchment areas					
d) IAPs has potential to outcompete native species					
e) The IAPs has potential to reduce grazing area and interfere with grazing activities					
f) IAPs has a potential to reduce land productivity					

Please feel free to make additional comments apart from the above_____

_____

_____

14. IAPs have the following advantages, please indicate what your sentiments towards the following statements are with regard to the above

[- SD = Strongly disagree, D = Disagree, N = Neutral, A = Agree & SA = Strongly agree]*

Statement	SD*	D	N	A	SA
a) IAPs provide firewood to local community					
b) IAPs provide building and fencing material such as timber and poles					
c) IAPs provide habitat and nesting sites for birds					
d) IAPs provide medicine					
e) IAPs can be used for production of mats, twine, rope, cloth, paper and dartboard					

SECTION B: GENERAL QUESTIONS ON WORKING FOR WATER PROGRAMME

15. How are you involved in the Working for Water Programme? Please indicate your involved in the programme

Level of involvement	Please tick appropriate box
a) Project Manager	
b) Biological Control Officer	
c) Implementer/ Service Provider	
d) Supervisor	
e) Herbicide Applicator	
f) SHE rep (Health & Safety/ First Aider)	

g) General Worker	

16. How often do you work in this project?

Period	Please tick appropriate box
a) Every month	
b) Once in three months	
c) Once in six months	
d) Once in a year	
e) Other (not specified above)	

17. Do you think the programme has improved your living conditions? Yes ☐ No ☐, If yes, please indicate what has improved in the table below

Improvement	Please tick in the appropriate box
a) Improved Household income	
b) Improved living condition (access to food, clean water, shelter, electricity, etc.)	
c) Improved Knowledge and skills (trainings)	
d) Improved job prospects (work opportunities)	

18. How do you think the programme has benefited the eastern Escarpment? please indicate below.

Benefits to the Blyde River Catchment	Please tick appropriate box
a) Increased stream flow and Water security	

b) Restoration of biodiversity (plants and insects)	
c) Maintenance of ecological systems, process, services and functions	
d) Restoration of Wetlands and Improved Water purification system	
e) Reduced fuel load	
f) Other (not specified above)	

19. Do you think the programme has benefited the communities in the northern Drakensberg? Yes ☐ No ☐, If yes, please indicate how?

Benefits to the Blyde River Catchment	Please tick in the appropriate box
a) Employment opportunities	
b) Water provision and improved gazing	
c) Knowledge and skills transfer	
d) Improved standard of living	
e) Other (not listed above)	

20. Has the delays in bidding process and issuing of order number affected you? Please indicate below

Impact	Please tick in the appropriate box
a) Loss of constant income	
b) Loss of skilled workers	

c) Loss of follow up work (revert back to initial stage)	
d) Inability to support family	
e) Other (not specified above)	

21. Has the delays in bidding process and issuing of order number affected the WfW programme implementation in your area? Please indicate below

Impact	Please tick in the appropriate box
a) IAPS have been allowed to regrow	
b) IAPS have been allowed to seed	
c) Relationships lost with landowners lost	
d) Loss of trained staff	
e) Loss of equipment and resources required to conduct work	
f) Other (not specified above)	

22. What do you think or suggest should be done by the department to improve and/ or better the implementation of WfW programme? please indicate below

Future improvements	Please tick in the appropriate box
a) Longer term contracts (3 years or more)	
b) Permanent employment	
c) Decent wages	

d) Danger allowance	
e) Collaboration with landowners and key stakeholders	
f) Provide funding and empower local communities	
g) Other (not specified)	

Thank you very much for you time and participation in the study.

Your assistance, time and input are greatly appreciated.

If there is anything further that you would like to make comment on, note, suggest, raise or otherwise divulge please feel free to include it in the "Additional Notes" section at the end of this booklet. Write to your hearts content.

If you wish to have the results from this study sent to you, please provide your email address: _____

_____

May I please remind you that none of this information will be shared publicly without your prior consent and that if you have any issues, queries or otherwise wish to get hold of me my email address is nthambe2@gmail.com and I am available on 079 4550495/ 066 489 6487.

Thank you for your time.

