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UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

School of Animal, Plant and Environmental Sciences

Assessment of the invasive potential of *Grevillea robusta* in South Africa.

Degree: Master of Science (Dissertation)

Rabelani Marikhele

A Dissertation submitted to the Faculty of Science, University of the Witwatersrand, in partial fulfilment of the requirements of the degree of Master of Science

September 2018

I. Declarations

I declare that this Dissertation is my own, unaided work. It is being submitted for the Degree of Master of Science at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.



_____

(Signature of candidate)

Signed on the 18th day of September 2018 in Johannesburg

II. Abstract

Grevillea robusta is classified as a Category 3 invader by the National Environmental Management: Biodiversity Act (NEMBA) in South Africa. The species has recently been observed invading riparian areas from old cultivated trees in Limpopo, Mpumalanga and Gauteng provinces. Since the early 1980's *Grevillea robusta* A.Cunn populations have increased from 15 observations in 1980─1985 to 39 in 1996─2000 and 47 between 2016 and 2017 in South Africa. The species is currently distributed in a total of 188 localities in 7 South African provinces. The aim of this study was to assess the invasiveness of *G. robusta* in South Africa and determine its appropriate Category status by assessing its invasive capacity by conducting a population census and assessing its transformative capacity at Moederlief farm, South Africa. *Grevillea robusta* is widespread in South Africa, however, there are no recorded observations in the Free State and Northern Cape provinces. The results from iSpot, CLIMEX, Southern African Plant Invaders Atlas (SAPIA) and field observations in figures 13, 14, 15 and 16 shows 52 observations in Limpopo and 37 between KwaZulu-Natal and Mpumalanga provinces. A climatic match index by CLIMEX was employed, and results indicate that *G. robusta* has the potential to grow well in Limpopo, Mpumalanga and Gauteng provinces and along the coastal regions. Furthermore, healthy populations of *G. robusta* were observed at Moederlief farm, where the biggest recorded tree in the field was estimated to be 45 to 52 years old. *Grevillea robusta* produces viable seed which may be dispersed 364 m away from parent trees. Looking at the population structure, age of reproduction, seed viability and ease of dispersal, the populations of *G. robusta* at Moederlief farm will continue to grow and invade even in other areas that are yet to be considered risk areas. *Grevillea robusta* is an invader that needs further evaluation of all the localities in South Africa. The species should be placed in Category 1b of invasive species and immediate control is required in all riparian zones.

Keywords: Distribution, Category, *Grevillea robusta*, Invasive assessment, NEMBA, Populations, SAPIA

III. Dedication

For God who made my studies a success. I dedicate this dissertation to my late father who always advised me to continue studying. To my two girls (Humbulani and Rolivhuwa) for their patience with me while I was busy with my MSc studies.

IV. Acknowledgements

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I would also like to acknowledge Dr Renee Reddy, Mr Felix Donkor and everybody in the herbarium for their advice and support.

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VI. Acronyms

ARC	Agricultural Research Council
GPS	Geographic Positioning System
NEMBA	National Environmental Management: Biodiversity Act
OLS	Oppenheimer Life Science Building
SACLPs	South African Criteria for Listing Plant species
SAPIA	Southern African Plant Invaders Atlas
SAWS	South African Weather Service
SPSS	Statistical Package for the Social Sciences
TTZ	Tetrazolium stain
WfW	Working for Water
WRA	Weed Risk Assessment

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Chapter 1: Background

1.1. Introduction

Invasive species can be defined as colonizers which establish populations and reproduce rapidly in non-native areas, hence affecting natural resource availability in the ecosystem (Jimenez-Valverde *et al*., 2011). There are several characteristic features of invasive species that some people find desirable, and thus introduce them into the country such as the ability to grow under a wide range of environmental conditions (Van Wilgen *et al*., 2008; Van Wilgen & Richardson, 2013; Geerts *et al*., 2013; Jacobs *et al*., 2014), and the ability to grow fast and ease of "establishment", drought tolerance and ability to resprout (as in species of *Casuarina, Eucalyptus* and *Grevillea*) and high seed production (Richardson, 1998; Richardson & Blanchard, 2011).

There can be several changes in native species that can be influenced by invasive species such as native species extinction, genetic composition of native populations through cross-pollination and ecosystem productivity (Richardson, 1998; Blackburn *et al.*, 2014). However, some of these changes are indirect or have not been well studied and can only be noticed after an extended period (Wilson *et al*., 2013). Most alien species do not show their invasive characteristics when they are first introduced into new environments since they are still under a lag period (Wilson *et al*., 2013; Moodley *et* al., 2014). Some invasive species may show very little evidence of being harmful to the environment during this phase (Blackburn *et al*., 2014).

Alien trees can bring benefits to the country but may also cause environmental harm, and that results in challenges in decision making on how to control them (Van Wilgen & Richardson, 2013). Alien species invasion in South Africa comes with opportunities and challenges. For example, the control of invasive species costs money but also leads to job creation (Wilson *et al*., 2013). Considerable investigation is needed for the benefits and negative impacts of a species before implementation of control strategies (Geerts *et al*., 2013).

To understand and identify species that may become invasive and ways to combat the invasion with success, understanding of native species ecosystems and traits are necessary (Hulme, 2006). Some invasive plants possess characteristics that increase plant movement and establishment such

as seed morphology (Davies & Sheley, 2007). Understanding seed dispersal pathways and vectors can improve the control of invasion dispersal and establishment success (Davies & Sheley, 2007).

It is critical to understand the invasive potential of alien species, and how fast they are invading specific areas, as this will help to prioritize our efforts in controlling widespread invaders (Blackburn *et al*., 2014). Considerable progress has been made towards understanding the determinants of invasiveness and the ability to become invasive. However, invasion remains challenging to predict because of the complex interactions between traits of alien species, features of the environment, and the context in which they have been introduced (Rejmánek *et al*., 2005). Researchers, directors, and policy-makers require useful and compelling metrics to enhance the understanding and management of biological invaders (Wilson *et al*., 2014).

Policy makers need to consider research on species behaviour and their potential to invade so that they can make informed decisions on preventing or allowing entry into a country for a specific species (Venette *et al.,* 2010). Furthermore, when an invasive species is found growing in a country, there is a need to assess the population of the invading species to determine if eradication is needed or to identify control measures to be used to contain it (Zenni *et al*., 2009). Understanding invasive species seed dispersal may also help to improve management of invasive species and to restrict dispersal into new areas (Davies & Sheley, 2007).

Grevillea robusta A.Cunn is a fast growing evergreen tree that is a member of the *Proteaceae* family and it is drought and cold tolerant (Mugunga, 2009). It has a single stem that grows straight reaching heights of about 20 m to 30 m. When in the adult stage, it has a stem diameter that can reach up to 80 cm, its canopy is cone-shaped and most of its branches grow at an angle of 45° to the trunk with spaces of about 1 m. The bark on the stem is grey (Harwood, 1997). *Grevillea robusta* has green leaves which are 10 cm to 34 cm long, and 9 cm to 15 cm wide (Glen & Van Wyk, 2016) with size depending on the age of the tree. The petioles are 1.5 cm to 6.5 cm long. *Grevillea robusta* has bright orange flowers, about 2 cm long, in numerous pairs along racemes and 15 to 20 mm long fruits (Glen & Van Wyk 2016), and pedicels which are 1.5 cm long (Mugunga, 2009).



Figure 1: Features of *Grevillea robusta*. A, Planted *G. robusta*; B, Leaves of *G. robusta* C, Flowers of *G. robusta*; D, Stem of *G. robusta*; E, Seed capsules of *G. robusta*, all pictures were taken from a tree planted at the University of the Witwatersrand.

The native distribution of *G. robusta* is in northern New South Wales and Southern Queensland, Australia, in the warm humid and sub-humid climatic zones (Harwood, 1992; Kalinganire, 1996). In Australia, *G. robusta* has two commonly known habitats which are small and discontinuous stands along river banks and streams, usually within 30 m of a river bank in well-drained and fertile soil where water availability is moderate, and the second habitat is rain forest (Kalinganire,

1992; Harwood, 1992; Henderson, 2001). *Grevillea robusta* occurs across a wide range of altitudes from sea level to mountaintops at 1120 m in the Bunya Mountains (Harwood, 1992; Brand *et al*., 2013). *Grevillea robusta* is categorized as a colonizer in other parts of Australia such as Perth and Tasmania Island (Orwa *et al*., 2009).

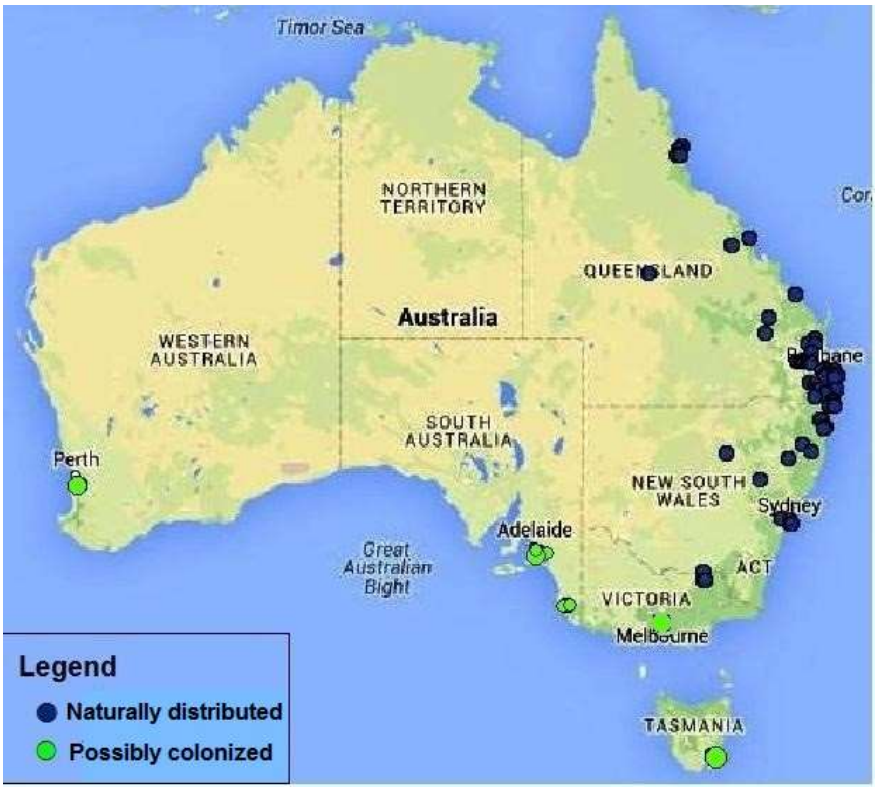


Figure 2: Distribution of *G. robusta* Australia, Source: http://www.gregsindigenouslandscapes.com.au/Category16.php, accessed on 09 September 2016

Grevillea robusta may depend on disturbance to regenerate as it is a light-demanding species (Harwood, 1992). *Grevillea robusta* is sensitive to fire and this means that anthropogenic and natural fires influence the natural distribution and the survival of young and mature trees (Harwood, 1997). Invasive species that are fire sensitive may be regarded as non-problematic in places where there are frequent fires of sufficient intensity (Geerts *et al*., 2013). *Grevillea robusta* is a good competitor for resources both above and below ground (Ong *et al*., 2000).

1.2. Problem statement

Grevillea robusta is classified as a Category 3 invader in South Africa by the National Environmental Management: Biodiversity Act (NEMBA), which was updated in 2014. Category 3 states that the plant can remain wherever it is already growing, but one cannot plant any new trees. Section 2 of Category 3 states that "Any plant species identified as a Category 3 Listed Invasive Species that occurs in riparian areas, must, for the purposes of these regulations, be considered to be a Category 1b Listed Invasive Species". Being aware of NEMBA regulations for *G. robusta,* trees have been observed to be invading from old cultivated plants which points to the need for further studies and indicates a review of the plant's categorization. The invaded areas were observed in some parts of Mpumalanga and Gauteng provinces. This study will help to determine if the Category status of *G. robusta* needs to be reviewed or can be left as it is.

1.3. Aim of the study

This study aims to assess the invasiveness of *G. robusta* in South Africa and the extent of invasion of *G. robusta* at Moederlief farm in order to determine in which Category it should appropriately be placed.

1.4. Objectives and key questions

1.4.1. To determine areas in South Africa which have similar geographical and climatic conditions as those of the native range of *G. robusta* and are thus vulnerable to infestation.

- What is the ecological tolerance of *G. robusta* in its native range?
- Which areas in South Africa experience the same minimum temperatures per year as those in the natural range of *G. robusta*?
- Which areas in South Africa experience annual rainfall that is the same as in the natural range of *G. robusta*?

1.4.2. To determine where *G. robusta* is distributed in South Africa.

- Where has *G. robusta* been recorded in South Africa?
- What is the current status of invasion in areas where *G. robusta* occurs?

1.4.3. Determine the population dynamics of *G. robusta* currently growing at Moederlief farm.

- What is the current distribution of *G. robusta* at Moederlief farm?

- What is the density of trees at Moederlief farm?
- What is the total number of trees in the surveyed area?
- What frequencies of trees occur in size classes of *G. robusta* trees growing at Moederlief farm?
- What is the mortality rate of *G. robusta* at Moederlief farm?
- What is the extent of damage to trees and are trees surviving the damage?

1.4.4. To determine how wind might influence *G. robusta* seed dispersal.

- What is the mean and range of mass of viable seeds of *G. robusta*?
- What is the terminal velocity reached by seeds of *G. robusta*?
- How long will it take for seeds to fall from the canopy to the ground?
- What is the prevailing wind speed in the areas where *G. robusta* occurs?
- How far from a parent plant may viable seeds of *G. robusta* be blown before they reach the ground?

1.4.5. To determine if *G. robusta* is a transformer species in South Africa.

- How does *G. robusta* litter influence understory vegetation growth and survival?
- How does tree canopy size influence understory vegetation?

3.5.6. To assess the invasive potential of *G. robusta* in South Africa using the WRA model and NEMBA decision tree.

- Is *G. robusta* already a problem or potential problem in South Africa?
- Is *G. robusta* likely to become more invasive in South Africa?
- Is *G. robusta* a commercial or subsistence species in South Africa?

Chapter 2: Literature review

2.1. Introduction of alien species into South Africa

Invasive tree species were introduced into South Africa to meet a high demand for wood products such as furniture, pulp, poles, firewood, tannins, ornamentals, reducing soil erosion, use as windbreaks, barriers, hedges, and some are used for trading between countries (Nyoka, 2003; Geerts *et al*., 2013). Invasive trees in South Africa were also introduced for forestry practices and the motivation can be summarized into two main reasons. The first being that most indigenous trees do not respond well to forestry management activities and native trees do not produce as good quality timber as invasive alien trees (Richardson, 1998). The second reason is that invasive alien trees grow much faster than native trees (Richardson, 1998). Use of plants for ornamental purposes constitutes the most prominent loophole for invasive species to move between countries around the world (Dehnen-Schmutz, 2011).

Invasion by alien tree species was first noted in South Africa in the 1920's (Richardson & Blanchard, 2011). Australian species are the most widespread invaders in South Africa (Geerts *et al*., 2013). After a species has been introduced or established in a new region it may take many decades before it shows signs of being an invader and few studies have been done to determine the mechanisms of the lag phase (Geerts *et al*., 2013). The lag phase can be very long. In Germany, it took 147 to 350 years and 14 years in Hawaii while in England it took 125 years (Dehnen-Schmutz, 2011). An example in South Africa is *Banksia ericifolia* that took 35 years to increase from 100 planted trees to 10000 individuals (Geerts *et al*., 2013).

2.2. Negative impacts of invasive alien species in South Africa

About ten million hectares (8%) of South African land is infested by invasive species, with the Western Cape, Northern Cape, and Mpumalanga being the top most invaded provinces (Van Wilgen *et al*., 2001). Invasive alien species influence the supply of natural goods and services and human well-being and they also threaten biodiversity (Shackleton *et al*., 2007; Roura-Pascual *et al*., 2009; Blackburn *et al.*, 2014). The continuous establishment of invasive species by humans increases the threat of invasive species to the ecosystem (Jacobs *et al*., 2014).

South African grasslands and savannas have been transformed by planting of trees for wood production, thus resulting in loss of grazing, agricultural land and threat to native biodiversity (Richardson, 1998). Invasive plants cost South Africa an estimated R6.5 billion per year (Wilson *et al*., 2013) and if spreading of invasive plants is not stopped, the cost of controlling invasive species is likely to increase, and invasive species will become even more problematic (Richardson, 1998; Wilson *et al*., 2013).

2.3. Effects of litter and canopy on the vegetation

Tree species influence the survival of all species growing below their canopies as they influence availability of nutrients, sunlight and water (Facelli & Pickett, 1991; Xiong & Nilsson, 1999; Barbier *et al*., 2008). Effects of plant litter are influenced by decomposition rates, as the litter of forbs decomposes fast and adds nutrients to the soil whereas the litter of evergreen trees takes longer to decompose (Facelli & Pickett, 1991). Large amounts of litter have a negative influence on seed germination and seedling establishment and seedlings that manage to germinate will have slow growth (Xiong & Nilsson, 1999). Litter influences vegetation positively and negatively as it reduces species competition for resources and reduces survival of other species in the same area (Facelli, 1994). Some species may not survive, although those that do will have enough available resources.

Leaf litter reduces germination and growth of species with small seeds and shade intolerance but encourages the growth and survival of species with large seeds and shade tolerance (Dupuy & Chazdon, 2008). When there is a buildup of litter on the ground, seedling emergence is delayed and some seeds and seedlings may be damaged (Facelli, 1994). Litter that accumulates from invasive species such as *Casuarina equisetifolia* suppresses seed germination and initial growth of other species (Hata *et al*., 2010). *Grevillea robusta* is an evergreen tree so its litter is likely to take a long period to decompose and will thus build up on the ground below the trees.

2.4. Ecological tolerance and distribution of *G. robusta* in its native range

Grevillea robusta was first described in 1827 by Allan Cunningham from along the Brisbane River, Queensland (Kalinganire 1992). In Australia, *G. robusta* is naturally distributed in warm humid and sub-humid climatic zones (Kalinganire, 1996). *Grevillea robusta* prevails in its natural

range with mean annual rainfall ranging from 700 mm to 2400 mm. Queensland experiences an average rainfall of 465 mm during the rainy season from November to April and an average of 223 mm in summer (November, December and January). Mean annual low temperatures ranging from 14 to 23˚C and mean high temperatures ranging from 25 to 31˚C have a positive influence on the growth of *G. robusta* (Brand *et al*., 2013).

Young *G. robusta* trees will not survive a drought season that is longer than 6 months and are less likely to survive climatic conditions outside those of its natural range (Henderson, 2001; Kalinganire, 1996). Mild frosts during the growing season can cause damage to young trees of *G. robusta* (Harwood *et al*., 1997). *Grevillea robusta* performs well on fertile and deep soils and does not do well in heavy clay soils (Kalinganire, 1996). Growth rate and performance of *G. robusta* can be affected by site and climatic conditions as well as the density of trees at the site (Kalinganire, 1992). *Grevillea robusta* may depend on land and vegetation disturbance to regenerate as it is a light-demanding species (Harwood *et al*., 1997).

2.5. Rainfall and temperature patterns of South Africa

Climate is a combination of rainfall and temperature at a given time. Northern Cape receives less than 250 mm per annum of rainfall while in North West rainfall ranges from 500 to 750 mm per annum (Cowling *et al*., 2001). The northern and central parts of South Africa receive rainfall in summer (from November to January) and the Cape in winter, whereas in the Eastern South coast rain falls all year round (Cowling *et al*., 2001). South Africa experiences annual mean temperatures over 20°C along the Northern and Eastern coast (Cowling *et al*., 2001). Some parts of the Free State, Eastern Cape and the central parts of the country experience annual mean temperatures ranging from 12 to 16°C (Cowling *et al*., 2001). North West and Northern Cape provinces experience frost while coastal areas of South Africa do not experience frost.

2.6. Pollination and seed dispersal of *G. robusta*

Eastern spinebill is the most noted bird visiting and foraging on many *Grevillea* species in Australia (Richardson *et al*., 2000; French *et al*., 2005). In Australia other *Grevillea* spp., such as *G. sphacelata,* are mostly visited by bees while *G. mucronulata* is visited by birds (Richardson *et al*., 2000). *Grevillea banksii* flowers are commonly visited by birds in Australia (French *et al*.,

2005). Nectar-feeding birds are the most common *G. robusta* flower visitors in Western Kenya (Kalinganire *et al*., 2001). In South Africa, pollination of *G. robusta* flowers has been presumed to be by bees and wasps (Rebelo, 2008) although sunbirds have been observed visiting flowers in Mpumalanga (K. Balkwill, pers. comm.).

Grevillea robusta is self-compatible, but male reproductive flower parts mature earlier than female reproductive organs and due to this mechanism, cross-pollination is enhanced in *G. robusta* (Kalinganire *et al*., 2000). *Grevillea robusta* produces fruits which are 2 cm from the pedicel to the tip (Skene *et al*., 1996). The seeds are flat and can be dispersed by wind and they are about 0.8 mm─0.9 mm in diameter and flat (Jackson, 2000).

2.7. Uses and benefits of *G. robusta*

Grevillea robusta trees were first grown in Australia for ornamental purposes and later became economically important across the world (Kalinganire, 1992). *Grevillea robusta* is now widely used economically in Eastern and Central Africa as a shade tree for coffee and fuel wood from small farms practicing Agro-forestry (Kalinganire, 1992; Harwood, 1992). Trees of *G. robusta* in South Africa are used mostly as windbreaks and for agroforestry in farms and along roads and as ornamental trees (Skene *et al*., 1996). The species has been widely introduced around the world including to South and North America and to South Asia where it is an ornamental tree and planted in rows between small farms to make boundaries (Orwa *et al*., 2009). In Kenya, the wood is used to make beehives (YouTube video on bee business in Kenya).