Additional Notes: _____

_____.

Annexure 2 : Landowner/ Managers questionnaires

My name is Nthambeleni Bologo. I am a postgraduate student at the University of Free State (QwaQwa campus) registered for Master of Science in Botany. I am under the supervision of Dr Sandy-Lynn Steenhuisen (Head and Senior Lecturer: Plant Science, Facility of Agriculture and Natural Science, University of Free State) and my co-supervisor is Dr Grant Martin (Deputy Director, centre for Biological control, Department of Zoology and Entomology, Rhodes University. The research is about the impact of the invasive alien plant species clearing programme on socio-economic benefits and plant biodiversity in the northern Drakensberg escarpment, South Africa and seeks to understand the effects of clearing programme on biodiversity, and the socio-economic benefits along the northern Drakensberg escarpment.

Instruction: Please put a tick [√] in the box next to the answer of your choice or write in the space provided as the case may be.

Details of the property (for administrative purposes and in case of follow-up should need arise)

Name and Surname	
Property name and registration	
Contact details (optional)	Contact number: _____ Email address: _____
Type of ownership and number of years under ownership or Lease	
Type of land use (e.g. livestock farming, game farming, crop farming)	

1. Are you aware of Invasive Alien Plants on your property?

Yes		No	

Can you name some of the worst one? _____

_____

4. Do you think Invasive Alien Plants are a major problem on your property? Yes ☐ No ☐,

If yes, please indicate the main problems in the table below and if no, please explain_____

_____

_____

Problems of IAPs	Please tick appropriate box
a) Alter environmental conditions	
b) Reduce grazing and land productivity	
c) Displace native and useful species and changing ecosystem	
d) Reduce stream flow and water availability	
e) Damage to infrastructure i.e. Increase fire intensity/ frequency	
f) Disturb ecological process, services and functions	
g) Loss of native vegetation	
h) IAPs cause severe erosion and degradation of soils	
i) Loss of tourism revenue	
j) Damage to infrastructure	

k) Other (not specified above)	

1. Are you aware of the Working for Water programme and work that the programme has done on your property?

Yes		No	

1.1 Please indicate the number of treatments, hectares cleared to date

Number of hectares treated (Estimate)	
Number of treatments done (Estimates)	

2. Are aware of the following legislative framework governing Invasive Alien Plants and catchment management? Please indicate below

Legislations	Yes	No
a) National Environmental Management Biodiversity Act, act 10 of 2004		
b) Conservation of Agricultural Resources Act, act 43 of 1983		
c) National Water Act, act 36 of 1998		

3. Do you agree with these regulatory measures? Yes ☐ No ☐

Please briefly explain based on your answer above_____

_____

_____

4. How do you rate your experience and level of satisfaction about the work that the programme has done on your property, where 1 is extremely dissatisfied and 10 extremely satisfied.

Experience with Working for Water Programme	1	2	3	4	5	6	7	8	9	10
Level of satisfaction	1	2	3	4	5	6	7	8	9	10

4.1 Please provide brief explanation of your choice and examples if feasible_____

_____

Were you satisfied with the competency of the teams working on your property where 1 is incompetent and 10 competent

Level of competency	1	2	3	4	5	6	7	8	9	10

Has the WFW programme reduced the amount of IAP on your property Y/NIf yes, by how much

Level of IAP reduction	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%

If no, by how much

Level of IAP reduction	Stayed the same	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%

5. Do you think the clearing of IAPs by WfW programme made significant impact on restoration and/ or preservation of ecosystem functions and services? Please select appropriate answer/s below

Positive impacts of clearing of IAPs	Please tick appropriate box
a) Increase stream flow and water availability	
b) Increase grazing land	
c) Increase land productivity	

d) Increase tourism revenue	
e) Restore ecosystem functioning and services	
f) Other (not specified)	

6. Do you think the Working for Water programme has had financial benefits to you? ☐ Yes ☐ No, if yes could you give an estimate. R_____

7. Do you think the Working for Water programme has saved you money? If yes could you estimate how much. R_____

8. Do you think the Department of Forestry, Fisheries and the Environment should continue implementing the WfW programme? Yes ☐ No ☐, please briefly elaborate based on your choice_____

_____

9. What do you think should be done to ensure improvement in the implementation of the project

Future improvements	Please tick appropriate box
a) Increase funding	
b) Long term contracts with Service Providers (three years and more)	
c) Improve awareness and education on AIPs	
d) Ensure compliance and enforce legislative framework (NEMBA other relevant legislations)	
e) Other (not specified)	

10. Any other comment/s regarding regulation and management of IAPs in South Africa_____

_____

Thank you very much for you time and participation in the study

Your assistance, time and inputs are greatly appreciated.

If there is anything further that you would like to make comment on, note, suggest, raise or otherwise divulge please feel free to include it in the “Additional Notes” section at the end of this booklet. Write to your hearts content.

If you wish to have the results from this study sent to you, please provide your email address: _____

May I please remind you that none of this information will be shared publicly without your prior consent and that if you have any issues, queries or otherwise wish to get hold of me my email address is nthambe2@gmail.com and I am available on 079 4550495/ 066 489 6487

Thank you for your time

Additional Notes: _____

_____

_____

Appendix 3: Research Ethics Approval: Environment & Biosafety Ethics Committee

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA

UFS·UV
RESEARCH DEVELOPMENT
NAVORSINGSONTWIKKELING

Environment & Biosafety Research Ethics Committee

13-Dec-2021

Dear **Mr Nthambeleni Bologo**

Project Title: **Impacts of Invasive Alien Plant Species clearing programme on Biodiversity, and Socio-economic benefits along the Blyde Catchment area, South Africa**

Department: **Plant Sciences Department (Qwaqwa Campus)**

APPLICATION APPROVED

This letter confirms that this research proposal was given ethical clearance by the Environment & Biosafety Research Ethics Committee of the University of the Free State.

Your ethical clearance number, to be used in all correspondence is: **UFS-ESD2021/0210/21**

Please note the following:

1. **This ethical clearance is valid for two years from the issuance of this letter.**
2. **If the research takes longer than two years to complete, please submit a Continuation Report to the Ethics Committee before ethical clearance expires.**
3. **If any changes are made during the research process (including a change in investigators), please inform the Ethics Committee by submitting an Amendment.**
4. **When the research is concluded, please submit a Final Report to the Ethics Committee.**

Approved

Thank you for your application and we wish you well in all of your research endeavours.

Yours Sincerely

Prof. RR (Robert) Bragg
Chairperson: Environment & Biosafety Research Ethics Committee
University of the Free State

Directorate: Research Development
T: +27 (0)51 401 9398 | +27 (0)51 401 2075 | E: smitham@ufs.ac.za
Johannes Brill Building, Room 106D, First Floor
205 Nelson Mandela Drive | Park West, Bloemfontein 9301 | South Africa

Appendix 4: Research Ethics approval: General/ Human Research Ethic Committee (GHREC)

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA

UFS UV

GENERAL/HUMAN RESEARCH ETHICS COMMITTEE (GHREC)

16-Nov-2021

Dear Mr Nthambeleni Bologo

Application Approved

Research Project Title:
Impacts of Invasive Alien Plant Species clearing programme on Biodiversity, and Socio-economic benefits along the Blyde Catchment area in Thaba Chweu Municipality, Ehlanzeni District, Mpumalanga Province, South Africa

Ethical Clearance number:
UFS-HSD2021/1102/21

We are pleased to inform you that your application for ethical clearance has been approved. Your ethical clearance is valid for twelve (12) months from the date of issue. We request that any changes that may take place during the course of your study/research project be submitted to the ethics office to ensure ethical transparency. furthermore, you are requested to submit the final report of your study/research project to the ethics office. Should you require more time to complete this research, please apply for an extension. Thank you for submitting your proposal for ethical clearance; we wish you the best of luck and success with your research.

Yours sincerely

Dr Adri Du Plessis
Chairperson: General/Human Research Ethics Committee

Dr Adri du Plessis
Digitally signed by Dr Adri du Plessis
Date: 2021.11.18 08:42:54 +02'00'

205 Nelson Mandela Drive
Park West
Bloemfontein 9301
South Africa

P.O. Box 339
Bloemfontein 9300
Tel: +27 (0)51 401 9337
duplessisA@ufs.ac.za
www.ufs.ac.za

Appendix 5: Research permit obtained from the Mpumalanga Tourism Parks Agency (MTPA).