2.8. Insect attack, herbivory and disease in *G. robusta*

Grevillea robusta trees are more vulnerable to termites in dry climates where termites are more prevalent (Moe *et al*., 2016). *Grevillea robusta* trees that are younger than 5 years old are found to be vulnerable to termites in the lowlands of Kenya, but this varies from tree to tree and trees older than 5 years are attacked less (Kalinganire, 1992). The sapwood of *G. robusta* is susceptible to *Lyctus* beetles (Orwa *et al*., 2009).

Trees of *G. robusta* were found to be susceptible to some large African herbivores such as Impala, Zebra and African Buffalo (Moe *et al*., 2016) and seedlings and coppice growth has been browsed in Mpumalanga at dry times of the year (K. Balkwill, pers. comm.). Exposure of *G. robusta*

seedlings to termites and large herbivores in dry climates results in very low survival as compared to when trees are grown in the absence of termites and herbivores (Moe *et al*., 2016). Trees of *G. robusta* grow much quicker than indigenous trees in the absence of large herbivores (Moe *et al*., 2016). Herbivores hinder growth of *G. robusta* in the same way as that of indigenous species (Moe *et al*., 2016).

Grevillea robusta was found to be vulnerable to a fungal disease called pink disease (*Corticium salmonicolor)*, which typically occurs in humid conditions. *Amphichaeta grevilleae* was observed attacking and causing significant damage on *G. robusta* seedlings in nurseries in Sri Lanka, mostly if they were subject to waterlogging or overwatering (Orwa e*t al*., 2009).

2.9. Risk assessment model

The Weed Risk Assessment (WRA) model is a computer spreadsheet developed by Pheloung *et al*. (1999) and was designed to be used for a species proposed to be introduced into a new area (Gordon *et al*., 2010). The WRA model assesses three aspects of a species namely the history, characteristics and ecology of the plant. The WRA model asks 49 questions about an alien species that is proposed to be brought into a country. For the assessment to be accepted it should have answered more than 2 questions under Agricultural assessment, more than 2 questions under Environment assessment and 6 questions under the combined assessment. A species with a score of less than 1 can be accepted into the country and one with a score between 1 and 6 should be evaluated before a decision can be made, but one with a score of more than 6 should be rejected (Pheloung *et al*., 1999; Caley *et al*., 2006).

Border authorities adopted the WRA model to assess all new plant arrivals in Australia and New Zealand (Pheloung *et al*., 1999). The model has also been used by Hawaii to reduce the number of alien species introduced into the country (Daehler *et al.*, 2004). The WRA model is based on scientific principles so that it does not only reject weeds but also assists in identifying areas with soil types, impacts on the environment and areas with climatic conditions that are thus at more risk from specific invaders using information from other countries.

Jefferson *et al*. (2004) tested the accuracy of the WRA model with 2 other risk assessment models, the IOWA and the shortened version of the WRA. During the test, the WRA model had 100%

accuracy for known invasive species. Before a species may be introduced in the area the risk assessment of the species should be evaluated for the whole country (Gordon *et al*., 2010). To improve the significance of the WRA, two conferences titled "Ecology and Management of Alien Plants" were held in Perth, Australia (Gordon *et al*., 2010). Clarity was provided under questions 2.01, 2.02 and 2.05 and 3.01 to 3.05.

2.10. Measures currently used to control invasive species in South Africa

The best way to control invasive species is to prevent them from establishing in new areas (Zenni *et al*., 2009; Venette *et al.,* 2010; Moore *et al*., 2010; Wilson *et al.,* 2013). Early detection and eradication mechanisms are ideal as costs of control are lower than when the species has invaded a big area (Geerts *et al*., 2013).

Eradication is the most efficient way to remove invasive species once they have established in an area and is defined as the removal of every individual tree, seed and seedling in the area (Wilson *et al*., 2013). Mechanical control methods of trees are cheap and effective and old trees are easy to identify as they are big (Geerts *et al*., 2013). Shrubs and small weeds can be removed by uprooting them when they are still small and more effectively after rainfall (Jacobs *et al*., 2014). Triethylammonium salt-Lumberjack™ was used to spray shrubs of *Acacia paradoxa* and was found to be effective in about 3 weeks (Zenni *et al*., 2009).

Working for Water (WfW) is a programme in South Africa that is responsible for controlling invasive species in partnership with the Department of Environmental Affairs and was established in 1995 (Roura-Pascual *et al*., 2009). A considerable amount of work has been done by the WfW programme to reduce invaded areas and the spread of some invasive species (Wilson *et al*., 2013). However, the quantity of invaders stays high and there is a need to enhance control strategies (Roura-Pascual *et al*., 2009). While WfW is controlling many invasive species, there are many invasive species that are not controlled or listed under species to be controlled, and there are no known reasons for not controlling those species (Wilson *et al*., 2013).

Since 1996, WfW has increased the number of resources for controlling invasive species such as biocontrol agents and the introduction of the most widely used herbicide triethylammonium salt-Lumberjack™ (Zenni *et al*., 2009; Wilson *et al*., 2013). The WfW standard clearing protocol is

the most effective programme for clearing invasive tree species in South Africa (Zenni *et al*., 2009).

Chapter 3: Materials and methods

3.1. Areas in South Africa with similar climatic conditions as Queensland using CLIMEX

A climatic match index can be determined by a prediction system (CLIMEX, BIOCLIM or CLIMATE) using native climatic data in the area proposed for introduction or currently introduced (Gordon *et al*., 2010). CLIMEX software can be used to compare the natural distribution (Home) of a species with locations outside its native range (Away) (Senaratne *et al*., 2006; Poutsma *et al*., 2008). CLIMEX can be used to produce pest risk maps which can then be used as a communication tool to describe the potential areas a pest can establish (Venette *et al.*, 2010). CLIMEX software can help predict a possible species distribution across the whole world or in a particular region of interest (Poutsma *et al*., 2008; Gordon *et al*., 2010). Similarities between two locations can be determined by using the Match Climate Function (Kriticos *et al*., 2015).

To match the climatic conditions of the natural distribution of *G. robusta* with the South African climate, CLIMEX 4.0.2 software was used. CLIMEX was employed to determine areas in South Africa with similar climatic conditions to Queensland which is the natural distribution of *G. robusta* in Australia (Figure 2). When running the overall climatic match index of Queensland (Home location) and South Africa (Away location). The home location is selected as Queensland and away location as South Africa under regional climatic matching. Parameters to be assessed, minimum temperature, maximum temperature, average temperature, total rainfall, rainfall season, relative humidity and soil moisture were set at 1. Climatic similarities in CLIMEX were assessed from 50 to 100% similarities between Queensland and South Africa. Climatic conditions of Queensland were mapped onto the African map and the focus was South Africa to determine where *G. robusta* would be likely to establish. The quality of climatic match index of *G. robusta* in South Africa was interpreted using the map.

3.2. Distribution of *G. robusta* in South Africa

A desktop survey of *G. robusta* in South Africa was conducted to determine the distribution and number of populations of *G. robusta* in South Africa. Data from Southern African Plant Invaders Atlas (SAPIA), the Agricultural Research council (ARC) databases and a paper by Moodley *et al.*, (2014). Other observations were received through an article posted on iSpot share nature

(Distribution of *Grevillea robusta* Silky Oak) and also personal observations. Observations were arranged by date and according to province, observation data are attached in a spreadsheet as observations of *Grevillea robusta* in South Africa (Appendix I). To determine the average density of *G. robusta* in the 9 South African provinces, the formula below was used:

$$\text{Average density} = \frac{number\ of\ observation\ in\ a\ provice}{\text{land area in a province } (km^2)}$$

3.3. Study area

The primary study area for the field investigations of this project was Moederlief farm which is 280 ha in size (Figure 4), located 30 km from Nelspruit at 25°32'5.10"S and 31°12'45.00"E. Nelspruit receives an average rainfall of 767 mm per year most of which is received in the summer with 13˚C average minimum temperature and 27˚C average maximum temperature per year. Moederlief farm is situated in a farming area surrounded by agricultural and game farms. Most of the tree and animal species are similar to those on neighbouring farms, and it is easy for seeds and animals to move between them. Part of Moederlief farm was previously used as a mining area (Figure 3) and has residential areas which are known to have been inhabited long before mining operations in the area.



Figure 3: Google maps view of quarry at Moederlief farm

Many invasive trees and shrubs were planted in areas that were used as residential areas. These invasive trees and shrubs have grown and are now invading the farm and include *Grevillea banksii*, *Lantana camara* and *Jacaranda mimosifolia.*

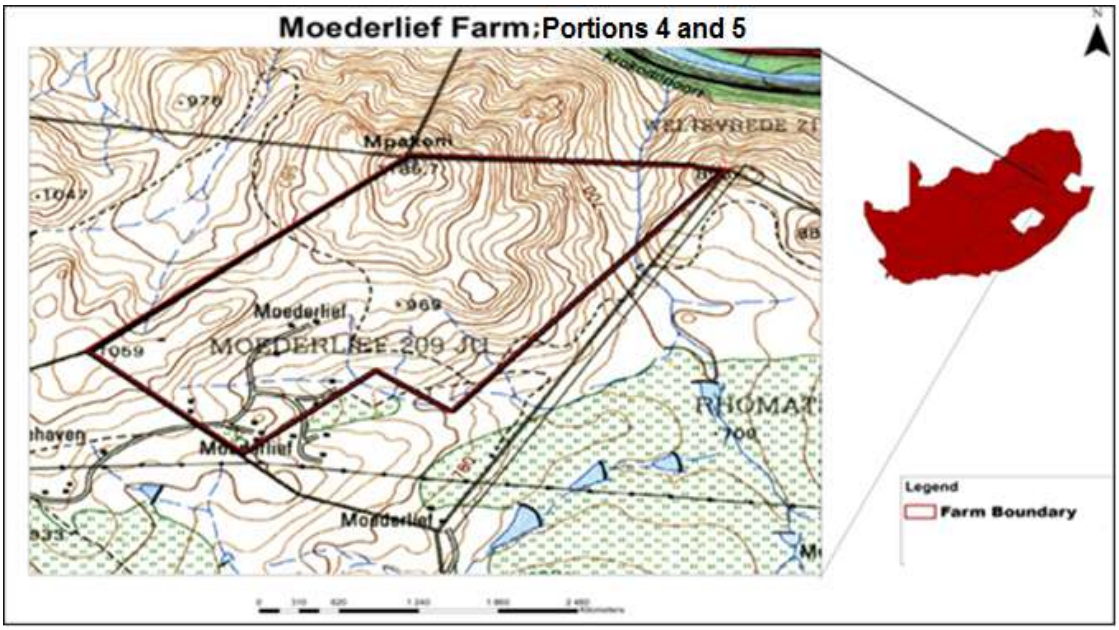


Figure 4: Study Area map; Topographic view of Moederlief farm Portions 4 and 5, the map shows contour lines and altitudinal ranges at Moederlief farm

3.4. Laying out of quadrats

During field work preparations, 11 transect lines were planned with 16 quadrats in each transect line. Transects lines were labeled T1 to T11 and quadrats were labeled according to transect lines from T1Q1 as the first quadrat on the first transect to T11Q16 and each quadrat was 100 m^2. The initial plan was to locate the first quadrat 200 m from the farm boundary. Quadrats were going to be 100 m apart on the transect line and a GPS would have been used to locate them in the field. Due to the topographical characteristics of the farm and the closed vegetation it was difficult to walk in a straight line. Google Earth was employed to plot all quadrats noting down the coordinates. The distances between Google Earth quadrats were measured along the ground and when mapped using ArcGIS some of the quadrats appear to be clustered together (Figure 17).

3.5. Population dynamics of *G. robusta* at Moederlief farm

Google Earth showed both open and treed areas on Moederlief farm. A Garmin Etrex 10 GPS was used to locate quadrats in the field using coordinates from Google Earth. A GPS was set to waypoint mode (Figure 5) and all set quadrats were assessed in the field.



Figure 5: Garmin Etrex 10 GPS on waypoint mode used during field survey to locate quadrats at Moederlief farm

In each quadrat, vegetation types were identified as well as land disturbance to determine where there are more *G. robusta* trees. A GPS was also used to record altitude for each quadrat to determine if altitude has an influence on the survival of *G. robusta* in South Africa. Some parts of the farm were slashed, sprayed and burnt and tree condition was noted in each quadrat in addition to whether there were any *G. robusta* trees present and then the number of trees was recorded. The amount of litter in each quadrat was measured with a 30 cm ruler (Figure 6). Data collected in each quadrat at Moederlief farm are attached as data collected per quadrat (Appendix D).



Figure 6: Measuring depth of litter above ground using a 30 cm ruler in one of the 159 quadrats

All *G. robusta* trees found within each quadrat (including dead and diseased) were tagged with tag numbers for identification at any stage of the project. In each quadrat, tree heights were estimated using a 3 m extendable rod (Figure 7B). Trunk diameters at the base and breast height of each tree were measured with tree calipers (Figure 7A). A 5 m tape was used to measure the circumference of trees that had a diameter that was larger than the calipers could measure. The circumference was converted to diameter using the formula:

$d = C/\pi$

d, is tree diameter and C, is circumference of the trunk



Figure 7: A, Measuring tree diameter with Calliper and B, estimating tree height with a 3m extendable rod in the field

During the field survey, tree canopy diameter was measured with a 30 m tape. To determine *G. robusta* canopy cover, the longest diameter and diameter at right angles were measured with a tape measure.

To determine canopy area cover of *G. robusta* the formula below was used:

$$r = \frac{\text{Longest diameter} + \text{diameter at right angles}}{4}$$

$$A = \pi r^2$$

A, is canopy area cover of a tree and **r,** is the radius of a tree canopy.

One hundred and fifty-nine quadrats were accessed and surveyed and all those with *G. robusta* and those without were recorded and mapped (Figure 17). Data were collected from all *G. robusta* trees that occurred within any quadrat (Appendix E).

Fieldwork was done during the flowering season to take note of flowering and non-flowering trees. Bees and birds are frequent visitors to flowers of *Grevillea* species (Richardson *et al*., 2000; French *et al*., 2005). It was intended to put four camera traps focusing on selected flowers to capture flower visitors, but due to inadequate rainfall leading to no inflorescences being produced in 2016, this could not be done. The findings would have been used to determine likely pollinators of *G. robusta* in South Africa.

3.6. Tree age

Basal diameter of a tree is the most significant parameter to determine the approximate age of a tree (Geerts *et al*., 2013). A Husqvarna 16 petrol-powered Chainsaw was used to cut down an initial sample of 10 selected living trees of different stem diameters to establish the relationship between tree diameter and age in 2016 (Figure 8). In 2018, a further 10 tree samples were sliced from trees that had already been cut to expand the sample.



Figure 8: Cutting a tree using a Husqvarna 16 petrol-powered Chainsaw for tree age estimates

The diameter at the base and breast height and the height of each tree were measured before it was cut. To determine age and growth rate of a tree, two wood samples were sliced from the same

individual. To obtain minimum age estimates of the trees using tree rings, slices of wood were cut from each tree at the base and at breast height.

The wood slices from the first 10 trees were dried in a drying room as it is easier to sand wood when dry than when wet. A 220 grit sanding belt was fitted in a Rockwell/Delta sanding machine to sand the wood and enhance age ring visibility. For the 2018 wood slices, a Bosch PBS7A belt sander fitted with a 100 grit sanding belt was used to sand the wood slices at Moederlief farm since they were sliced from already cut stumps. Age rings were assessed and counted under the Wild Heerbrugg M7A dissecting microscope (Figure 9). All tree diameters and age rings were recorded in a spreadsheet and are attached together with age estimates (Appendix H).



Figure 9: Viewing and counting of age rings from wood slice with a dissecting microscope (80X) inside OLS Laboratory

3.7. Seed dispersal and viability testing

Seeds were collected at Moederlief farm and kept in paper envelopes to be used for seed dispersal and viability tests. From the collected seeds, 50 seeds were selected randomly and weighed. Dispersal tests were done over the weekend when Oppenheimer Life Science (OLS) building doors were closed as the cross winds were minimal and there were no students in the building. A weighed seed was dropped 3 times from a height of 20 m inside OLS and the time it took to reach the floor was recorded.

Trees of *G. robusta* were observed invading in Nelspruit, Pretoria and Warmbaths. A request for wind speed and direction data for 4 months (January, February, March and December as seeds are dispersed from December until March) for 5 years (2012 to 2016) from the South African Weather Service (SAWS) was made. Data were used to determine how far seed could be dispersed at maximum wind speeds and in which direction.

To determine the potential distance to which *G. robusta* seed could be dispersed at Moederlief farm, all viable seed, various tree heights and the strongest wind speed in a year from 2012 until 2016 were considered to estimate how far seed could be dispersed. The equations below were used:

1. Average terminal velocity (m/s) = $\frac{Dropping\ height\ (m)}{Time(s)}$
2. Maximum time to reach the ground (s) = $\frac{Tallest\ tree\ (m)}{Average\ terminal\ velocity(m/s)}$
3. Dispersal distance (m)= Fastest wind (m/s)*Time to reach ground (s)



Figure 10: Seeds of *Grevillea robusta* used for dispersal and germination tests

After the seed dispersal tests, seeds in figure 10 above were placed under a dissecting microscope to determine which seeds had an embryo and which were empty. To determine seed viability, a

1% solution of tetrazolium stain (TTZ) solution was prepared in the laboratory by making a buffer solution from two solutions. One solution contains 0.908 g of KH_2PO_4 and 100 ml of distilled water and the second solution consists of 0.947 g of Na_2HPO_4 and 100 ml of distilled water. Three (3) parts (75 ml) of solution 1 were mixed with 2 parts (50 ml) of solution 2 (a sum of 125 ml) and it gave a pH of 6.8. Tetrazolium salt of 1.25 g was then put into the 125 ml buffer solution and produced the TTZ solution required. To prepare seeds for staining, they were cut longitudinally and placed in a Petri dish before they were covered with TTZ stain and put in a cardboard box to avoid light for 24 hrs. (International Seed Testing Association, 2003). Seed mass, viability and dispersal data were recorded in a spreadsheet and are attached as seed viability and dispersal data (Appendix G).

3.8. Effects of *G. robusta* on natural vegetation

To determine if *G. robusta* was suppressing indigenous vegetation, 20 *G. robusta* trees and 20 *S. chirindensis* trees with similar heights and stem diameters were selected. *Searsia chirindensis* (Baker f.) Moffett was selected for this project as it is the most dominant indigenous tree species at Moederlief farm. All heights, diameters, canopy sizes and amounts of litter below each of the 40 trees were measured, and all plots were classified as disturbed or natural. All individual species growing below each canopy were identified and counted. To identify individual species growing below each of the 40 trees, a specimen of every species within each plot was collected in plant presses and later identified in the C.E. Moss Herbarium. Invasive species growing in each plot were classified as such. A 30 cm ruler was used to measure the amount of litter below each tree and 1 m away from the canopy (Figure 6). The depth of litter was measured to determine if there was more litter below *G. robusta* trees than below *S. chirindensis*. Data collected within 40 plots of *G. robusta* and *S. chirindensis* were recorded in a spreadsheet and are attached as vegetation data (Appendix F).

3.9. Invasive assessment of *G. robusta* in South Africa

The risk assessment of *G. robusta* was done through desktop, field and laboratory work and through compiling information from the literature. To evaluate the risk assessment of *G. robusta*, the South African Criteria for Listing Plant Species (SACLPs) for NEMBA established in 2004/2005 by Lesley Henderson was employed (Appendix A). The SACLPs consists of 5 NEMBA

Categories and is considered outdated. An updated version was requested, but it has not been updated. For the sake of this project, focus was placed on the 3 common Categories (Category 1, 2 and 3). The invasive potential of *G. robusta* was assessed using SACLPs and WRA attached as the WRA question sheet (Appendix B) and the WRA score sheet (Appendix C) and given a score and a decision was made. Climatic information of the distribution of *G. robusta* in Queensland, Australia was compared to the South African climatic conditions using CLIMEX to determine areas in South Africa that are most likely to be invaded by *G. robusta*.

3.10. Data analysis

All measurements done in the field and laboratory were recorded in a printed spreadsheet and transferred to a computer. Raw data (Appendices D to H) were analyzed with Pearson correlation, regression models (to determine the relationships between variables) and student's t-test (to test for the significant difference between population means) using IBM SPSS (Statistical Package for the Social Sciences) statistics version 23. Data were interpreted using graphs, maps, tables and numbers obtained during analysis and assessment. To determine the Category in which *G. robusta* should be placed, a decision tree was used. Since the WRA model works in many geographical types (Gordon *et al*., 2008; Zenni *et al*., 2009; Jacobs *et al*., 2014) it was also employed to assess the risk of *G. robusta*.

Chapter 4: Results

4.1. South African areas with similar climatic conditions to Queensland

4.1.1. Areas in South Africa experiencing average temperatures that are similar to Queensland

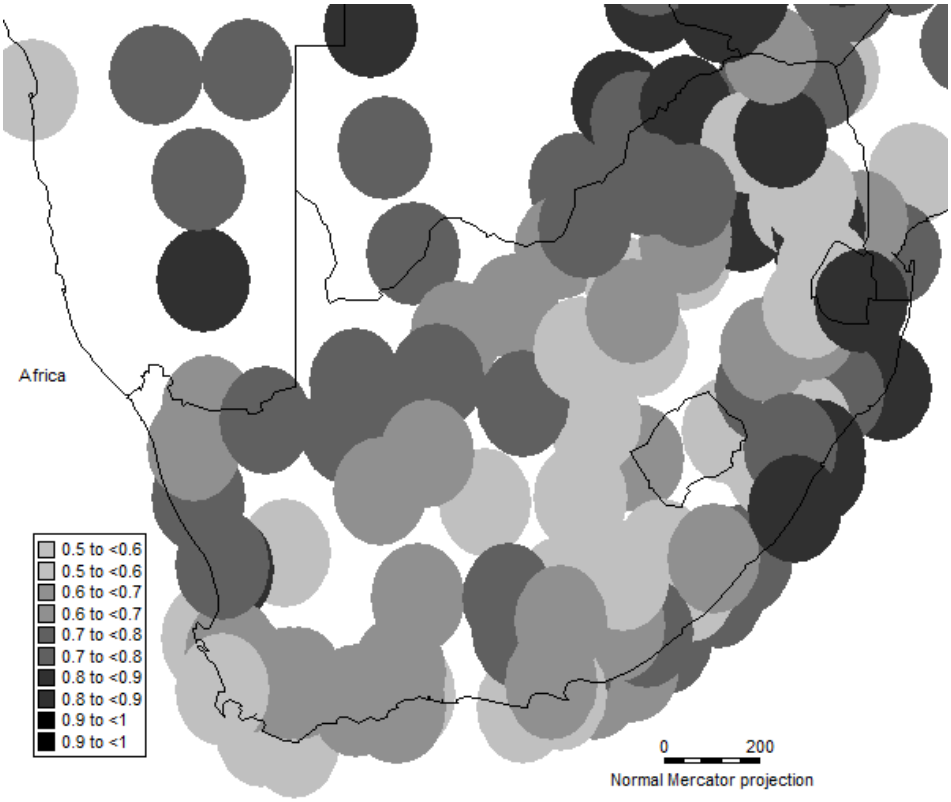


Figure 11: South African CLIMEX map showing average temperature similarities between Queensland and South Africa

Some areas in South Africa have a temperature index that is 80% similar to that of Queensland (Figure 11). These areas are in KwaZulu-Natal, Mpumalanga and Limpopo provinces. Temperature index favours the establishment of *G. robusta* in most parts of the country. If the establishment of *G. robusta* was only dependent on temperature, the tree could potentially grow widely in the country.

4.1.2. Areas in South Africa experiencing annual rainfall that is similar to Queensland

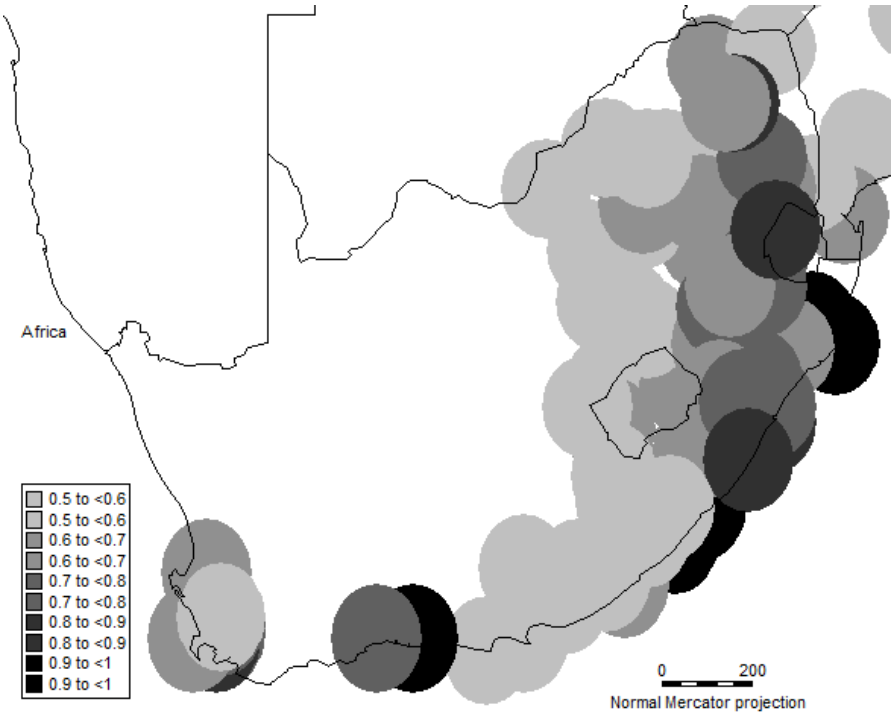


Figure 12: South African CLIMEX map showing average rainfall similarities between Queensland and South Africa

Rainfall between Queensland and South Africa has fewer similarities than temperature. There are pixels with over 70% similarity in parts of Limpopo, KwaZulu-Natal and Eastern Cape and 50% similarity in some parts of Limpopo, Gauteng, Mpumalanga and Eastern Cape.

4.1.3. Areas in South Africa experiencing climatic index that is similar to Queensland

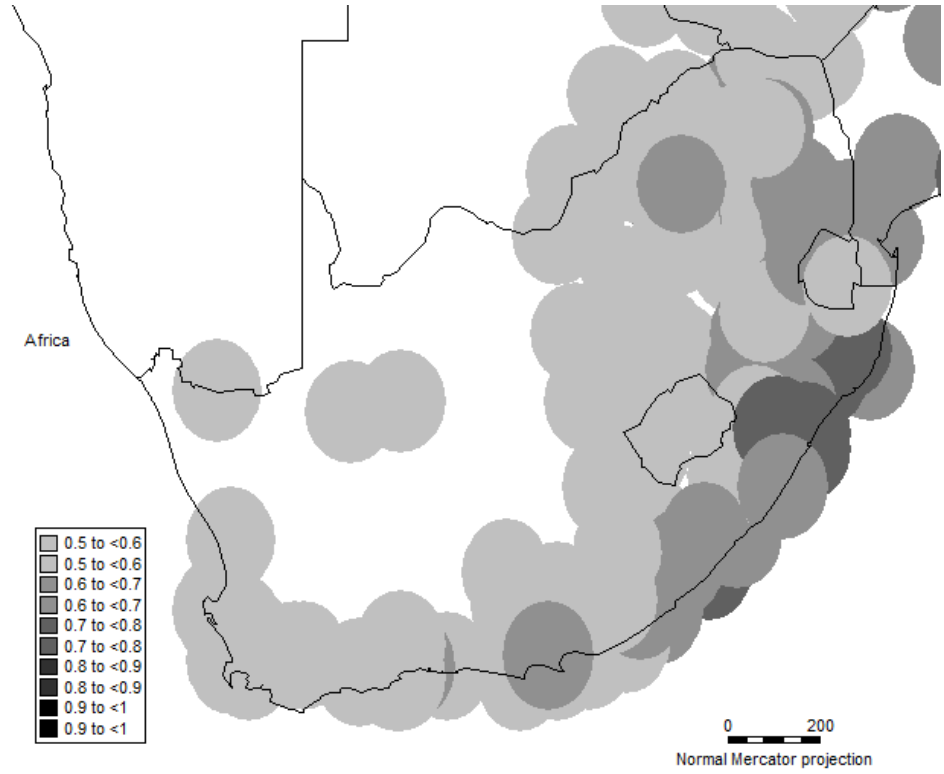


Figure 13: South African CLIMEX map showing climatic similarities between Queensland and South Africa

Climatic match index shows over 70% overall similarities between Queensland and the Eastern Cape. There are over 60% similarities in Limpopo, Gauteng and down the East and South East coastal regions of the country. Most parts of North West, Northern Cape and Free State provinces have less than 50% similarities and *G. robusta* is unlikely to establish in these areas.

4.2. Distribution of *G. robusta* in South Africa

4.2.1. Observations that have been recorded for *G. robusta* in South Africa and the current state of invasion

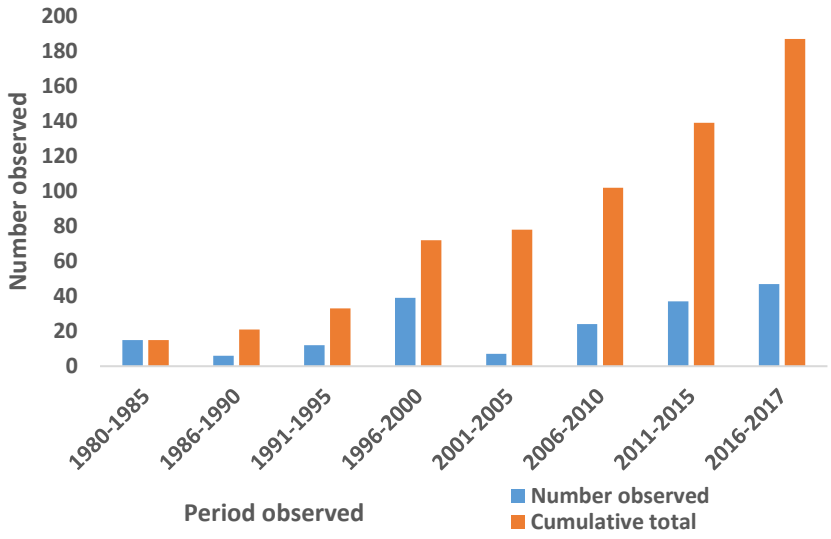


Figure 14: Number of observed localities and the cumulative total of localities of *G. robusta* in South Africa from 1980—2017, the 188 localities were obtained from iSpot and SAPIA databases

The first observation of naturalised *G. robusta* in South Africa was recorded in the early 1980's and since then more observations have been recorded. The number of new observations has steadily increased since 2001, which suggests that the plant is becoming more and more common across the country (Figure 14). The decrease in number of observations between 2001 and 2005 may have been partly due to drought conditions in some of those years, which would have led to reduced flowering and thus reduced perceptibility. The decline in observations may also have been due to the species being declared a Category 3 invader and thus there would have been less focus on it.

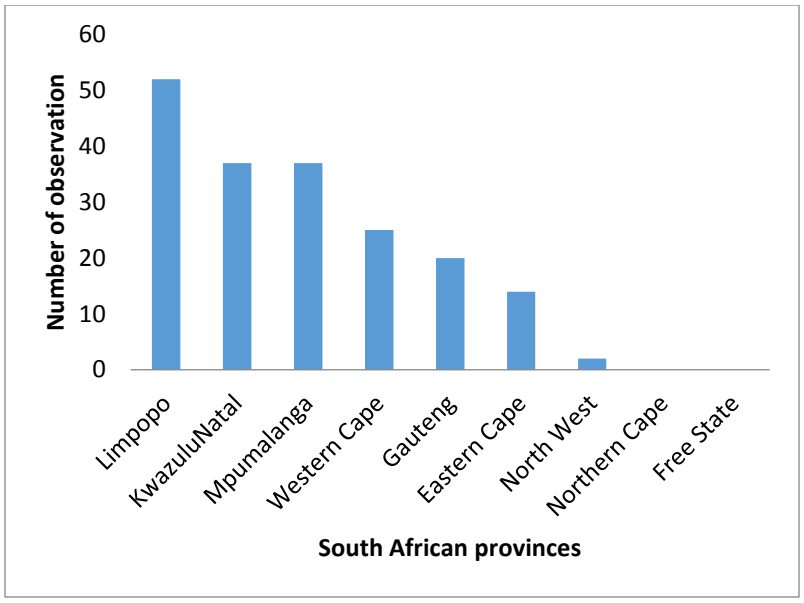


Figure 15: Number of observations made for *G. robusta* in the 9 provinces of South Africa from 1980—2017, the 188 localities were obtained from iSpot and SAPIA databases

Observations of *G. robusta* trees are not evenly distributed in all South Africa's 9 provinces. There were no observations in the Northern Cape and Free State province with only two in the North West province. Limpopo has the most observations followed by KwaZulu-Natal and Mpumalanga with more than 30 observations.

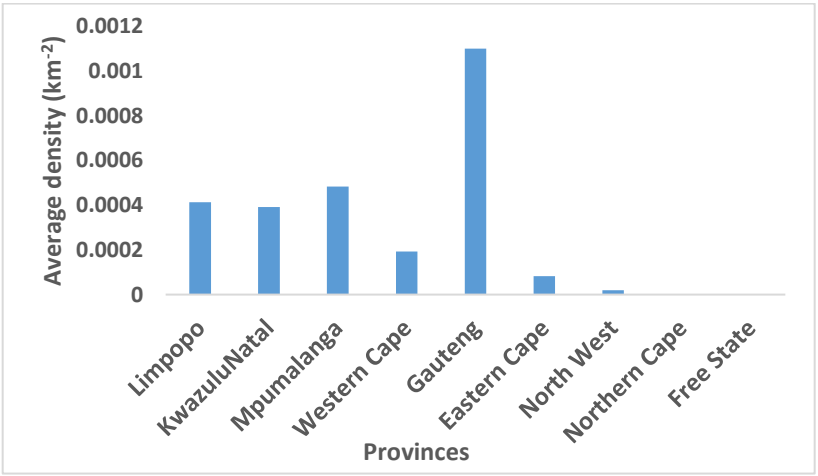


Figure 16: Average density of *G. robusta* in the 9 provinces using land area and number of observations

To get the infested proportion in each province the formula introduced in 3.2 was employed. *Grevillea robusta* has an average density of infestation in the 9 South African provinces of 0.0028 per km^{-2}. Limpopo has the most observations (Figure 15) but Gauteng is the most infested province

due to high number of observations and small surface area of the province (Figure 16). Limpopo province is 125755 km^2 in size and has 52 observations while Gauteng province is 18176 km^2 in size and has 20 observations.

4.3. Population dynamics of *G. robusta* currently growing at Moederlief farm

4.3.1. Current distribution of *G. robusta* at Moederlief farm

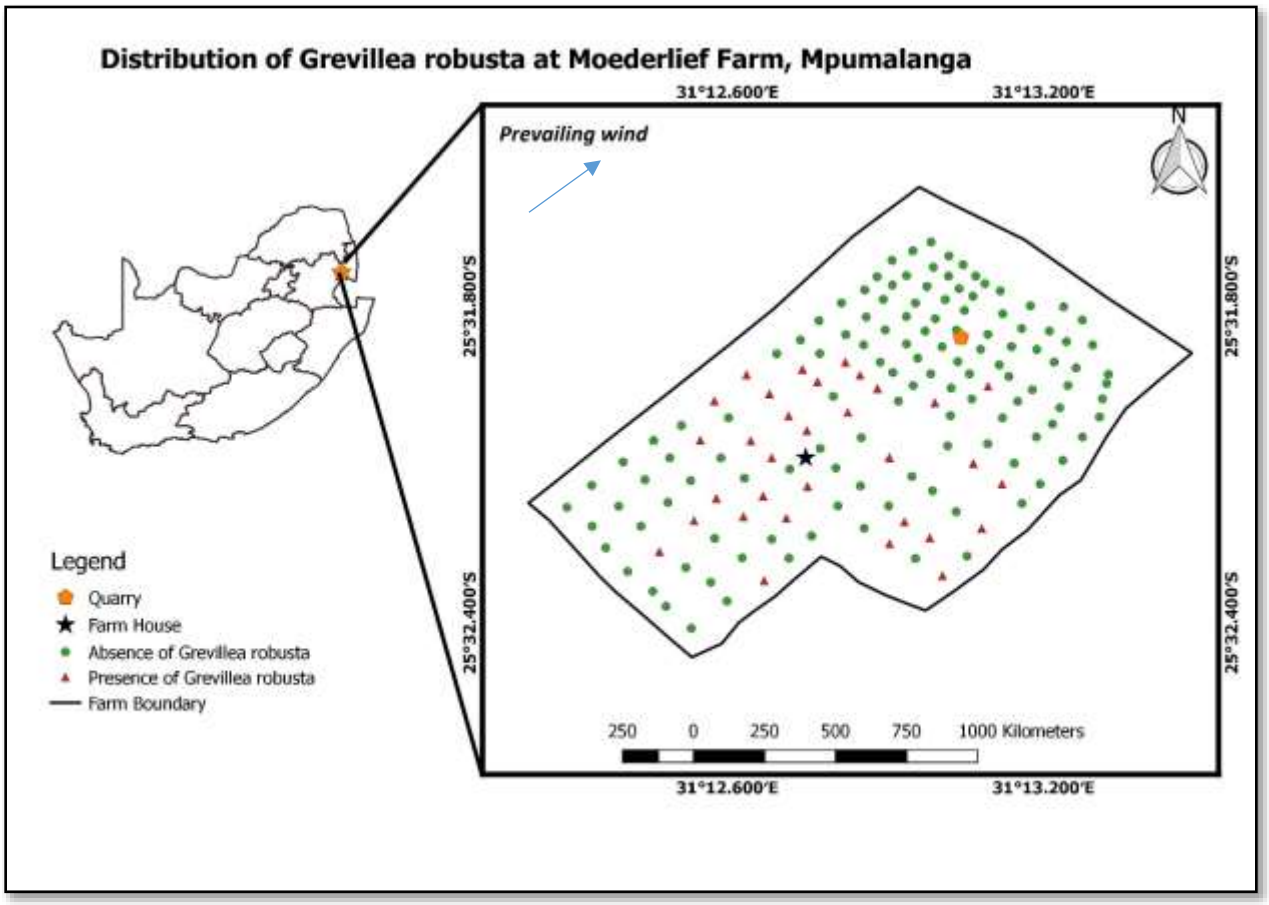


Figure 17: Map of the 159 quadrats of which 32 had *G. robusta* trees (green circles) and 127 did not have *G. robusta* trees (red triangles) at Moederlief farm

Trees of *G. robusta* are scattered in 32 quadrats around the farm with no common pattern. No specimens of *G. robusta* were observed in any quadrat north of the quarry (Figure 17). Since the 159 quadrats surveyed were categorized as the observation window, it was found that 20.12% of the farm is infested with *G. robusta*.

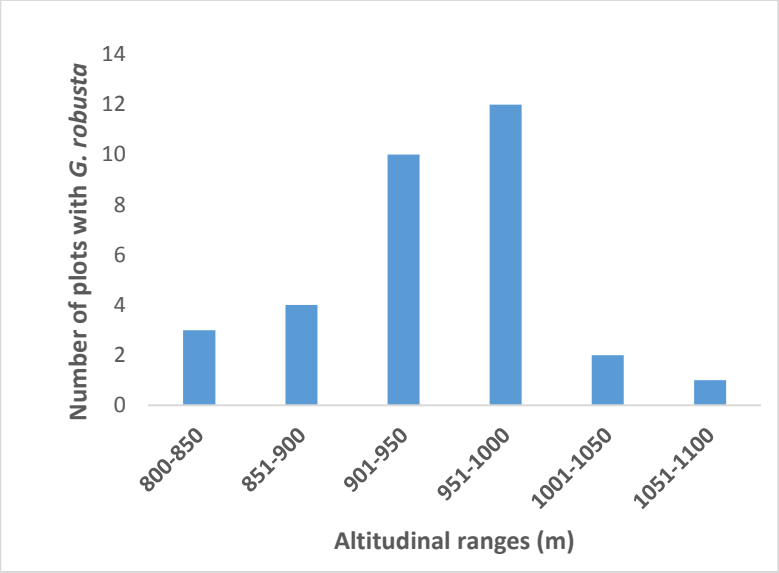


Figure 18: Number of quadrats with *G. robusta* trees at various altitudinal ranges, with a mean altitude of 967 m at Moederlief farm

There were 55 quadrats at 951─1000 m, but only 12 were infested with *G. robusta* and 3 of the 12 quadrats at 800─850 m were infested with *G. robusta* at Moederlief farm (Figure 18). There is a negative relationship between altitude and *G. robusta* survival with fewer trees at higher altitudes (Pearson $r = 0.955$, $N = 6$, $P < 0.003$), there is only 13.4% infested quadrats at altitudes above 1000 m.

Table 1: *Grevillea robusta* trees growing in various vegetation types at Moederlief farm

Vegetation type	Quadrats with *G. robusta* tree at various vegetation types		
	No. of quadrats with *G. robusta*	**% presence**	**Total no. of quadrats**
Forest	25	19.69	127
Grassland	7	21.88	32

Moederlief farm consisted of forest vegetation and grass, but similar proportions of quadrats were infested with *G. robusta* (Table 1) in the two vegetation types. This suggests that *G. robusta* trees invaded both forest and grassland vegetation at Moederlief farm.

4.3.2. Size classes of *G. robusta* trees at Moederlief farm

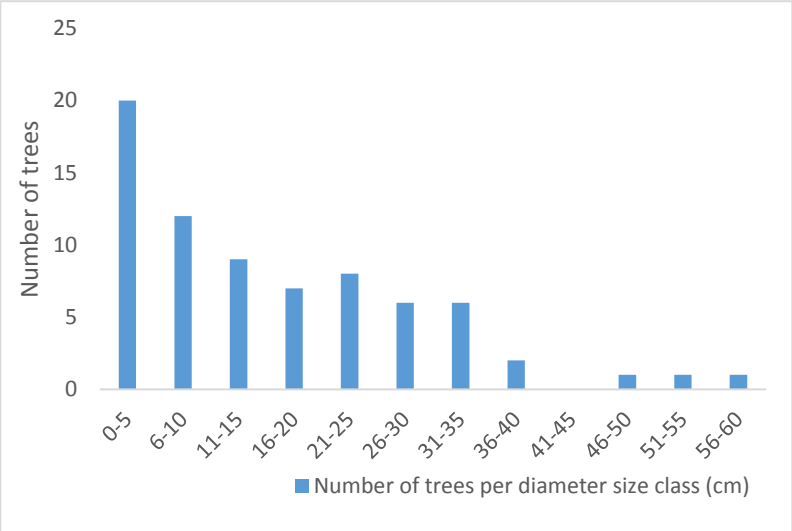


Figure 19: Number of trees within each of 12 basal diameter size classes growing at Moederlief farm, mean of 16.1 and a standard deviation of 13.4

The population structure of *G. robusta* trees at Moederlief is an inverse J-curve consisting of more small diameters than big diameters. Based on the results as stipulated by figure 19, there are 20 seedlings of population size 0─5 cm and only 1 tree in population size 56─60 cm in basal diameter. The results show that the population structure of *G. robusta* is increasing at Moederlief farm. (Pearson correlation $r= -0.9029$, $N= 12$, $P< 0.00001$), results show a negative correlation between size and the number of trees of *G. robusta* at Moederlief.



Figure 20: Six G. robusta seedlings growing at Moederlief farm on the area that was previously excavated during mining operations

Excavated, eroded and burnt areas at Moederlief farm have more *G. robusta* trees present than undisturbed areas. This could be due to regeneration of *G. robusta* usually following land disturbance incidents.