Mpumalanga
TOURISM AND PARKS AGENCY

MPUMALANGA TOURISM & PARKS AGENCY
2022 -03- 03
CONSERVATION SERVICES
PERMITS

MPB 1427

PERMIT

TO COLLECT/CONVEY PROTECTED PLANTS FOR SCIENTIFIC PURPOSES
(Issued in terms of the provisions of the Nature Conservation Act 10 of 1998)

Name and residential address of permit holder: ***N. Bologo***
Department of Forestry, Fisheries
No. 31 Brown Street, Old Standard Bank
Mbombela 1200

Name and address of institution or department of whose behalf shall be collected and conveyed: ***Department of Forestry, Fisheries***
Mbombela- MPUMALANGA

PARTICULARS OF PLANTS WHICH MAY BE COLLECTED

Number	Species
1(one)	Flowering Species-(*Asteraceae sp*)
1(one)	Grass species-(*Poaceae Sp*)
1(one)	Herbaciouse Species

PLACE: MPUMALANGA PROVINCE

In terms of and subject to the provisions of the Nature Conservation Act (Act No. 10 Of 1998) and the regulations framed thereunder , the above-mentioned person is hereby authorised, subject to the conditions and requirements appearing on this permit, to collect and convey protected plants referred to above during the period of validity of this permit on behalf of the institution or department referred to above

- **All fieldwork/research must be done in accordance with the project proposal**
- **Copies of research reports are forwarded to the MTPA**

Period of validity of permit: From date of issue to: ***28 February 2023***

for CHIEF EXECUTIVE OFFICER

Signature of permit holder

Appendix 6: List of plants species collected per sites during vegetation survey.