4.3.3. Size at which trees of *G. robusta* reproduce

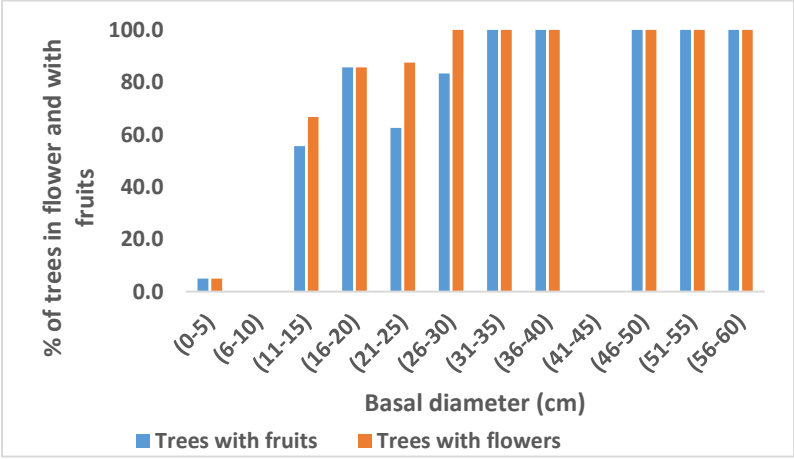


Figure 21: *Grevillea robusta* size of reproduction of 12 basal diameter size classes at Moederlief farm

Trees over 11 cm in basal diameter had all flowered and those over 30 cm had fruits from the previous year and flowers. There is a positive Pearson correlation between fruits and flowers (Pearson *r= 0.980, N= 12, P< 0.00001*) which indicates that trees were reproductive in the previous season.

4.3.4. The density and number of individuals of *G. robusta* in each quadrat at Moederlief farm

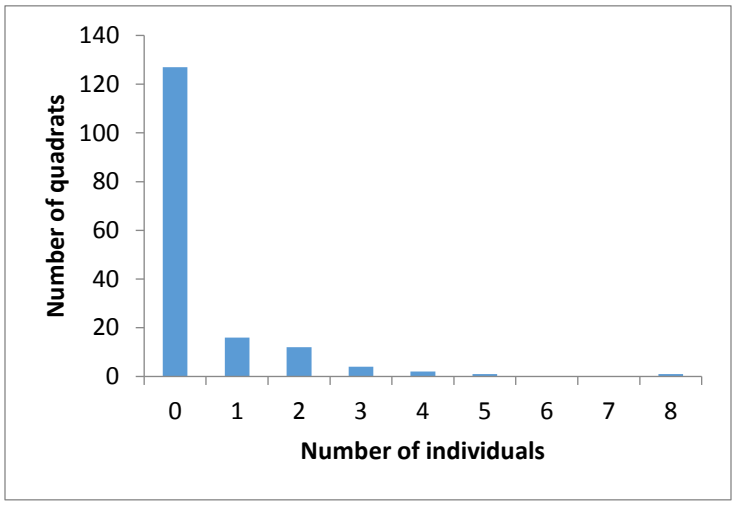


Figure 22: Number of trees in 32 quadrats at Moederlief farm

There were 73 trees dispersed in 32 of the 159 surveyed quadrats and it is more likely to find 1 or 2 trees in a quadrat than 5 trees in a quadrat.

4.3.5. Mortality rate of *G. robusta* at Moederlief farm

Table 2: Mortality of *G. robusta* trees per size class at Moederlief farm

Basal diameter size classes	*Status of tree*		
	Living	*Dead*	*Total*
0—5	*13*	*8*	*21*
6—10	*12*	*0*	*12*
11—15	*7*	*0*	*7*
16—20	*7*	*0*	*7*
21—25	*8*	*0*	*8*
26—30	*7*	*0*	*7*
31—35	*5*	*0*	*5*
36—40	*2*	*0*	*2*
46—50	*0*	*1*	*1*
51—55	*2*	*0*	*2*
56—60	*1*	*0*	*1*
Total	*64*	*9*	*73*

There are 64 living and 9 dead trees in quadrats at Moederlief farm. This shows that the mortality rate for *G. robusta* at Moederlief farm is low (Table 2).

4.3.6. Damage to trees and survival of damaged trees

Table 3: Damaged trees in 5 of the 12 size classes at Moederlief farm

Size class (cm)	*Cut*	*Fire*	*Living*	*Dead*
5─10	*0*	*8*	*13*	*8*
6─10	*0*	*4*	*12*	*0*
11─15	*0*	*0*	*7*	*0*
16─20	*0*	*0*	*7*	*0*
21─25	*0*	*1*	*8*	*0*
26─30	*0*	*1*	*7*	*0*
31─35	*0*	*0*	*5*	*0*
36─40	*0*	*0*	*2*	*0*
46─50	*1*	*0*	*0*	*1*
51─55	*0*	*0*	*2*	*0*
56─60	*0*	*0*	*1*	*0*
Total	*1*	*14*	*64*	*9*

Trees of *G. robusta* observed at Moederlief farm show evidence of fire damage in the 0─30 cm diameter classes. There were 14 trees burnt and only 1 cut from the sample. All burnt individuals in size class 0─5 cm were dead and 1 each in size class 21─25 and 26─30 cm diameter were alive (Table 3). Younger trees are more vulnerable to damage and more likely to die than older trees if they are damaged.



Figure 23: Two dead stumps of *G. robusta* at Moederlief farm that have been sprayed with Plenum 160ME and now with termite nests

During field visits to Moederlief farm in 2018, it was found that some of the trees had been previously cut and sprayed with Plenum 160ME herbicide and all sprayed stumps were dead. The observed stumps ranged from 16 to 39 cm in diameter.

4.4. Relationship between age and tree size

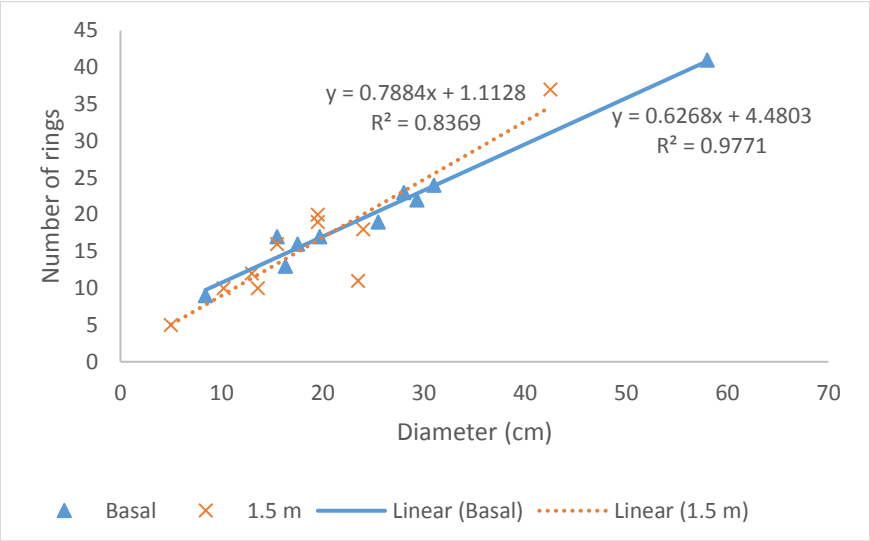


Figure 24: Relationship between tree age and diameter at the base and 1.5 m above ground using tree age rings of 10 *Grevillea robusta* trees

There is a close relationship between diameter sizes and age rings at the base of a tree than at 1.5 m (Pearson *r= 0.977, N= 10, P= 0.0001*). A *G. robusta* tree has a size increment of 0.63 cm diameter in a year. Therefore the biggest tree at the house is likely to have been planted in 1965 (2018 - (84.1 cm * 0.63 years per cm = 52.92 years). Diameter sizes and age rings at 1.5 m above the ground also have a positive relationship (Pearson *r= 0.836, N= 10, P= 0.000206*).

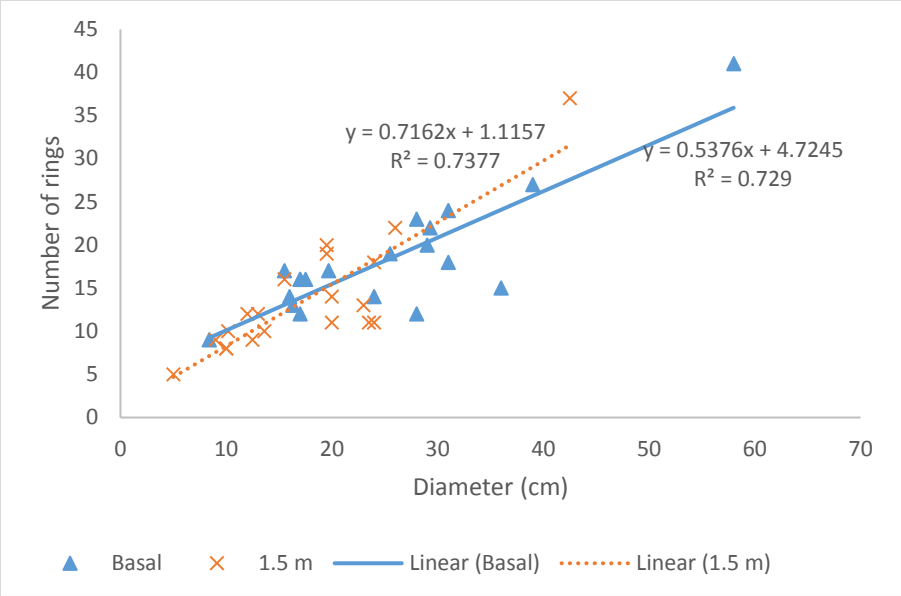


Figure 25: Relationship between tree age and diameter at the base and 1.5 m above ground using tree age rings of 20 *Grevillea robusta* trees

There is also a positive relationship between diameter sizes and age rings at the base of a tree (Pearson *r= 0.859, N= 20, P= 0.00001*), with an addition of 10 samples of diameter sizes ranging from 17 to 39 cm. Using all 20 tree samples, a *G. robusta* tree has a size increment of 0.54 cm diameter in a year. Using this calculation, the biggest tree at the house is likely to have been planted in 1972 (2018 - (84.1 cm * 0.54 years per cm = 45.4 years). Diameter sizes and age rings at 1.5 m above the ground also have a positive relationship that is similar to basal diameter (Pearson *r= 0.850, N= 20, P= 0.00001*).

Table 4: Likely ages of nine *G. robusta* trees found next to the house and nine *G. robusta* trees found away from the house at Moederlief farm, using 10 and 20 wood samples

Possible planted trees at the house			*Possible self-seeded trees from the plots*		
Diameter (cm)	*Age with 10 samples*	*Age with 20 samples*	*Diameter (cm)*	*Age with 10 samples*	*Age with 20 samples*
84.1	*52.97*	*45.40*	*50*	*31.50*	*27.00*
77.7	*48.96*	*41.96*	*47.0*	*29.61*	*25.38*
62.4	*39.32*	*33.71*	*38.2*	*24.08*	*20.64*
59.9	*37.74*	*32.35*	*28.7*	*18.06*	*15.48*
56.7	*35.71*	*30.61*	*28.7*	*18.06*	*15.48*
44.6	*28.09*	*24.08*	*28.0*	*17.66*	*15.13*
43.3	*27.29*	*23.39*	*26.8*	*16.85*	*14.45*
42.4	*26.68*	*22.87*	*26.8*	*16.85*	*14.45*
42.0	*26.48*	*22.70*	*26.8*	*16.85*	*14.45*
26.8	*16.85*	*14.45*	*26.5*	*16.70*	*14.31*

The biggest *G. robusta* tree at Moederlief farm was found next to the main house with a diameter of 84.1 cm. The biggest tree found away from the house was 50 cm in diameter. The tree was estimated to be 31.5 years of age with 10 samples and this suggest that trees started colonizing the farm 21.47 years (or 18.4 years with 20 samples) after the original was planted.

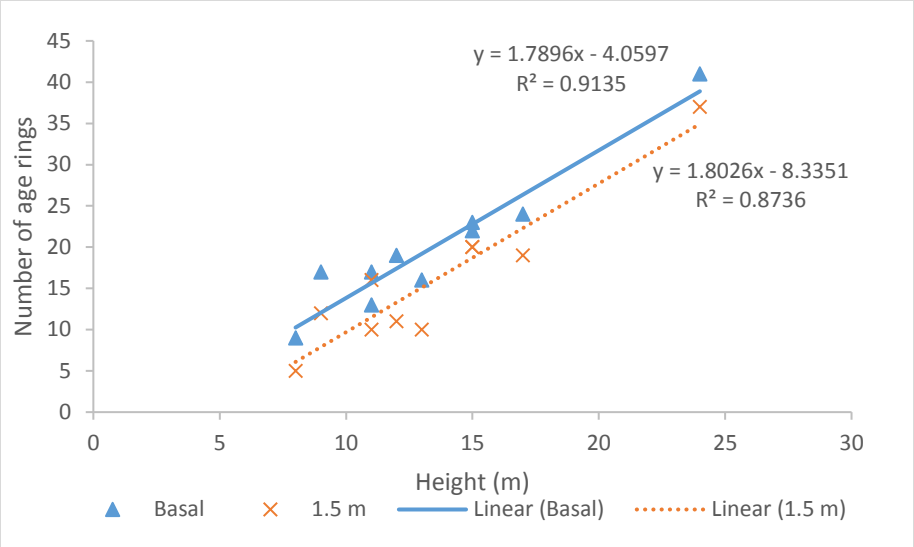


Figure 26: Relationship between tree age and height using tree age rings of 10 *Grevillea robusta* trees

There is a positive correlation between height and number of age rings of *G. robusta* at the base (Pearson *r= 0.913, N= 10, P< 0.0001*) and at 1.5 m above ground (*Pearson r= 0.873, N= 10, P< 0.0001).* Height and age rings have a positive correlation at Moederlief farm.

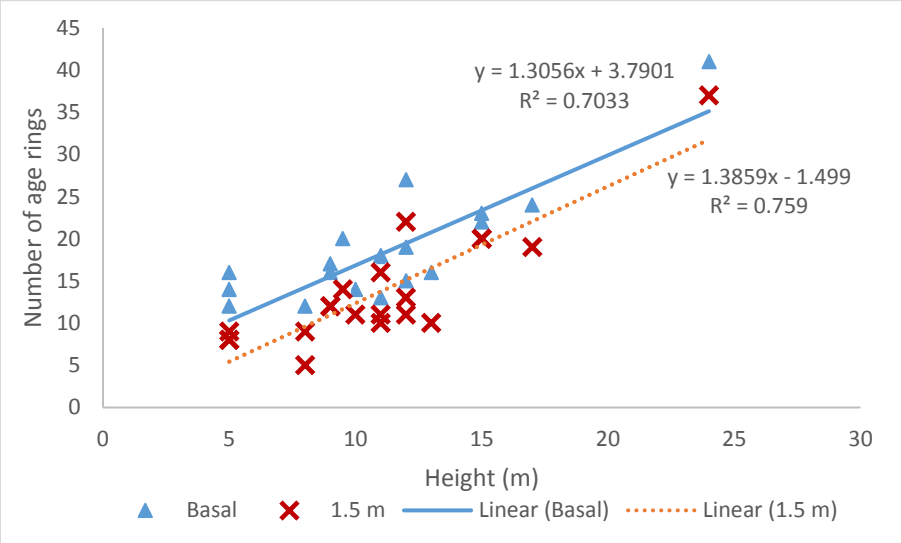


Figure 27: Relationship between tree age and height using tree age rings of 20 *Grevillea robusta* trees

There is a positive correlation between height and number of age rings using 20 *G. robusta* wood slices at the base of a tree (Pearson *r= 0.703, N= 20, P< 0.00001*), which is slightly less than when using 10 trees of diameter sizes ranging from 8.5 to 58 cm. The number of rings at 1.5 m above the ground has a positive correlation with height (Pearson *r= 0.971, N= 20, P< 0.00001).*

4.5. Mass and dispersal of seed of *G. robusta*

4.5.1. Seed viability

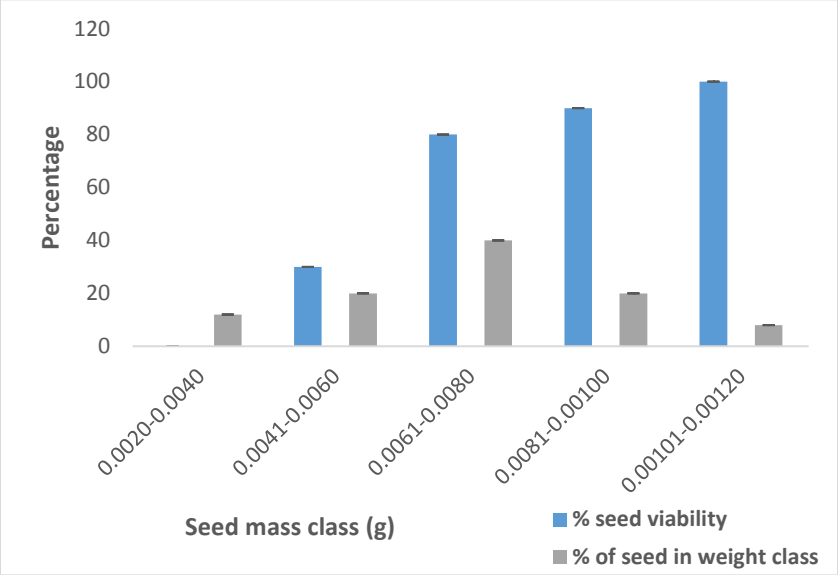


Figure 28: Seed viability percentage of 32 viable and 18 non-viable seeds and percentage of *Grevillea robusta* seed within each mass class

Seed viability within the 5 size classes is influenced by mass (Pearson r= 0.956, N= 5, P= 0.0110). A total of 64% seeds collected at Moederlief farm were viable and at least 80% of seeds that weighed more than 0.0061 g were viable (Figure 28). All *G. robusta* seeds weighing less than 0.0040 g are not viable.

4.5.2. Mean seed mass of *G. robusta* at Moederlief farm

Seed from Moederlief farm has a mass ranging from 0.0048 to 0.108 g, a mean mass of 0.0068 g with the standard deviation of 0.0021 g. The time it took a seed to reach the ground depended on the mass of the seed with a mean time of 11.15s for all 50 seeds. Seed dispersal distance depends on the mass of the seed and wind speed. Non-viable seeds have a dispersal distance mean of 212 m compared to 152 m of viable seeds (Table 5).

Table 5: Means and standard deviations of 32 viable and 18 non-viable seed masses and dispersal distances, velocities and times

	Viable seeds		*Non-viable seeds*	
Treatment	*Mean*	*Standard deviation*	*Mean*	*Standard deviation*
Seed mass (g)	*0.0078*	*0.0017*	*0.0051*	*0.0018*
Falling time (s)	*9*	*1.09*	*12.44*	*3.046*
Terminal velocity (m/s)	*2.27*	*0.3019*	*1.7008*	*0.4152*
Potential dispersal time (s) from 25 m	*11.15*	*1.36*	*15.5556*	*3.8081*
Potential dispersal distance (m)	*151.67*	*18.53*	*211.5556*	*50.351*
n		*32*		*18*

4.5.3. Potential seed dispersal distances at Nelspruit

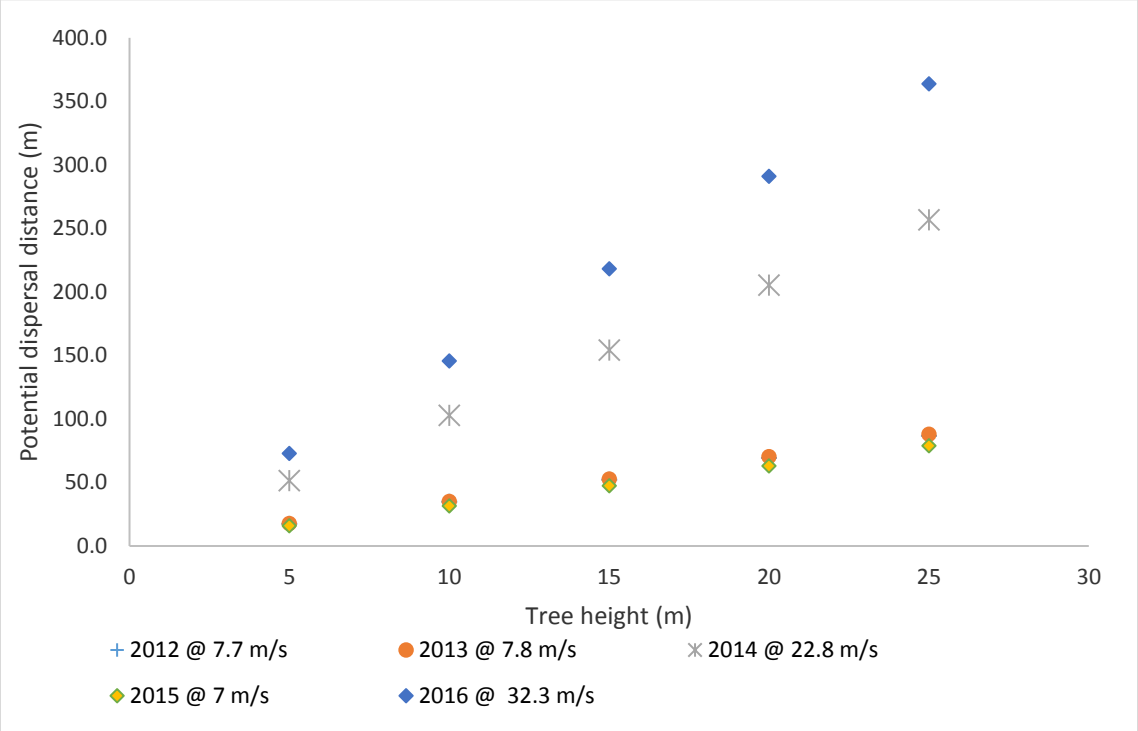


Figure 29: Potential distances of dispersal for viable seeds of *G. robusta* in Nelspruit from 2012 to 2016 at maximum wind speeds

Grevillea robusta seed dispersal distance was determined for the previous 5 years using the formula described in Chapter 3 section 3.6. The maximum wind speed in each year was employed to determine how far seeds could be dispersed. The shortest *G. robusta* tree with seed at Moederlief

farm was 10 m high and could disperse seed over 146 m away at 32.3 m/s and the tallest tree was 25 m high and can disperse seed 364 m away at 32.3 m/s which is the strongest recorded wind speed at Nelspruit between 2012 and 2016. Seed from the top of tall trees can be dispersed further from canopies than seeds from short trees at the same wind speed.

4.6. Effects of *G. robusta* on natural vegetation at Moederlief farm

Table 6: Means and standard deviations of number of all species (weeds and indigenous), number of weeds and number of all individuals (weeds and indigenous) of 20 *G. robusta* and 20 *S. chirindensis* plots at Moederlief farm

***G. robusta* plots (n= 20)**			***S. chirindensis* plots (n= 20)**	
	Disturbed vegetation		***Disturbed vegetation***	
	Mean	**Standard deviation**	**Mean**	**Standard deviation**
No. of all species	*4.78*	*1.3*	*6.44*	*1.81*
No. of individual weeds	*0.78*	*0.97*	*6.33*	*9.29*
No. of all individuals	*26*	*13.13*	*28.22*	*16.84*
	Natural vegetation		***Natural vegetation***	
	Mean	***Standard deviation***	***Mean***	***Standard deviation***
No. of all species	*5.73*	*1.68*	*6*	*1.89*
No. of individual weeds	*0.36*	*1.2*	*4.27*	*4.62*
No. of all individuals	*30.27*	*14.81*	*40*	*15.52*

There is a no significant difference in the number of species (Indigenous and weeds) growing below *G. robusta* and *S. chirindensis* at Moederlief farm (P= 0.0642). There is no significant difference between number of all individual (indigenous and weeds) growing below *G. robusta* and *S. chirindensis* at Moederlief farm (P=0.1350). There is no significance difference in the number of weed species growing below *G. robusta* and *S. chirindensis* (P = 0.1422).

Table 7: Depth of litter below and 1 m away from each of 20 *G. robusta* and 20 *S. chirindensis* trees

	Mean (cm)	*Standard deviation (cm)*
Litter below G. robusta trees	*2.33*	*1.56*
Litter 1 m away G. robusta trees	*1.38*	*1.28*
Litter below S. chirindensis trees	*1.42*	*1.26*
Litter 1 m away S. chirindensis trees	*2.5*	*1.41*

There is more litter below *G. robusta* trees than below *S. chirindensis* tree canopies with a mean of 2.33 cm (*P= 0.00024*).

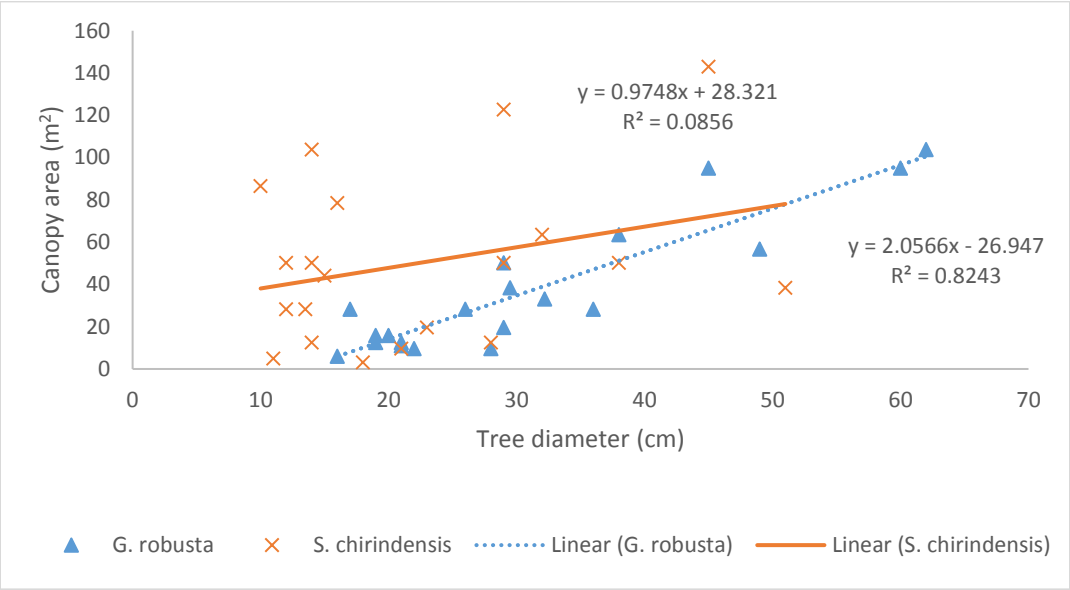


Figure 30: Tree canopy cover and tree diameter of 20 *G. robusta* and 20 *S. chirindensis* trees

There is a positive correlation (Pearson *r= 0.9079, N= 20, P= 0.00001)* between tree diameter size and canopy area covered by selected trees of *G. robusta*. There was no correlation between tree diameter size and area covered by *S. chirindensis* tree canopy area (Pearson *r= 0.293, N= 20, P= 0.210). Grevillea robusta* canopy area increases with an increase in stem diameter.

5. Chapter 5: Discussion

5.1. Distribution of *G. robusta* in South Africa

About 8% of South African land is infested with invasive species, with the Western Cape, Northern Cape and Mpumalanga being the top most invaded provinces (Van Wilgen *et al*., 2001). Ecological information is combined with statistical data to make a prediction of the distribution of a species (Elith & Leathwick, 2009). The first naturalised record of *G. robusta* trees in South Africa was in the 1980's (Rebelo, 2008), but there is no specific date of the first introduction or when it was first planted (Nyoka, 2003). *Grevillea robusta* trees in South Africa are widely planted as windbreaks around farms and as ornamental trees on the roadside and in households (Richardson & Rejmánek, 2011; Moodley *et al*., 2014). Records from SAPIA, iSpot and personal observations also recorded *G. robusta* planted as an ornamental and windbreak tree. Limpopo has the most observations of *G. robusta* (Figure 15), so the province should be considered a high risk area.

5.2. South African areas with similar climatic conditions to the native range of *G. robusta*

Grevillea robusta is an Australian tree occurring in the warm humid and sub-humid climatic zones (Kalinganire, 1996). *Grevillea robusta* is naturally distributed in northern New South Wales and southern Queensland, Australia (Figure 2). The use of pest risk maps is key in determining the potential places where a pest could establish, spread and cause environmental harm (Venette *et al.,* 2010). A climatic match index map shows that Limpopo province, Eastern Cape and the coastal regions of the country are suitable for colonisation by *G. robusta* (Figures 11, 12 and 13) and this is supported by figures 14, 15 and 16. Most observations of *G. robusta* were noted in Limpopo province and the coastal regions. The climatic match index map in figure 13 shows unsuitability (climatic dissimilarities) of *G. robusta* to grow in Northern Cape and Free State provinces and this is later confirmed by figure 15. Populations of *G. robusta* can be expected to increase in the Eastern and coastal regions due to the similarity of the climate in coastal regions to that of the native range of *G. robusta* (Figure 2).

Grevillea robusta tolerates minimum temperatures between 1°C and 12°C and high temperatures ranging from 25°C to 31°C (Kalinganire, 1992; Harwood & Booth, 1992; Harwood, 1992; Brand

et al., 2013). The species can also survive temperatures down to -8°C (Harwood, 1997). Temperature match index has similarities of *G. robusta* ecological tolerance with most parts of South Africa. Parts of Limpopo, Mpumalanga and Western Cape provinces have a match index of over 70% which suggests a good chance of *G. robusta* establishment (Figure 11).

In its native range *G. robusta* occurs where rainfall is between 700 to 2500 mm per annum (Brand *et al*., 2013) most of which is received in summer. Northern Cape receives rainfall of less than 250 mm per annum while in North West rainfall ranges from 500 to 750 mm per annum (Cowling *et al*., 2001) and thus is suitable for colonisation by *G. robusta.* There were only a few observations made in North West as it is at the edge of the range (Figure 15). With reference to rainfall match index (Figure 12), Limpopo, Mpumalanga and coastal parts of the country except for Northern Cape, Free State and North West province are suitable for colonisation by *G. robusta.* Queensland and most parts of South Africa receive summer rainfall and this may improve the chances of establishment of *G. robusta* in South Africa. Rainfall seasons and temperatures in Nelspruit fall within the ecological tolerance of *G. robusta* and trees invading farms such as Moederlief farm are likely to continue invading.

5.3. Populations of *G. robusta* at Moederlief farm

Future population demography and regeneration status have been frequently predicted using current population size structure (Baker *et al*., 2005; Virillo *et al*., 2011). The population structure of *G. robusta* at Moederlief farm matches an inverse J-curve (Figure 19) showing that it is a healthy, expanding population. The populations of *G. robusta* at Moederlief farm consist of more small individuals than large individuals. Thus the population of *G. robusta* at Moederlief farm is increasing and is likely to invade even further. The populations at Moederlief farm are expected to increase steadily as the structure comprises many healthy seedlings and few very large trees (Figure 19). Populations of *G. robusta* have been increasing since first introduction of the trees and Moederlief farm has favorable growing conditions. *Grevillea robusta* trees are dispersed around the farm (Figure 17), and it was unlikely to get more than 2 trees growing in a 10*10 m quadrat (Figure 22). 20.12% of the quadrats in Moederlief farm were infested with *G. robusta*. Seedlings at Moederlief farm are likely to survive and reach maturity as there are trees in all size groups.

Growth rate and performance of *G. robusta* are affected by site and the density of trees growing at a particular location (Kalinganire, 1992). In the native range, trees of *G. robusta* have an average growth rate of 0.13 m in height per month (1.56 m per year) (Harwood, 1992). *Grevillea robusta* has a growth rate of 2 m per year in height and 2 cm in diameter per year in a suitable environment (Harwood & Booth, 1992). In Rwanda, diameter growth rate of *G. robusta* ranges from 0.9 cm to 3.4 cm per year and from 2 m to 3 m in height per year (Kalinganire 1996). The growth rate of *G. robusta* can vary with tree age, growing seasons and place.

Trees of *G. robusta* growing at Moederlief farm have a growth rate of 0.54 cm per year with the 20 sample data set and 0.63 cm in diameter per year with the 10 sample data set (Figures 24 and 25). Height increases at 1.7 m for 10 samples and 1.3 m for 20 samples per year (Figures 26 and 27). *Grevillea robusta* trees at Moederlief farm have a slow growth rate compared to its native range and other places out of the natural distribution. The biggest tree at Moederlief farm was found next to the house and had age estimates of 52 or 45 years in 2017 (Table 4). This tree is likely to have been planted in 1964 or 1972 (depending on the curve that is used for calculation ─ i.e. figure 24 or 25) or shortly thereafter.

5.4. Reproduction of *G. robusta*

Flowering and fruiting in *G. robusta* starts when trees are 4 years old (Kalinganire, 1992). Trees of *G. robusta* produce mature seed at the age of 8 years but may fail to produce seed in the following one or two reproductive seasons (Harwood, 1992). Trees with a diameter of 5 cm were flowering and had fruits (Figure 21). This suggests that trees are ready for reproduction at the age of 8. *Grevillea robusta* is a light-dependent species (Kalinganire, 1992; Harwood *et al*., 1997), and the tree does not easily regenerate under closed canopies (Harwood, 1992). Trees of *G robusta* were observed growing in disturbed areas at Moederlief farm (Figure 20) and 9 of the 20 *G. robusta* plots were disturbed (Table 6). Seedlings of *G. robusta* were found to be more common in disturbed and open vegetation as there is enough light in disturbed areas (Figure 20).

5.5. Damage to trees and how trees survive damage

The owners of Moederlief farm have cut and sprayed some of the stumps of *G. robusta* with Plenum 160ME and stumps show no signs of regeneration (Figure 23). *Grevillea robusta* is not

listed under species which are effectively controlled by Plenum 160ME (Ecoguard, 2018) such as *Lantana camara* and Psidium *guajava*, but the herbicide is working effectively.

Young *G. robusta* trees are sensitive to frost damage in the growing season (Harwood *et al.*, 1997). There is only 50% chance of frost in Mpumalanga (Cowling *et al*., 2004), and SAWS has no records of frost in Nelspruit since 2012. Seedlings of *G. robusta* which were 3 to 4 months old in Uganda had over 60% survival after being exposed to termites and large herbivores (Moe *et al*., 2016). During dry seasons in Mpumalanga, seedlings and coppice of *G. robusta* were observed to be browsed.

Grevillea robusta is a fire sensitive species so its natural distribution and the survival of young and mature trees may depend on the absence of fires (Harwood, 1997; Geerts *et al*., 2013). Trees of *G. robusta* of size class (0-5 cm) did not recover after being burnt at Moederlief farm (Table 2). Frequent burning of grassland at intervals of not less than 5 years can stop *G. robusta* trees from colonizing grassland (Table 3). At Moederlief farm, 14 trees showed evidence of burning and only 6 of them were alive (Table 3). Trees were cut, slashed and sprayed at Moederlief farm as an attempt to control invasive species such as *Lantana camara* and *G. robusta*. However, the cut stumps were coppicing and growing but those sprayed with herbicides had no signs of recovering during field survey (Figure 23). There was evidence of termite nests on *G. robusta* trees at Moederlief farm (Figure 23), however, this was only noted on dead stumps.

5.6. Effects of altitude on growth of *G. robusta* in South Africa

In Australia, *G. robusta* is found to grow at altitudes of over 1000 m (Harwood, 1992, Brand *et al.*, 2013) but altitudes above 2500 m have a negative impact on tree survival (Kalinganire 1992, Henderson, 2001). In Kenya, trees of *G. robusta* have good growth rates (height and diameter) at altitudes between 1000 and 2000 m above sea level (Kalinganire, 1996). In the survey at Moederlief farm, trees did not occur above 1000 m. Moederlief farm is 25˚ south of the equator (Figure 18). The equator receives direct sun rays while the polar regions receives sun rays at a lower angle and this leads to higher temperatures at the equator and lower temperatures at the polar regions (Quora, 2016). There are higher temperatures at lower latitude and lower temperatures at higher altitude (Reich & Oleksyn, 2004; Xiao *et al*., 2014). As altitude increases by 1000m, temperature decreases by 9.8˚C (Onthesnow, 2018). Temperature decreases by approximately

0.6˚C per 1˚ latitude from the equator (Quora, 2016), thus Moederlief farm would be expected to have temperatures that are 15˚C cooler than areas at the equator at the same altitude. Taking the two compensations into account, there is a difference of 5.2 ˚C difference between where *G. robusta* will grow in Kenya and at Moederlief. Areas in South Africa that are below 1000 m altitude are vulnerable to infestation by *G. robusta*.

5.7. Mass, dispersal and viability of seeds of *G. robusta*

Flattened and winged seeds are known to be wind dispersed and may be dispersed for long distances (Jongejans & Telenius, 2001). *Grevillea robusta* has flat and winged seed (Jackson, 2000). Seed of *G. robusta* in figure 29 shows the potential to be dispersed away from parent trees. Seeds are more likely to leave the fruit when the wind speed is higher and dispersed further away from the parent trees. Heavy seeds fall much quicker than lighter seeds but lighter seeds are dispersed much further away than heavy seeds. Seeds of trees of *G. robusta* at Moederlief farm has a mean mass of 0.0068 g with the standard deviation of 0.0021 g (Table 5). A tree that is 8 years old is 5 m in height and can disperse seed over 72.7 m from its canopy at a wind speed of 32.3 m/s while the tallest recorded tree (25m) at Moederlief farm can disperse seed over 364 m from the canopy (Figure 29).

The larger trees of *G. robusta* found at the house were most likely planted and other trees in the area are likely to have dispersed from these cultivated trees. On the basis of the largest trees near the house having a basal diameter of 84.1 cm, they are likely to have been planted in 1964 or 1972. The oldest naturalized tree surveyed on the farm had a basal diameter of 50 cm, so that it is likely to be 27 or 30.5 years old. Thus there appears to have been a lag phase of between 18 and 22 years before colonization began. The prevailing wind direction at Moederlief farm is east north east. In this direction from the house, where the original trees were planted is a very steep and high slope. It is likely that the wind would deviate to the West and East to avoid the steep slope and those are the directions in which the highest number of quadrats with *G. robusta* trees are found. Seeds are dispersed from the main house trees towards the north and east direction which are in the lower areas of the farm.

Heavy seeds germinate and grow better than lighter seeds which are less viable (Tripathi & Khan, 1990). Old trees from 20 to 40 years produce more viable *G. robusta* seed than younger trees (Harwood, 1992). Seed from trees of *G. robusta* at Moederlief farm had 64% overall viability. Heavy seeds of *G. robusta* are more viable (Figure 28) than lighter seed at Moederlief farm.

5.8. Effects of *G. robusta* on natural vegetation at Moederlief farm

A large amount of alien tree litter (such as *Casuarina equisetifolia L.*) suppresses native vegetation germination and early growth (Hata *et al*., 2010), due to damage and poor resource availability. A considerable amount of litter may delay germination of native seed (Hata *et al*., 2010) and it may also result in slow growth of native seedlings (Xiong & Nilsson, 1999; Hata *et al*., 2010). There is a mean of 2.3 cm thickness of litter below *G. robusta* trees and the amount of litter is likely to suppress the growth of indigenous seedlings compared to 1.4 cm below *S. chirindensis* trees (Table 7). More litter was found below *G. robusta* trees than *S. chirindensis* trees.

Less seedling cover below *G. robusta* trees could be as a result of seed not being able to germinate, or those that grew not being able to survive. Seeds dispersed under *G. robusta* are likely to remain above ground (on top of litter) and thus unable to obtain the moisture needed to trigger germination while those that reach the soil could be buried by litter and rot before they can germinate.

Grevillea robusta trees always compete for soil water and nutrients with any vegetation growing below and near the canopies of *G. robusta* as the tree has shallow roots (Smith *et al*., 1999). The ground below *G. robusta* canopies has an average of 5 species while *S. chirindensis* trees support up to 6 species per tree (Table 6). Up to an average of 34 individuals were growing below *S. chirindensis* trees and 15% of those are invasive species. *Grevillea robusta* is not the only problematic invader at Moederlief farm as there are an average percentage of 4% weeds such *Lantana camara*, *Psidium guajava* and *Ageratum conyzoides* growing with *G. robusta* at Moerderlief farm. *Grevillea robusta* tree canopies hinder not only natural vegetation but also weeds.

Canopy sizes of *G. robusta* can shade other tree species especially in cultivated agricultural farms, but pruning of the tree can limit shading (Smith *et al*., 1999). Old trees of *G. robusta* have a slow growth rate, but younger trees grow faster with a small crown (Harwood, 1992). *Grevillea robusta*

is a light-dependent tree species (Kalinganire, 1992; Harwood *et al*., 1997), and the tree does not easily regenerate under closed canopies (Harwood, 1992). *Grevillea robusta* trees have much bigger canopy areas as compared to *S. chirindensis* with similar trunk basal diameters (Figure 30).

5.9. Weed Risk Assessment question and score sheet

The WRA model was employed to assess the invasive potential of *G. robusta* and determine the extent of risk the species holds in the environment. Since *G. robusta* is already growing in South Africa the WRA will assist in making a decision about whether the species should be removed, controlled or left as it is.