Plants collected per site during vegetation survey							
Robbers Pass		**Blyde River Catchment**		**Pilgrim's Rest**		**Graskop**	
Stratum	Common name	**Stratum**	**Common name**	**Stratum**	Common name	**Stratum**	Common name
woody	Acacia mernsii	woody	Shrub 1	fern	Bracken fern	herbaceous	Blue flower
bulb	African hyacinth	Grass	Grass 1		Bare ground	Grass	Grass A spike
herbaceous	Alternathra sp 1	Grass	Grass 2	shrub	Pseudogeranium (stricley bury)	Grass	Grass B furry leaves
herbaceous	Asteraceae sp 1	Shrub	Shrub 2	grass	Eragrostis curvula	herbaceous	Weedy red flower
herbaceous	Asteraceae sp 2	Grass	Tiny eragrostis	grass	Small Eragrostis	sedge	Yellow restio
herbaceous	Asteraceae sp 3	Grass	Thermeda triandra	grass	Big Eragrostis		
herbaceous	Asteraceae sp 4	herbaceous	bulb 1	sedge	Pine Sedge 1	Grass	Little grass C
herbaceous	Asteraceae sp 5	Grass	Hyparrhenia hirta	herbaceous	Trifoliate	herbaceous	Comolina
herbaceous	Asteraceae sp 6	Grass	Hyparrhenia sp	shrub	Polygala	Grass	Grass D Tall brown
herbaceous	Asteraceae sp 7	woody	Shrub 3	herbaceous	Aster 1	herbaceous	Helichrysum sp 1
herbaceous	blue flowers	Grass	Black Tridant grass	grass	Grass 1	sedge	Tiny sedge
grass	blue green grass			grass	Trident Grass	herbaceous	Helichrysum sp 2
grass	Blue/Red grass	woody	Fabaceae sp 1	shrub	Indogofera	sedge	Tiny sedge sp 2
herbaceous	comolina	herbaceous	Forb 1	shrub	Solanum	Grass	Grass E (large corm)
herbaceous	creeper sp 1	herbaceous	scenecio 1	herbaceous	Runuculus	herbaceous	Savanna Hyacinth
herbaceous	creeper sp 2	Grass	Tiny Grass	Shrub	Shrub A	sedge	Little sedge 3
grass	Cynodon dactylon	Grass	Purple vlei grass	herbaceous	Oxalis	sedge	Moss sedge 4
herbaceous	cynoglossum	herbaceous	scenecio 2	herbaceous	Aster 2	herbaceous	Gladiolus
herbaceous	cynoglossum sp 2	herbaceous	forb 2	herbaceous	Aster 3	herbaceous	Yellow flower 1
grass	Eragrostis capensis	herbaceous	Fury forb	herbaceous	Rubiaceae 1	Grass	Grass F
grass	eragrostis curvula	herbaceous	Asteraceae 1	shrub	Shrub 1	Grass	Grass G
shrub	erica sp 1	herbaceous	Herb 1	herbaceous	Aster 4	herbaceous	Lilac flowers
shrub	erica sp 2	herbaceous	Oxalis	herbaceous	Serrated forb	herbaceous	Grass H
shrub	erica sp 3	Shrub	Fragile shrub	grass	Grass 2	sedge	Tiny sedge 2
shrub	Fabacea sp 2	herbaceous	scencio 3	sedge	Sedge 2	herbaceous	Hyacinth sp
shrub	Fabaceae	herbaceous	scencio 4	herbaceous	Aster 5	herbaceous	Rununculus
grass	Fine blue grass	shrub	Shrub 4	grass	Cynodon dactylon	Grass	Grass I
grass	fine grass	Grass	grass 3	grass	Themeda triandra	sedge	Sedge 5
herbaceous	Flower (Asteracea)	herbaceous	forb 3	herbaceous	Forb A	Grass	Grass J
herbaceous	forb 1	shrub	Shrub 5	shrub	Shrub 2 (Lamianeae)	herbaceous	Hyacinth sp 2
herbaceous	fury asteraceae	Grass	Blue grass	herbaceous	Aster 6	Grass	Grass K
herbaceous	fury forb	herbaceous	Forb 4	grass	Grass 3	Grass	Grass L
herbaceous	fury forb 2	shrub	shrub 6	herbaceous	Aster 8	sedge	Little sedge 1
grass	fury grass	shrub	Shrub 7	grass	Grass 4	sedge	Sedge 6
shrub	fury shrub	herbaceous	burkea sp 1	shrub	Shrub 3	Grass	Grass M
herbaceous	Gazania	herbaceous	Helichrysum sp 1	shrub	Polygala Shrub 2	Grass	Grass N
herbaceous	Grass orcid sp 1					herbaceous	Thunbergia
herbaceous	Heart fruit (Aster)	herbaceous	Unknown	grass	Eragrostis capensis	herbaceous	Forb
herbaceous	helichrysum sp 1	herbaceous	creeper sp 1	herbaceous	Purple flower	herbaceous	Orchid
herbaceous	helichrysum sp 2	shrub	Shrub 9	herbaceous	Weed 1	shrub	Erica thing
herbaceous	helichrysum sp 3	Grass	grass 4	herbaceous	Helichrysum rogulosum	Grass	Grass O
herbaceous	herb 1	Grass	Grass 5	herbaceous	Pigweed	sedge	Sedge 7
herbaceous	herb 2	Grass	Grass 7	shrub	Plec 1	sedge	Sedge 2
grass	kikuya	shrub	shrub 10	herbaceous	Tagetes (Khakibos)	sedge	Tall rastio
herbaceous	little forb	herbaceous	herb 2	herbaceous	Stem burrs	herbaceous	Scabiosa
herbaceous	little forb sp 2	shrub	Shrub 11	herbaceous	Peperthorn	herbaceous	Purple Forb
grass	medium eragrastis	herbaceous	scenecio 6	grass	Grass 5	sedge	Sedge 1
herbaceous	mint sp 1	herbaceous	herb 4	herbaceous	Weed 2		Bare ground
		Grass	grass 6	grass	Serrated forb 2	herbaceous	Helichrysum sp 3
herbaceous	orcid sp 2	shrub	erica 1	herbaceous	Forb 2	sedge	Sedge 8
herbaceous	Oxalis	herbaceous	scenecio 5	grass	Grass 6	herbaceous	Tiny grass C
sedge	Pineapple sedge	shrub	shrub 12	grass	Grass 7	herbaceous	Serrated Forb
grass	Poaceae sp 1	herbaceous	scenecio 7	herbaceous	Pseudo gompho	herbaceous	Drosera sp
grass	Poaceae sp 2	shrub	shrub 13	shrub	Plec Manthus	herbaceous	Tall pink
herbaceous	purple flower	herbaceous	helichrusum sp 2	herbaceous	Bulb	sedge	Sedge 9
Grass	purple grass	Grass	grass 8	herbaceous	Serrated forb 3	sedge	Sedge 10
Grass	Purple vlei grass	Shrub	shrub 14	grass	Grass 8		Water
fern	rock fern	Shrub	shrub 15	shrub	Erica thing	Grass	Tall brown grass D
shrub	Rubus sp	Shrub	Tiny forb	herbaceous	Aster 10	Grass	Grass P
herbaceous	scencio 6	Shrub	Shrub 16	grass	Blue grass	Grass	Moss Grass 4
herbaceous	scenecio sp 1	Shrub	Shrub 17	herbaceous	Seroph3	sedge	Tall yellow rastio
herbaceous	scenecio sp 2	Shrub	Shrub 18	herbaceous	Forb C	herbaceous	Forb with purple underneath
herbaceous	Scenecio sp 3	herbaceous	Gazania	shrub	Shrub 4	herbaceous	3 Drosera