WRA questions sheet

Answer yes (y) or no (n), or don't know (leave blank or?), unless otherwise indicated

	Botanical name:	*Grevillea robusta*		Outcome: Evaluate	
	Common name:	Silky Oak		Score: 6	
	Family name:	Proteaceae		Your name: Rabelani Marikhele	
	History/Biogeography				
A	**1** *Domestication/*	1.01	Is the species highly domesticated. If answer is 'no' got to question 2.01		Y
C	*cultivation*	1.02	Has the species become naturalised where grown		Y
C		1.03	Does the species have weedy races		N
	2 *Climate and*	2.01	Species suited to South African climates (0-low; 1-intermediate; 2-high)		Y
	Distribution	2.02	Quality of climate match data (0-low; 1-intermediate; 2-high)		Y
C		2.03	Broad climate suitability (environmental versatility)		Y
C		2.04	Native or naturalised in regions with extended dry periods		Y
		2.05	Does the species have a history of repeated introductions outside its natural range		
C	**3** *Weed*	3.01	Naturalised beyond native range		Y
E	*elsewhere*	3.02	Garden/amenity/disturbance weed		
A		3.03	Weed of agriculture/horticulture/forestry		Y
E		3.04	Environmental weed		Y
		3.05	Congeneric weed		Y
	Biology/Ecology				
A	**4** *Undesirable*	4.01	Produces spines, thorns or burrs		N
C	*traits*	4.02	Allelopathic		
C		4.03	Parasitic		N
A		4.04	Unpalatable to grazing animals		
C		4.05	Toxic to animals		
C		4.06	Host for recognised pests and pathogens		
C		4.07	Causes allergies or is otherwise toxic to humans		
E		4.08	Creates a fire hazard in natural ecosystems		
E		4.09	Is a shade tolerant plant at some stage of its life cycle		Y
E		4.10	Grows on infertile soils		Y
E		4.11	Climbing or smothering growth habit		N
E		4.12	Forms dense thickets		N
E	**5** *Plant type*	5.01	Aquatic		N
C		5.02	Grass		N
E		5.03	Nitrogen fixing woody plant		
C		5.04	Geophyte		N
C	**6** *Reproduction*	6.01	Evidence of substantial reproductive failure in native habitat		N
C		6.02	Produces viable seed		Y
C		6.03	Hybridises naturally		N
C		6.04	Self-fertilisation		
C		6.05	Requires specialist pollinators		N
C		6.06	Reproduction by vegetative propagation		N
C		6.07	Minimum generative time (years)		≥4
A	**7** *Dispersal*	7.01	Propagules likely to be dispersed unintentionally		Y
C	*mechanisms*	7.02	Propagules dispersed intentionally by people		Y
A		7.03	Propagules likely to disperse as a produce contaminant		N
C		7.04	Propagules adapted to wind dispersal		Y
E		7.05	Propagules buoyant		Y
E		7.06	Propagules bird dispersed		N
C		7.07	Propagules dispersed by other animals (externally)		N
C		7.08	Propagules dispersed by other animals (internally)		N
C	**8** *Persistence*	8.01	Prolific seed production		Y
A	*attributes*	8.02	Evidence that a persistent propagule bank is formed (>1 yr)		
A		8.03	Well controlled by herbicides		Y
C		8.04	Tolerates or benefits from mutilation, cultivation or fire		Y
E		8.05	Effective natural enemies present in Australia		N

A= agricultural, E = environmental, C= combined

WRA score sheet

		a	B	c	d	e
Section		Question	Response [1]	Score	*N* Score	*Y* Score
A	C	1.01	Y	-3	0	-3
	C	1.02	y	1	-1	1
	C	1.03	n	-1	-1	1
		2.01	y	2		2
		2.02	y	2		2
	C	2.03	y	1	0	1
	C	2.04	y	1	0	1
		2.05				
	C	3.01	y	-2	-1	-2
	E	3.02		0	0	0
	A	3.03	y	0	0	0
		3.04	y	0	0	0
	C	3.05	y	0	0	0
B	C	4.01	n	0	0	1
	C	4.02			0	1
	C	4.03	n	0	0	1
	A	4.04			-1	1
	C	4.05	n	0	0	1
	C	4.06			0	1
	C	4.07			0	1
	E	4.08			0	1
	E	4.09	y	1	0	1
	E	4.10	y	1	0	1
	E	4.11	n	0	0	1
	C	4.12	N	0	0	1
C	E	5.01	N	0	0	5
	C	5.02	N	0	0	1
	E	5.03			0	1
	C	5.04	n	0	0	1
	C	6.01	n	0	0	1
	C	6.02	y	1	-1	1
	A	6.03	n	-1	-1	1
	C	6.04			-1	1
	C	6.05	n	0	0	-1
	A	6.06	n	-1	-1	1
	C	6.07	≥4	-1		
	A	7.01	y	1	-1	1
	C	7 02	y	1	-1	1
	A	7.03	n	-1	-1	1
	C	7.04	y	1	-1	1
	E	7.05	y	1	-1	1
	E	7.06	n	-1	-1	1
	C	7.07	n	-1	-1	1
	C	7.08	n	-1	-1	1
	C	8.01	y	1	-1	1
	C	8.02			-1	1
	A	8.03	y	-1	1	-1
	A	8. 4	y	1	-1	1
	C	8.05	n	1	1	-1
		Total Score [3]		3		
		Outcome [4]		Evaluate		
		Agricultural score [6]		4		
		Environmental score [6]		2		

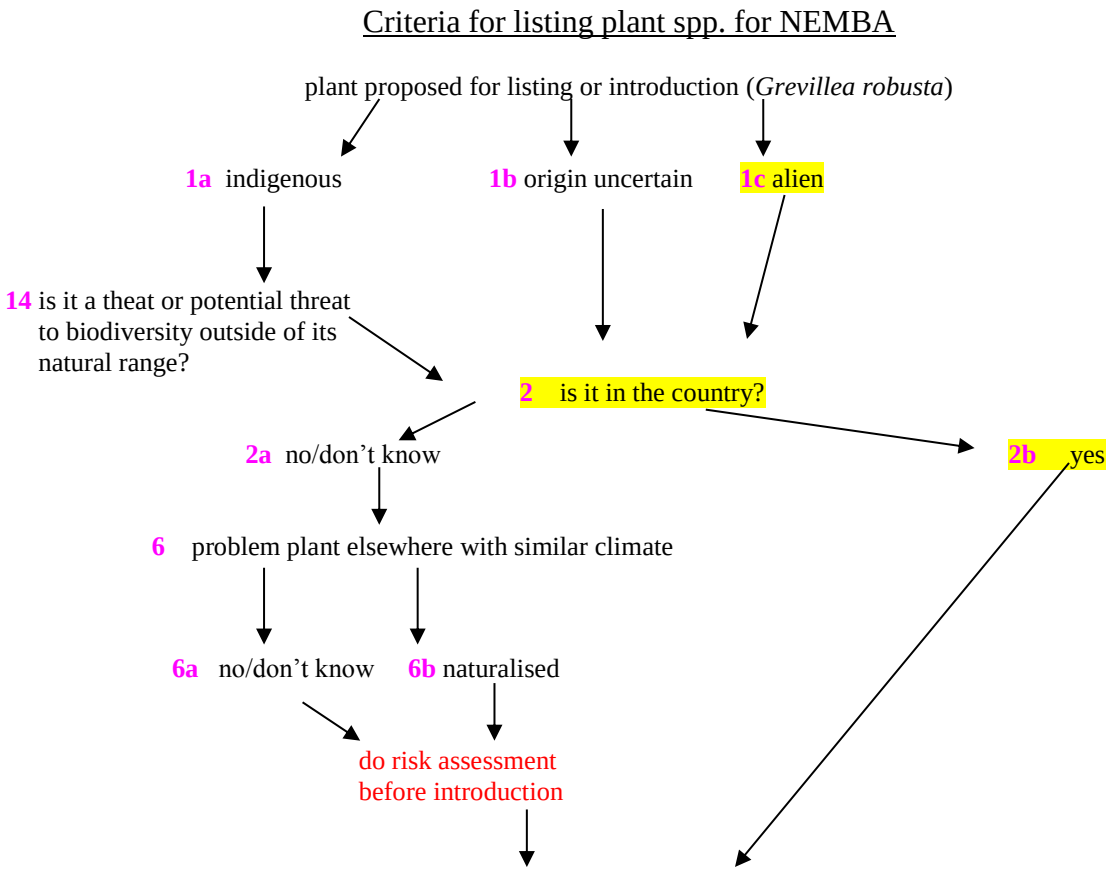
Score	Outcome
< 1	Accept
1 – 6	Evaluate
> 6	Reject

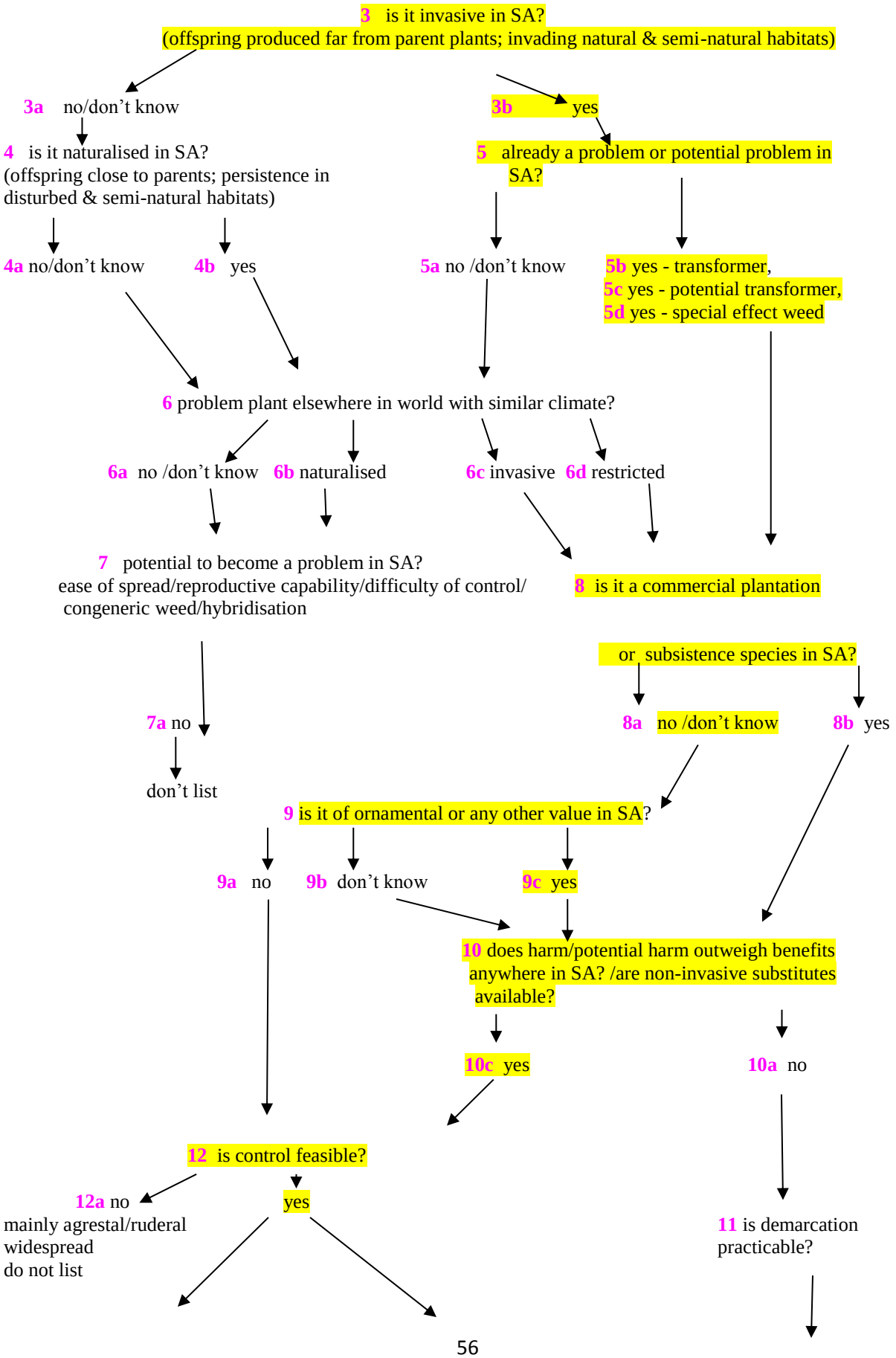
Section Mininmum # Question [5]	
A	6
B	7
C	22
Total	35

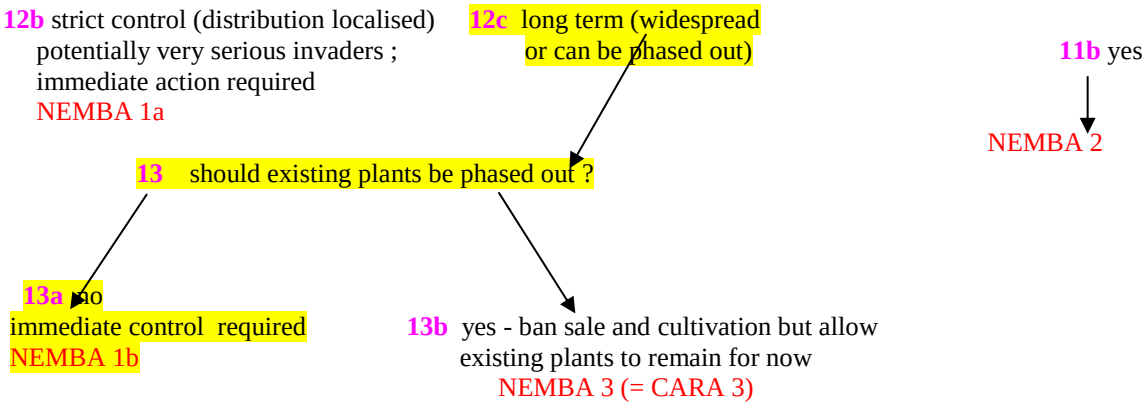
Grevillea robusta is widely cultivated in South Africa (Figure 14) and at over 100 localities it appears to have naturalised (Figure 17). *Grevillea robusta* grows in other countries outside of its native range and it has even been declared a weed in Australia. The tree grows well in fertile soil (Kalinganire, 1992; Harwood, 1992; Henderson, 2001). *Grevillea robusta* is a prolific seed producer that produces viable seed (Figure 28) that are dispersed by wind (Figure 29). The plant has a score of 3, which would indicate that there is a need to evaluate *G. robusta*, as has been done in this study.

5.10. Criteria for listing plant spp. for NEMBA

To determine the appropriate NEMBA Category in which *G. robusta* should be placed, SACLPs was employed to assess the invasive potential of *G. robusta* in South Africa. Since the number of individuals of the species is currently increasing in South Africa, a decision on the Category will assist policy makers on the management of the species going forward.




3 is it invasive in SA?
(offspring produced far from parent plants; invading natural & semi-natural habitats)
3a no/don't know
3b yes
4 is it naturalised in SA?
(offspring close to parents; persistence in disturbed & semi-natural habitats)
5 already a problem or potential problem in SA?
4a no/don't know
4b yes
5a no /don't know
5b yes - transformer,
5c yes - potential transformer,
5d yes - special effect weed
6 problem plant elsewhere in world with similar climate?
6a no /don't know
6b naturalised
6c invasive
6d restricted
7 potential to become a problem in SA?
ease of spread/reproductive capability/difficulty of control/
congeneric weed/hybridisation
8 is it a commercial plantation
or subsistence species in SA?
7a no
don't list
8a no /don't know
8b yes
9 is it of ornamental or any other value in SA?
9a no
9b don't know
9c yes
10 does harm/potential harm outweigh benefits anywhere in SA? /are non-invasive substitutes available?
10c yes
10a no
12 is control feasible?
12a no
mainly agrestal/ruderal
widespread
do not list
yes
11 is demarcation practicable?



Summary for NEMBA listing

Grevillea robusta is indigenous to Australia and is thriving in South Africa. The plant is already a problem in South Africa with seedlings establishing in natural vegetation. *Grevillea robusta* has characteristics that suppress indigenous tree species (i.e. dense litter and shade below its canopies). *Grevillea robusta* has shown evidence of suppressing indigenous species. The tree has been widely planted as an ornamental and a windbreak. The plant is a good competitor for resources with big canopies shading other trees. Trees of *G. robusta* can survive fires once they have reached 6─10 cm in basal diameter (i.e. 5 years of age) and resprout after being cut but will not survive herbicides. *Grevillea robusta* trees are producing viable seeds which can be dispersed far from parent trees and into riparian areas. *Grevillea robusta* should be placed under NEMBA Category 1b of invasive species.

Chapter 6: Conclusions

The southern cold-hardiness zone and maps from Vegetation of Southern African shows broad climatic conditions which may enhance the distribution of *G. robusta* in South Africa. The distribution of *G. robusta* in South Africa is in the northern and coastal regions. Since the first recorded observation of *G. robusta* in South Africa, the number of localities is increasing. *Grevillea robusta* has been found to be growing in 7 of the 9 South African provinces. This indicates that South Africa has a conducive environment for the survival of *G. robusta*. The number of *G. robusta* trees in South Africa and infested areas is an ecological problem which needs to be checked. Although Limpopo province has the most observations, Gauteng province remains the most densely infested area.

Moederlief farm which is situated near Nelspruit also falls within the possible ecological tolerance of *G. robusta*. Trees of *G. robusta* were planted in Moederlief farm in 1965 or 1972 and since then the tree has established itself and produced more seedlings. Populations of *G. robusta* at Moederlief farm are distributed over 20.12% of the surveyed farm area. There is a range of tree age and size at Moederlief farm which consists of young and mature trees.

Temperature poses no limits on the survival and establishment of *G. robusta* in South Africa, but rainfall limits the establishment of *G. robusta* in the central and western regions. Rainfall seasons pose no limit to the establishment of *G. robusta* in South Africa as trees are able to grow in the Cape where rainfall is in winter with dry summers. Trees of *G. robusta* are limited by fire as very young trees fail to survive if burnt. Cutting and spraying of old trees with the appropriate herbicides can reduce the number of old trees. Trees of *G. robusta* were not growing at altitudes over 1000 m at Moederlief farm.

Grevillea robusta trees showed a slow growth rate, but they produce viable seeds at the age of 8. *Grevillea robusta* trees growing in South Africa produce viable seed which will grow if dispersed into suitable growth conditions. The seeds of *G. robusta* are wind dispersed as they are flat and winged. Seeds are blown from tree canopies to different directions in the farm and mostly to the east north east direction by Nelspruit heavy winds

Trees of *G. robusta* can grow in both vegetation types at Moederlief farm (Table 1). *Grevillea robusta* supresses other tree species as it has bigger canopies that shade indigenous trees. It is known that the litter of evergreen species takes longer to decompose than deciduous species (Facelli & Pickett, 1991). As an evergreen species and dropping a considerable amount of litter averaging 2.3 cm, the amount of litter is likely to take longer to decompose and contribute to germination failure of potentially competing species. There was only an average of 28 individuals below *G. robusta* canopies of which 4% are other weeds, while *S. chirindensis* had an average of 35 individuals of which 15% were weeds.

From this detailed study conducted at Moederlief farm which is one of *G. robusta* localities in South Africa. It was found that *G. robusta* is tolerant to South African climatic conditions and now widely distributed in 188 localities in the country. *Grevillea robusta* has infested 20.12% of the 159 quadrats at Moerderlief farm and is able to produce viable and wind dispersed seeds. Trees of *G. robusta* are thriving in both grass and forest vegetation (Table 1) and only limited to higher altitudes. According to the WRA model, *G. robusta* has a score of 3 which states that the species should be evaluated. It is thus advisable that detailed investigations be conducted in other localities in South Africa in addition to Moederlief farm. According to SACLPs, *G. robusta* should be listed as Category 1b invader that needs immediate control. The major economic value for *G. robusta* in South Africa is as a windbreak. Indigenous trees, such as *Searsia pendulina* (Jacq.) Moffett, are very suitable replacements.

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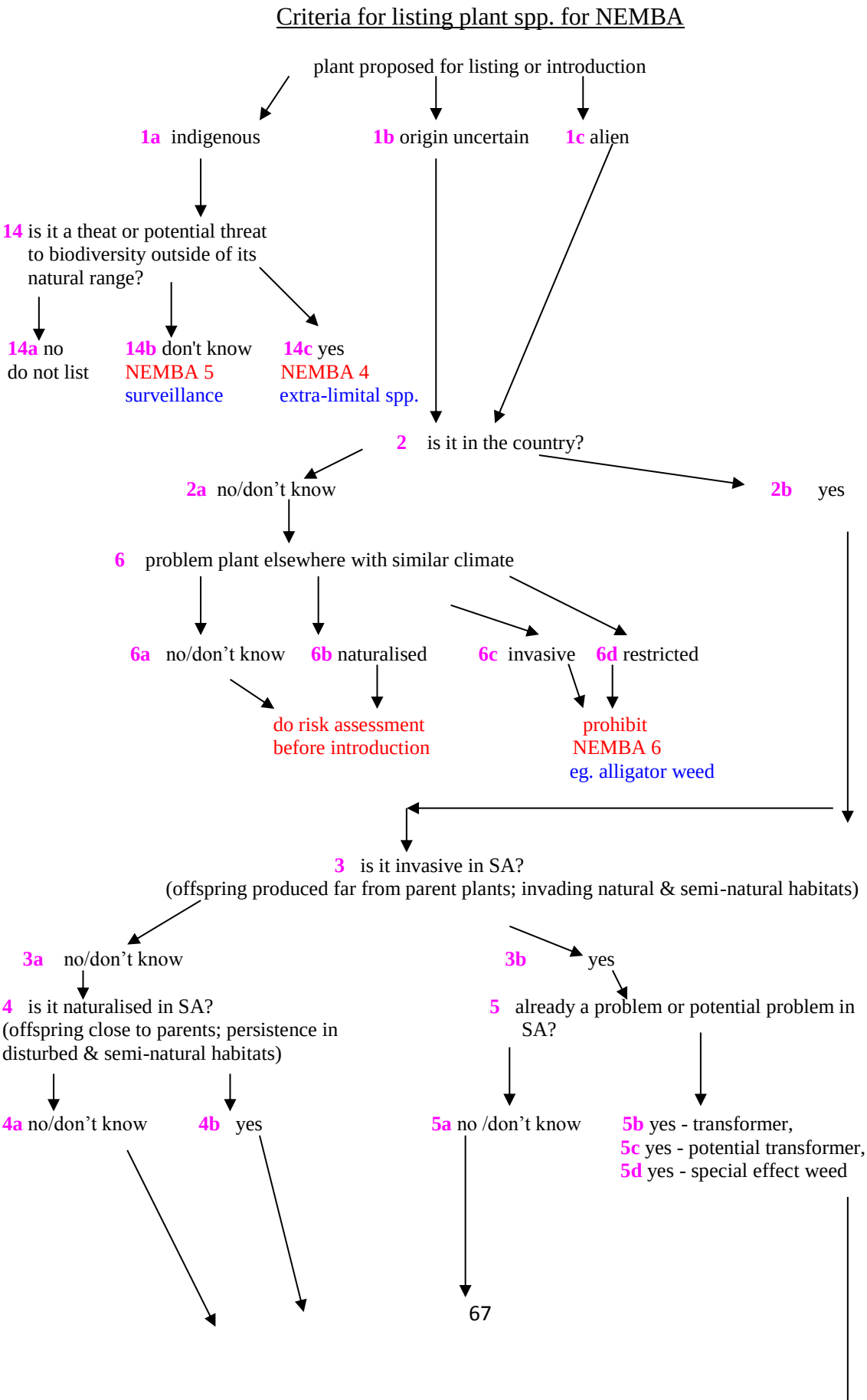
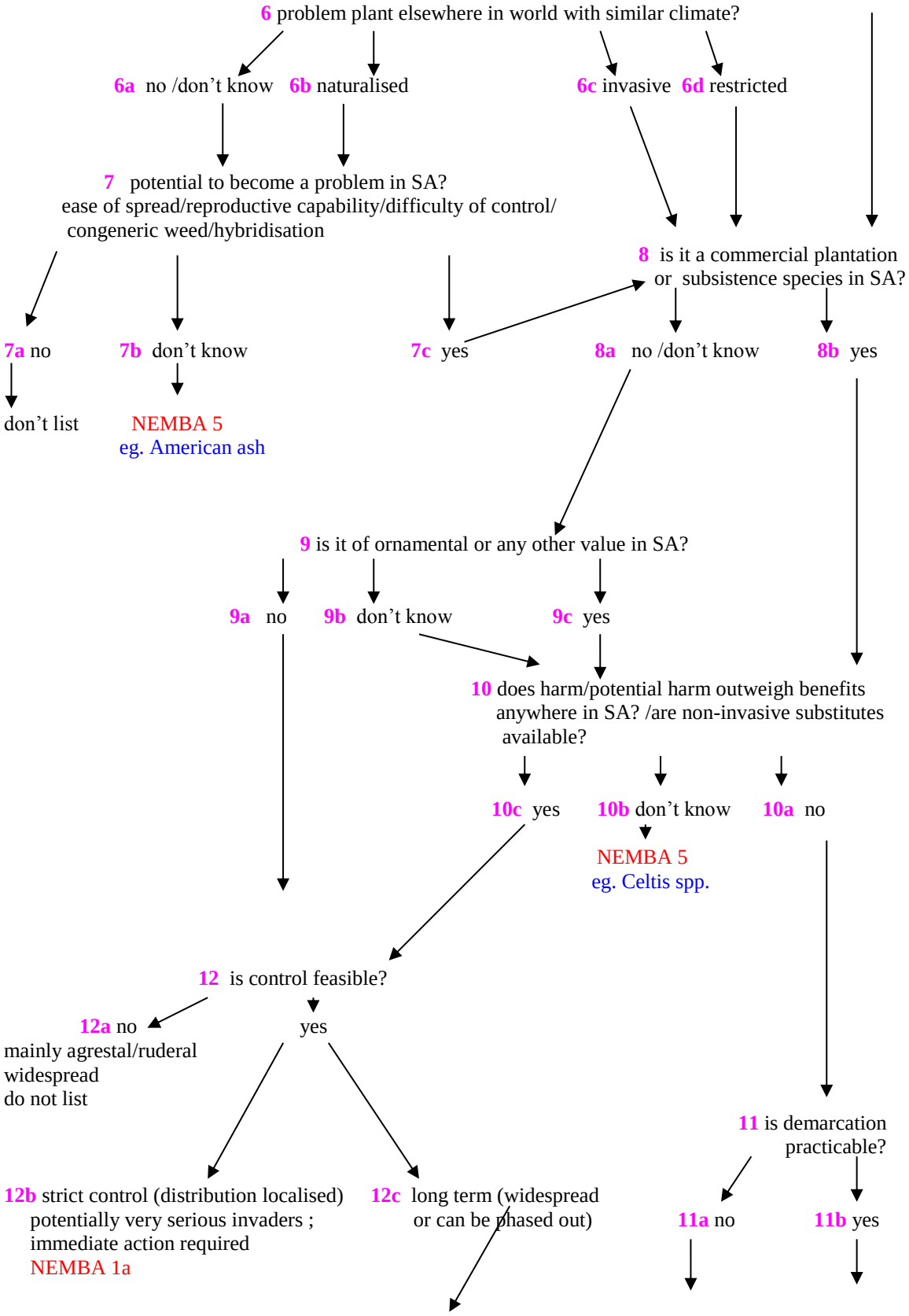
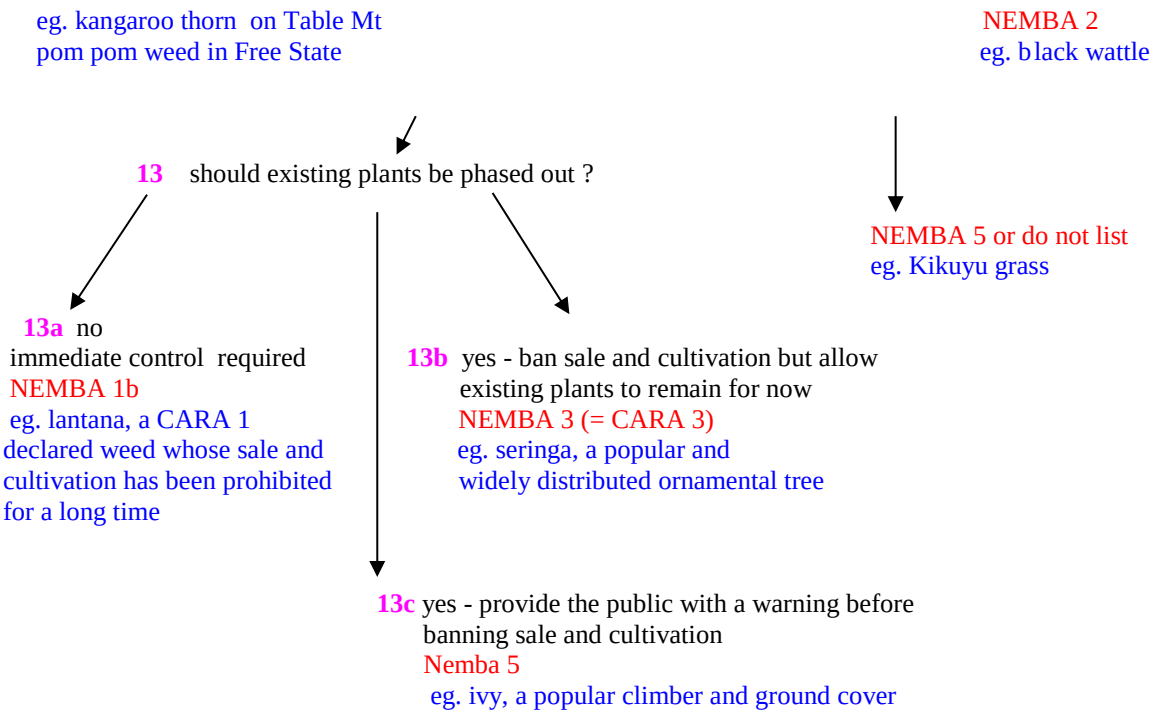
7. Appendix A: Criteria for listing plant spp. for NEMBA




6 problem plant elsewhere in world with similar climate?
6a no /don't know
6b naturalised
6c invasive
6d restricted
7 potential to become a problem in SA?
ease of spread/reproductive capability/difficulty of control/
congeneric weed/hybridisation
8 is it a commercial plantation
or subsistence species in SA?
7a no
7b don't know
7c yes
8a no /don't know
8b yes
don't list
NEMBA 5
eg. American ash
9 is it of ornamental or any other value in SA?
9a no
9b don't know
9c yes
10 does harm/potential harm outweigh benefits
anywhere in SA? /are non-invasive substitutes
available?
10c yes
10b don't know
10a no
NEMBA 5
eg. Celtis spp.
12 is control feasible?
12a no
mainly agrestal/ruderal
widespread
do not list
yes
11 is demarcation
practicable?
12b strict control (distribution localised)
potentially very serious invaders ;
immediate action required
NEMBA 1a
12c long term (widespread
or can be phased out)
11a no
11b yes


eg. kangaroo thorn on Table Mt
pom pom weed in Free State
NEMBA 2
eg. black wattle
13 should existing plants be phased out ?
NEMBA 5 or do not list
eg. Kikuyu grass
13a no
immediate control required
NEMBA 1b
eg. lantana, a CARA 1
declared weed whose sale and
cultivation has been prohibited
for a long time
13b yes - ban sale and cultivation but allow
existing plants to remain for now
NEMBA 3 (= CARA 3)
eg. seringa, a popular and
widely distributed ornamental tree
13c yes - provide the public with a warning before
banning sale and cultivation
Nemba 5
eg. ivy, a popular climber and ground cover

8. Appendix B: WRA question sheet

Answer yes (y) or no (n), or don't know (leave blank or?), unless otherwise indicated

		Botanical name:		Outcome:	
		Common name:		Score:	
		Family name		Your name:	
	History/Biogeography				
A	**1**	*Domestication/*	1.01	Is the species highly domesticated. If answer is 'no' got to question 2.01	
C		*cultivation*	1.02	Has the species become naturalised where grown	
C			1.03	Does the species have weedy races	
	2	*Climate and*	2.01	Species suited to Australian climates (0-low; 1-intermediate; 2-high)	2
		Distribution	2.02	Quality of climate match data (0-low; 1-intermediate; 2-high)	2
C			2.03	Broad climate suitability (environmental versatility)	
C			2.04	Native or naturalised in regions with extended dry periods	
			2.05	Does the species have a history of repeated introductions outside its natural range	
C	**3**	*Weed*	3.01	Naturalised beyond native range	
E		*elsewhere*	3.02	Garden/amenity/disturbance weed	
A			3.03	Weed of agriculture/horticulture/forestry	
E			3.04	Environmental weed	
			3.05	Congeneric weed	
	Biology/Ecology				
A	**4**	*Undesirable*	4.01	Produces spines, thorns or burrs	
C		*traits*	4.02	Allelopathic	
C			4.03	Parasitic	
A			4.04	Unpalatable to grazing animals	
C			4.05	Toxic to animals	
C			4.06	Host for recognised pests and pathogens	
C			4.07	Causes allergies or is otherwise toxic to humans	
E			4.08	Creates a fire hazard in natural ecosystems	
E			4.09	Is a shade tolerant plant at some stage of its life cycle	
E			4.10	Grows on infertile soils	
E			4.11	Climbing or smothering growth habit	
E			4.12	Forms dense thickets	
E	**5**	*Plant type*	5.01	Aquatic	
C			5.02	Grass	
E			5.03	Nitrogen fixing woody plant	
C			5.04	Geophyte	
C	**6**	*Reproduction*	6.01	Evidence of substantial reproductive failure in native habitat	
C			6.02	Produces viable seed	
C			6.03	Hybridises naturally	
C			6.04	Self-fertilisation	
C			6.05	Requires specialist pollinators	
C			6.06	Reproduction by vegetative propagation	
C			6.07	Minimum generative time (years)	1
A	**7**	*Dispersal*	7.01	Propagules likely to be dispersed unintentionally	
C		*mechanisms*	7.02	Propagules dispersed intentionally by people	
A			7.03	Propagules likely to disperse as a produce contaminant	
C			7.04	Propagules adapted to wind dispersal	
E			7.05	Propagules buoyant	
E			7.06	Propagules bird dispersed	
C			7.07	Propagules dispersed by other animals (externally)	
C			7.08	Propagules dispersed by other animals (internally)	
C	**8**	*Persistence*	8.01	Prolific seed production	
A		*attributes*	8.02	Evidence that a persistent propagule bank is formed (>1 yr)	
A			8.03	Well controlled by herbicides	
C			8.04	Tolerates or benefits from mutilation, cultivation or fire	
E			8.05	Effective natural enemies present in Australia	

A= agricultural, E = environmental, C= combined

9. Appendix C: WRA score sheet

		a	b	c	d	e
Section		Question	Response [1]	Score	*N* score	*Y* score
A	C	1.01			0	-3
	C	1.02			-1	1
	C	1.03			-1	1
		2.01		The response for these questions is 2 unless a climate analysis is done		
		2.02				
	C	2.03			0	1
	C	2.04			0	1
		2.05				
	C	3.01		Refer to lookup table		
	E	3.02				
	A	3.03				
	E	3.04				
	C	3.05				
B	C	4.01			0	1
	C	4.02			0	1
	C	4.03			0	1
	A	4.04			-1	1
	C	4.05			0	1
	C	4.06			0	1
	C	4.07			0	1
	E	4.08			0	1
	E	4.09			0	1
	E	4.10			0	1
	E	4.11			0	1
	C	4.12			0	1
C	E	5.01			0	5
	C	5.02			0	1
	E	5.03			0	1
	C	5.04			0	1
	C	6.01			0	1
	C	6.02			-1	1
	A	6.03			-1	1
	C	6.04			-1	1
	C	6.05			0	-1
	A	6.06			-1	1
	C	6.07				
	A	7.01			-1	1
	C	7.02			-1	1
	A	7.03			-1	1
	C	7.04			-1	1
	E	7.05			-1	1
	E	7.06			-1	1
	C	7.07			-1	1
	C	7.08			-1	1
	C	8.01			-1	1
	C	8.02			-1	1
	A	8.03			1	-1
	A	8.04			-1	1
	C	8.05			1	-1

Total score [3]	
Outcome [4]	
Agricultural score [6]	
Environmental [6]	

Only score 1.02 and 1.03 if you answered yes to 1.01

Lookup table for section 3.

Locate value of inputs and lookup output for each question

	Yes to questions 3.01 - 3.05									**default**
Inputs	2.01	0	0	0	1	1	1	2	2	**2**
	2.02	0	1	2	0	1	2	0	1	**2**
Results	3.01	2	1	1	2	2	1	2	2	**2**
	3.02	2	1	1	2	2	1	2	2	**2**
	3.03	3	2	1	4	3	2	4	4	**4**
	3.04	3	2	1	4	3	2	4	4	**4**
	3.05	2	1	1	2	2	1	2	2	**2**

	No to questions 3.01 - 3.05			
Input	2.05	?	N	Y
Results	3.01	-1	0	-2
	3.02-3.05	0	0	0

Procedure for scoring assessment

1 Record appropriate responses in column b.
2 Look up score in columns d & e and record result in column c.
3 Calculate total score.
4 Lookup and record recommendation.
5 Verify that minimum number of questions from each section are answered.
6 Compute Agricultural (A&C) and Environmental (E&C) scores: if either score is less than 1, the outcome pertains to the other sector.

Lookup table for 6.07			
years	1	2	4
score	1	0	-1

Score	Outcome
< 1	Accept
1-6	Evaluate
> 6	Reject

Section	Minimum # questions [5]
A	2
B	2
C	6
Total	10

10. Appendix D: Data collection per quadrat

Quadrat no	Presence of G. robusta trees	GPS co-ordinates S	GPS co-ordinates E	Altitude (M)	Land disturbance	Vegetation type	Slope	Slope Aspect	Litter at deepest point (cm)	Proportion of land disturbance (%)
T10Q10	No	25°32'5.81"S	31°13'8.62"E	910	None	Forest	Flat	None	4	0
T10Q6	No	25°32'16.63"S	31°12'57.37"E	837	None	Guava trees	Flat	None	4	0
T10Q7	Yes	25°32'14.27"S	31°12'59.00"E	850	None	Forest	Steep	East	0	0
T10Q8	No	25°32'11.30"S	31°13'2.01"E	902	None	Forest/Grass	Flat	None	0	0
T10Q9	Yes	25°32'8.16"S	31°13'7.23"E	886	Erosion	Forest	steep	East	2	60
T11Q10	No	25°32'8.17"S	31°13'11.55"E	815	Erosion	Forest	steep	North	1	30
T11Q6	Yes	25°32'18.59"S	31°13'0.45"E	827	None	Forest	steep	South	3	0
T11Q7	No	25°32'16.35"S	31°13'3.26"E	837	None	Forest	Flat	None	2	0
T11Q8	Yes	25°32'13.22"S	31°13'4.92"E	858	None	Forest	steep	North	2	0
T11Q9	No	25°32'10.37"S	31°13'9.49"E	826	None	Forest	steep	South	2	0
T1Q1	No	25°32'10.81"S	31°12'17.71"E	1034	None	Forest	Flat	None	0	0
T1Q10	No	25°31'49.58"S	31°12'46.40"E	993	None	Forest	steep	South	3	0
T1Q11	No	25°31'47.56"S	31°12'48.95"E	1013	None	Forest	steep	West	2	0
T1Q12	No	25°31'46.08"S	31°12'51.61"E	1036	None	Forest	steep	East	0	0
T1Q13	No	25°31'44.58"S	31°12'53.02"E	1051	None	Forest	steep	East	0	0
T1Q2	No	25°32'8.31"S	31°12'20.51"E	1021	None	Forest	Semi	West	1	0
T1Q3	No	25°32'5.64"S	31°12'24.11"E	1028	None	Forest	steep	West	2	0
T1Q4	No	25°32'3.22"S	31°12'27.57"E	1014	None	Forest	steep	West	0	0
T1Q5	No	25°32'1.49"S	31°12'30.73"E	1028	None	Forest	steep	West	3	0
T1Q6	Yes	25°31'58.70"S	31°12'34.50"E	1009	None	Forest	steep	West	0	0
T1Q7	Yes	25°31'55.72"S	31°12'38.15"E	988	None	Forest	Flat	None	0	0
T1Q8	No	25°31'53.34"S	31°12'41.60"E	981	None	Forest	steep	West	1	0
T1Q9	No	25°31'51.78"S	31°12'44.29"E	986	None	Forest	Semi	South	1	0
T2Q1	No	25°32'12.96"S	31°12'20.58"E	1005	None	Grass	steep	East	1	0
T2Q10	No	25°31'51.16"S	31°12'49.45"E	989	None	Forest	steep	South	2	0
T2Q11	no	25°31'49.15"S	31°12'51.77"E	1007	None	Forest	Flat	None	5	0
T2Q12	No	25°31'47.16"S	31°12'53.73"E	1020	None	Forest	steep	East	4	0
T2Q13	No	25°31'45.53"S	31°12'54.75"E	1041	None	Forest	Flat	None	1	0
T2Q2	No	25°32'10.69"S	31°12'23.59"E	1025	None	Forest	steep	West	0	0
T2Q3	No	25°32'7.66"S	31°12'26.59"E	964	None	Forest/Grass	Flat	None	1	0

T2Q4	No	25°32'5.19"S	31°12'29.42"E	1027	None	Forest	steep	East	1	0
T2Q5	Yes	25°32'3.18"S	31°12'32.89"E	1023	None	Grass	steep	East	1	0
T2Q6	No	25°32'0.63"S	31°12'36.11"E	963	None	Grass	steep	North	0	0
T2Q7	Yes	25°31'57.91"S	31°12'40.76"E	983	None	Forest	steep	East	2	0
T2Q8	Yes	25°31'55.11"S	31°12'44.51"E	977	None	Forest	Flat	None	3	0
T2Q9	No	25°31'53.32"S	31°12'46.49"E	978	None	Forest/Grass	Flat	None	4	0
T3Q1	No	25°32'15.40"S	31°12'22.14"E	958	None	Forest	steep	East	1	0
T3Q10	No	25°31'52.32"S	31°12'51.47"E	970	None	Grass	steep	North	0	0
T3Q11	no	25°31'50.62"S	31°12'53.94"E	1013	None	Forest	steep	North	2	0
T3Q12	No	25°31'49.11"S	31°12'56.35"E	1014	None	Grass	steep	East	0	0
T3Q13	No	25°31'47.56"S	31°12'57.37"E	1048	None	Forest/Grass	Flat	None	0	0
T3Q2	No	25°32'12.96"S	31°12'26.14"E	940	Erosion	Forest	steep	North	2	50
T3Q3	No	25°32'10.26"S	31°12'29.20"E	972	None	Grass	steep	East	5	0
T3Q4	No	25°32'7.78"S	31°12'31.80"E	930	None	Forest	steep	North east	2	0
T3Q5	No	25°32'5.19"S	31°12'35.23"E	1017	None	Forest/Grass	steep	East	2	0
T3Q6	Yes	25°32'3.24"S	31°12'38.63"E	949	None	Forest	steep	East	3	0
T3Q7	Yes	25°32'0.43"S	31°12'42.94"E	983	None	Forest	steep	East	4	0
T3Q8	Yes	25°31'56.52"S	31°12'46.23"E	984	Excavation	Grass	Flat	None	0	50
T3Q9	Yes	25°31'54.29"S	31°12'49.41"E	986	None	Forest/Grass	steep	North West	1	0
T4Q1	No	25°32'18.12"S	31°12'24.63"E	937	None	Forest	steep	East	2	0
T4Q10	No	25°31'54.30"S	31°12'53.36"E	976	None	Forest	Semi	North	1	0
T4Q11	no	25°31'52.22"S	31°12'56.36"E	998	None	Forest	steep	North	1	0
T4Q12	No	25°31'50.76"S	31°12'58.49"E	978	None	Grass	steep	East	1	0
T4Q13	No	25°31'49.35"S	31°12'59.64"E	1036	None	Forest	steep	North	2	0
T4Q14	No	25°31'47.17"S	31°13'0.78"E	1045	None	Forest	Flat	None	3	0
T4Q2	Yes	25°32'15.85"S	31°12'28.24"E	936	None	Forest	steep	East	2	0
T4Q3	Yes	25°32'12.34"S	31°12'32.18"E	984	None	Grass	steep	East	3	0
T4Q4	yes	25°32'9.79"S	31°12'34.72"E	916	None	Forest	steep	East	3	0
T4Q5	No	25°32'7.50"S	31°12'37.92"E	911	None	Forest	steep	East	4	0
T4Q6	yes	25°32'5.18"S	31°12'41.02"E	927	Trench	Grass	steep	South East	0	40
T4Q7	Yes	25°32'2.09"S	31°12'45.02"E	969	None	Forest/Grass	steep	East	1	0
T4Q8	No	25°31'58.18"S	31°12'48.03"E	964	None	Forest/Grass	steep	North	1	0
T4Q9	Yes	25°31'55.77"S	31°12'51.07"E	965	None	Grass	Flat	None	0	0
T5Q1	No	25°32'20.36"S	31°12'27.49"E	934	None	Forest	Semi	North	2	0
T5Q10	no	25°31'55.48"S	31°12'54.81"E	983	Rock dump	Grass	Flat	None	0	100
T5Q11	no	25°31'53.84"S	31°12'57.63"E	984	Rock dump	Grass	Flat	None	0	100
T5Q12	no	25°31'52.55"S	31°13'0.41"E	973	Excavation	Forest/Grass	Flat	None	0	50
T5Q13	No	25°31'50.64"S	31°13'2.04"E	1011	Excavation/Rock dump	Grass	Flat	None	0	100
T5Q14	No	25°31'48.42"S	31°13'2.95"E	1008	None	Forest	steep	South	2	0

T5Q2	No	25°32'17.66"S	31°12'31.24"E	913	None	Forest	Flat	None	3	0
T5Q3	No	25°32'14.35"S	31°12'34.52"E	912	None	Grass	steep	West	1	0
T5Q4	Yes	25°32'11.87"S	31°12'37.80"E	925	None	Forest	steep	West	1	0
T5Q5	Yes	25°32'9.53"S	31°12'40.04"E	905	None	Forest	Flat	West	3	0
T5Q6	No	25°32'6.47"S	31°12'43.07"E	911	Slashing	Forest	Flat	None	2	10
T5Q7	No	25°32'4.12"S	31°12'46.53"E	951	Excavation	Grass	Flat	None	0	100
T5Q8	Yes	25°32'0.03"S	31°12'49.68"E	930	Trench	Forest	Flat	None	3	10
T5Q9	Yes	25°31'57.29"S	31°12'53.06"E	955	Excavation	Grass	Flat	None	0	100
T6Q1	No	25°32'22.08"S	31°12'28.98"E	927	None	Forest	Semi	East	3	0
T6Q13	No	25°31'52.83"S	31°13'4.79"E	997	Rock Dump	Grass	Flat	None	0	100
T6Q14	No	25°31'51.15"S	31°13'5.62"E	1008	Mine	Grass	Flat	None	4	100
T6Q15	No	25°31'48.80"S	31°13'7.31"E	903	Mine	Grass	Flat	None	0	100
T6Q2	No	25°32'19.33"S	31°12'34.08"E	907	Erosion	Grass	Semi	North	3	30
T6Q3	No	25°32'16.55"S	31°12'37.66"E	918	None	Forest	Semi	East	5	0
T6Q5	Yes	25°32'12.04"S	31°12'42.69"E	887	None	Forest	Flat	None	0	0
T6Q4	No	25°32'14.45"S	31°12'41.02"E	909	None	Forest	Flat	None	3	0
T6Q6	Yes	25°32'8.42"S	31°12'45.09"E	929	None	Forest	steep	East	3	0
T6Q7	No	25°32'6.33"S	31°12'48.31"E	925	Fire	Forest/Grass	Semi	North	0	100
T6Q8	No	25°32'2.87"S	31°12'51.21"E	943	Excavation	Grass	Flat	None	1	100
T6Q9	No	25°31'58.74"S	31°12'55.44"E	984	Excavation	Forest	Flat	None	2	0
T7Q1	No	25°32'24.57"S	31°12'31.88"E	940	None	Forest	Flat	None	3	0
T7Q15	No	25°31'50.47"S	31°13'9.46"E	903	Mine	Grass	Flat	None	0	100
T7Q16	No	25°31'47.89"S	31°13'10.45"E	1032	Mine	Grass	Flat	None	0	100
T7Q2	No	25°32'21.48"S	31°12'35.93"E	908	Erosion	Forest	steep	North east	4	20
T7Q3	Yes	25°32'19.13"S	31°12'40.17"E	887	None	Forest	Flat	None	3	0
T7Q4	No	25°32'16.59"S	31°12'42.99"E	887	None	Forest	Flat	None	0	0
T7Q6	No	25°32'10.65"S	31°12'48.54"E	912	None	Forest	Flat	None	3	0
T7Q7	No	25°32'8.38"S	31°12'51.11"E	880	None	Forest	Flat	None	1	0
T7Q8	Yes	25°32'5.14"S	31°12'54.40"E	911	None	Forest	Flat	None	5	0
T8Q6	No	25°32'13.18"S	31°12'51.55"E	883	None	Forest/Grass	steep	East	1	0
T8Q7	No	25°32'10.66"S	31°12'54.34"E	871	None	Forest	Flat	None	3	0
T9Q6	Yes	25°32'14.94"S	31°12'54.43"E	847	Erosion	Forest	Semi	East	3	30
T9Q7	Yes	25°32'12.46"S	31°12'56.12"E	902	None	Grass	steep	East	3	0
T9Q8	No	25°32'8.92"S	31°12'59.32"E	811	None	Forest	steep	East	1	0
T9Q9	Yes	25°32'5.82"S	31°13'3.96"E	1075	None	Forest	steep	East	3	0
T7Q5	No	25°32'14.06"S	31°12'45.54"E	894	None	Forest	Flat	None	3	0
T3Q14	No	25°31'45.69"S	31°12'58.69"E	984	None	Forest	Semi	East	3	0
T8Q16	No	25°31'48.01"S	31°13'14.24"E	985	None	Forest	steep	North	2	0

T9Q16	No	25°31'49.51"S	31°13'16.38"E	976	None	Forest	steep	North	3	0
T9Q15	No	25°31'51.97"S	31°13'14.56"E	990	None	Forest	Flat	None	1	0
T10Q16	No	25°31'52.33"S	31°13'17.54"E	975	None	Forest	Flat	None	2	0
T10Q15	No	25°31'54.96"S	31°13'15.65"E	1000	None	Forest	steep	West	2	0
T11Q14	No	25°31'58.47"S	31°13'18.67"E	997	None	Forest	Flat	None	1	0
T11Q15	No	25°31'56.73"S	31°13'19.13"E	997	None	Forest	Flat	None	2	0
T11Q16	No	25°31'55.68"S	31°13'19.32"E	993	None	Forest	Flat	None	3	0
T8Q15	No	25°31'50.75"S	31°13'12.63"E	1002	None	Forest	steep	East	3	0
T9Q14	No	25°31'54.29"S	31°13'13.16"E	995	None	Forest	Flat	None	2	0
T7Q5	No	25°32'14.06"S	31°12'45.54"E	883	None	Forest	Flat	None	3	0
T7Q14	No	25°31'52.53"S	31°13'8.30"E	1058	None	Forest	Semi	East	3	0
T2Q14	No	25°31'44.46"S	31°12'56.36"E	1065	None	Forest/Grass	Flat	None	2	0
T1Q14	No	25°31'42.72"S	31°12'54.70"E	1062	None	Forest/Grass	Flat	None	0	0
T1Q15	No	25°31'41.64"S	31°12'57.09"E	1077	None	Forest	Flat	None	2	0
T6Q10	No	25°31'56.97"S	31°12'57.13"E	962	Mine	Grass	Flat	None	0	100
T6Q11	No	25°31'55.63"S	31°12'59.12"E	970	Mine	Grass	Flat	None	0	100
T7Q9	No	25°31'54.22"S	31°13'2.20"E	946	None	Forest	Flat	None	2	0
T8Q9	No	25°32'3.82"S	31°13'1.03"E	931	None	Grass	Flat	None	3	0
T8Q8	No	25°32'7.30"S	31°12'56.96"E	910	None	Forest	Flat	None	2	0
T5Q15	No	25°31'46.79"S	31°13'3.92"E	1054	Mine	Grass	steep	South	3	100
T4Q15	No	25°31'45.94"S	31°13'2.35"E	1062	Mine	Grass	Flat	None	0	100
T3Q15	No	25°31'44.52"S	31°13'1.13"E	1076	None	Forest	steep	West	2	0
T2Q15	No	25°31'43.50"S	31°12'59.42"E	1080	None	Forest	Flat	None	3	0
T1Q15	No	25°31'41.64"S	31°12'57.09"E	1076	None	Forest	Flat	None	2	0
T1Q16	No	25°31'40.64"S	31°12'59.15"E	1096	None	Forest	Flat	None	1	0
T2Q16	No	25°31'42.21"S	31°13'1.18"E	1096	None	Forest	Flat	None	2	0
T3Q16	No	25°31'43.21"S	31°13'2.80"E	1090	None	Forest	Flat	None	3	0
T4Q16	No	25°31'44.50"S	31°13'4.24"E	1075	None	Forest	Flat	None	0	0
T5Q16	No	25°31'45.37"S	31°13'5.28"E	1064	None	Forest	Flat	None	0	0
T6Q16	No	25°31'46.19"S	31°13'7.04"E	1048	None	Forest	Flat	None	2	0
T7Q11	No	25°31'57.24"S	31°13'1.44"E	962	None	Grass	Flat	None	0	0
T8Q11	No	25°31'58.48"S	31°13'3.79"E	957	None	Forest	Flat	None	1	0
T9Q11	No	25°32'0.64"S	31°13'7.28"E	937	None	Forest	Flat	None	2	0
T9Q10	No	25°32'3.58"S	31°13'5.60"E	926	None	Forest	Flat	None	3	0
T10Q11	No	25°32'2.81"S	31°13'11.14"E	922	Seasonal River	Forest	steep	South	1	100
T11Q11	No	25°32'5.47"S	31°13'14.15"E	900	None	Forest	Flat	None	2	0
T11Q12	No	25°32'2.82"S	31°13'16.39"E	940	None	Forest	steep	South	4	0
T10Q12	No	25°32'1.34"S	31°13'12.96"E	946	None	Forest	steep	South	3	0

T9Q12	No	25°31'58.75"S	31°13'9.02"E	949	None	Forest	Flat	None	2	0
T8Q12	Yes	25°31'57.05"S	31°13'5.63"E	961	None	Forest	Flat	None	1	0
T7Q12	No	25°31'55.62"S	31°13'3.52"E	969	None	Forest	steep	South	0	0
T6Q12	No	25°31'54.22"S	31°13'2.20"E	979	None	Forest	Flat	None	3	0
T7Q14	No	25°31'52.53"S	31°13'8.30"E	1009	Mine	Grass	Flat	None	0	0
T7Q10	Yes	25°31'58.90"S	31°12'59.59"E	956	None	Forest	Flat	None	2	0
T8Q14	No	25°31'52.86"S	31°13'11.19"E	999	None	Forest	Flat	None	2	0
T11Q13	No	25°32'0.54"S	31°13'18.33"E	978	None	Forest	Flat	None	3	0
T10Q13	No	25°31'59.48"S	31°13'13.81"E	970	None	Forest	Flat	None	2	0
T7Q13	No	25°31'54.61"S	31°13'6.92"E	983	None	Forest	Flat	None	2	0
T9Q13	No	25°31'57.45"S	31°13'10.67"E	960	Seasonal River	Forest	steep	South	1	100
T8Q13	No	25°31'55.94"S	31°13'8.02"E	973	Seasonal River	Forest	Flat	None	1	30
T10Q14	No	25°31'56.96"S	31°13'14.73"E	995	None	Forest	Flat	None	2	0
T8Q10	No	25°32'0.38"S	31°13'1.35"E	947	None	Forest	steep	South	1	0

11. Appendix E: Data collected per tree

Quadrat NO	Tag No	DAH (CM)	DBH (CM)	Height (M)	Damage scale	Damage type	Canopy longest spread (M)	Canopy Longest cross (M)	Condition of tree	Previous year fruits	Tree at flower	Litter below canopy (CM)	Litter away from canopy (M)
T5Q4	1	0.1	0.0	0.2	0	None	0	0	Dead	NO	NO	1	3
T5Q5	2	0.1	0.0	0.2	0	None	0	0	Dead	NO	NO	1	2
T5Q5	3	0.3	0.0	0.3	0	None	0	0	Alive	NO	NO	1	0
T4Q2	4	0.2	0.0	10	0	Dead stem	0	0	Dead	NO	NO	0	0
T4Q2	5	0.2	0.0	1.2	0	None	0.3	0.2	Dead	NO	NO	2	2
T4Q2	6	1.9	0.0	0.4	0	None	0.57	0.37	Dead	NO	NO	3	2
T4Q2	7	1.9	0.0	0.4	0	None	0	0	Dead	NO	NO	3	2
T4Q2	8	2.5	1.6	1.5	0	None	0.5	0.3	Dead	NO	NO	3	2
T4Q2	9	2.5	0.0	0.5	0	None	0.2	0.2	Alive	NO	NO	1	1
T4Q2	10	2.9	1.3	1.6	0	None	0.68	0.59	Alive	NO	NO	4	4
T4Q2	11	2.9	0.0	1.5	0	None	0.5	0.2	Alive	NO	NO	1	0
T4Q3	12	3.2	2.2	1.7	0	None	0.5	0.4	Dead	NO	NO	3	2
T4Q3	13	3.2	2.2	3	0	None	2	1	Alive	Yes	Yes	2	4
T7Q3	14	3.8	1.3	0.9	0	None	0.5	0.1	Alive	NO	NO	0	0
T7Q4	15	3.8	1.9	3	0	None	1	0.5	Alive	NO	NO	1	3
T7Q4	16	4.1	1.6	3.5	0	None	2	2	Alive	NO	NO	4	4
T6Q5	17	4.8	1.9	2.5	0	None	2	1	Alive	NO	NO	1	0
T4Q4	18	4.8	3.8	3.2	0	None	4	3	Alive	NO	NO	2	0
T4Q4	19	4.8	2.9	4	0	None	3	2	Alive	NO	NO	1	3
T4Q4	20	5.1	2.5	3	0	None	3	2	Alive	NO	NO	2	0
T2Q5	21	5.7	3.5	3	0	None	3	3	Alive	NO	NO	3	0
T4Q6	22	6.4	2.9	2.5	0	None	1	0.5	Alive	NO	NO	0	0
T4Q6	23	6.4	3.5	3.1	0	None	2	2	Alive	NO	NO	3	1
T3Q6	24	6.4	1.0	2.5	0	None	4	1.5	Alive	NO	NO	1	0
T3Q6	25	7.0	0.0	0.3	70	Fire	0.2	0.3	Coppice	NO	NO	0	1
T1Q6	26	7.6	5.4	7	0	None	2	0.5	Alive	NO	NO	1	0
T1Q6	27	7.6	2.9	0.4	80	Fire	0.5	0.5	Coppice	NO	NO	1	1
T1Q7	28	8.0	4.8	4	0	None	1.5	1.5	Alive	NO	NO	2	0
T3Q9	29	8.6	0.0	1.5	50	Dying	1	0.3	Alive	NO	NO	0	0
T3Q9	30	8.9	2.9	1	30	Fire	0.4	0.3	Coppice	NO	NO	0	1
T3Q9	31	9.6	7.6	5	0	None	4	4	Alive	NO	NO	2	0
T3Q9	32	10.2	6.7	8	0	None	2.5	2	Alive	NO	Yes	2	2
T3Q8	33	10.5	7.6	7	100	Fire	0	0	Dead	NO	NO	1	2
T2Q8	34	10.8	5.7	14	0	None	4	2	Alive	Yes	Yes	2	3
T2Q8	35	11.5	9.2	4.2	0	None	1	0.5	Alive	NO	NO	1	1
T2Q8	36	11.8	8.3	9	0	None	4	2	Alive	NO	NO	1	0

T2Q7	37	12.7	7.3	4	80	Dying	3	2.5	Alive	NO	NO	3	0
T3Q7	38	13.7	12.7	10	0	None	4	4	Alive	Yes	Yes	3	2
T3Q7	39	14.6	8.9	10	0	None	5	2	Alive	Yes	Yes	0	0
T4Q7	40	14.6	10.8	15	0	None	5	4	Alive	Yes	Yes	3	2
T4Q7	41	15.0	11.8	13	0	None	3	2	Alive	Yes	Yes	2	2
T4Q7	42	15.9	11.5	9	0	None	4	4	Alive	Yes	Yes	4	1
T4Q7	43	16.2	10.8	15	0	None	3	3	Alive	Yes	Yes	3	4
T4Q7	44	17.5	13.7	16	0	None	5	3	Alive	Yes	Yes	2	3
T5Q8	45	17.8	11.8	9.5	0	None	5	4	Alive	Yes	Yes	4	1
T5Q8	46	19.7	14.6	9	0	None	9	6.5	Alive	Yes	Yes	2	1
T3Q8	47	19.7	18.5	18	0	None	5	5	Alive	Yes	Yes	3	0
T4Q8	48	20.1	17.2	10	0	None	6	6	Alive	Yes	Yes	2	2.5
T4Q9	49	20.7	15.9	16	0	None	8	4	Alive	Yes	Yes	3	2
T5Q9	50	22.3	16.9	6	6	None	4.5	3	Alive	Yes	Yes	5	0
T5Q9	51	22.3	18.5	10	70	Burnt	4	3	Alive	NO	Yes	0	0
T5Q9	52	22.3	15.6	9	0	None	4	4	Alive	Yes	Yes	1	1
T5Q9	53	24.5	15.3	14	0	None	7	6	Alive	NO	Yes	4	1
T6Q6	54	24.8	19.1	15	0	None	5	5	Alive	Yes	Yes	5	3
T7Q8	55	25.2	18.2	13	0	None	6	4	Alive	NO	Yes	1	1
T7Q8	56	26.1	18.5	14	0	None	10	7	Alive	Yes	Yes	4	4
T7Q8	57	26.8	20.1	15	0	None	6	4	Alive	Yes	Yes	3	2
T9Q6	58	29.0	23.6	18	0	None	8	7	Alive	Yes	Yes	6	3
T11Q6	59	29.0	20.1	11	0	None	6	4	Alive	Yes	Yes	1	0
T11Q6	60	29.9	26.8	9	75	Burnt	6	4	Alive	NO	Yes	0	0
T11Q8	61	29.9	13.7	15	0	None	7	6	Alive	Yes	Yes	4	1
T11Q8	62	31.2	25.8	20	0	None	6	3	Alive	Yes	Yes	2	0
T10Q9	63	31.8	26.8	18	0	None	8	8	Alive	Yes	Yes	5	2
T9Q9	64	32.5	28.7	22	0	None	10	8	Alive	Yes	Yes	4	0
T9Q9	65	33.4	26.8	20	0	None	11	8	Alive	Yes	Yes	2	1
T9Q9	66	35.0	17.8	17	0	None	8	7	Alive	Yes	Yes	3	3
T10Q7	67	36.6	28.0	19	0	None	7	4	Alive	Yes	Yes	4	3
T10Q7	68	38.2	28.7	21	0	None	10	9	Alive	Yes	Yes	4	2
T9Q7	69	50.3	38.2	22	0	None	10	9	Alive	Yes	Yes	5	2
T8Q12	70	57.0	47.0	23	0	None	7	6	Alive	Yes	Yes	6	3
T8Q13	71	22.4	13.3	10	0	None	3	2	Alive	NO	NO	3	1
T7Q10	72	34.5	26.5	16	0	None	8	8	Alive	Yes	Yes	3	2
T7Q10	73	53.4	50.0	25	0	None	10	9.5	Alive	Yes	Yes	5	2

12. Appendix F: Vegetation data

Species Name	***Sub Plot No***			**Tree height (m)**	**DGH (CM)**	**DBH (CM)**	**Canopy cover (m2)**	**litter below (cm)**	**Liter 1 cm away (cm)**	**Individuals**	**Species**	**No. invasive**	**% invasive**	**vegetation**
G. robusta	*1*	-25.53883	31.21053	19	60	45	95	5	3	7	12	4	33.33	Natural
Field code	***Species name***	**Number**	**Invader**											
G1A	*Lantana camara*	1	yes											
G1B	*Antidesma venosum*	1	no											
G1C	*Dalbergia armata*	3	no											
G1D	*Gymnosporia buxifolia*	1	no											
G1E	*Chromolaena odorata*	3	yes											
G1F	*Searsia chirindensis*	1	no											
G1G	*Diospyros whyteana*	2	no											
G. robusta	*2*	-25.53809	31.21046	11	22	12	10	5	2	3	9	0	0	Natural
Field code	***Species name***	**Number**	**Invader**											
G2A	*Phyllanthus meyerianus*	1	no											
G2B	*Mimusops zeyheri*	2	no											
G2C	*Diospyros whyteana*	6	no											
G. robusta	*3*	-25.53777	31.21049	15	32.2	24	33	3	0	4	29	0	0	Natural
Field code	***Species name***	**Number**	**Invader**											
G3A	*Hippobromus pauciflorus*	8	no											
G3B	*Canthium inerme*	6	no											
G3C	*Diospyros whyteana*	4	no											
G3D	*Acacia ataxacantha*	11	no											

G. robusta	*4*	-25.53799	31.2101	18	49	33	57	2	0	5	33	0	0	Disturbed
Field code	***Species name***	**Number**	**Invader**											
G4A	*Trimeria grandifolia*	3	no											
G4B	*Diospyros lycioides var. lycioides*	21	no											
G4C	*Bauhinia galpinii*	3	no											
G4D	*Trimeria grandifolia*	4	no											
G4E	*Maytenus undata*	2	no											
G. robusta	*5*	-25.53664	31.21156	16	26	16.4	28	4	2	3	4	1	25	Disturbed
Field code	***Species name***	**Number**	**Invader**											
G5A	*Pereskia aculeata*	1	yes											
G5B	*Diospyros whyteana*	2	no											
G5C	*Gymnosporia buxifolia*	1	No											
G. robusta	*6*	-25.53692	31.21153	8	19	15	16	6	2	6	23	0	0	Natural
Field code	***Species name***	**Number**	**Invader**											
G6A	*Flemingia grahamiana*	4	no											
G6B	*Athrixia phylicoides*	8	no											
G6C	*Pearsonia sessilifolia*	1	no											
G6D	*Mimusops zeyheri*	1	no											
G6E	*Phyllanthus meyerianus*	8	no											
G6F	*Pellaea viridis var viridis*	1	no											
G. robusta	*7*	-25.53655	31.21027	20	62	45	104	5	2	6	21	1	4.762	Disturbed
Field code	***Species name***	**Number**	**Invader**											
G7A	*Abrus precatorius*	3	no											
G7B	*Smilax kraussiana*	4	no											
G7C	*Chromolaena odorata*	1	yes											
G7D	*Scolopia zeyheri*	2	no											
G7E	*Dalbergia armata*	3	No											
G7F	*Englerophytum magalismontanum*	8	no											

G. robusta	*8*	-25.53714	31.21031	7	20	17	16	3	2	4	17	0	0	Natural
Field code	***Species name***	**Number**	**Invader**											
G8A	*Pittosporum viridiflorum*	10	no											
G8B	*Bridelia micrantha*	1	no											
G8C	*Pearsonia sessilifolia*	4	no											
G8D	*Hippobromus pauciflorus*	2	no											
G. robusta	*9*	-25.53774	31.21009	12	36	28	28	4	1	5	52	3	5.769	Disturbed
Field code	***Species name***	**Number**	**Invader**											
G9A	*Lantana camara*	3	yes											
G9B	*Bridelia micrantha*	10	no											
G9C	*Isoglossa delicatula*	20	no											
G9D	*Diospyros whyteana*	15	no											
G9E	*Olea europaea subsp. africana*	4	no											
G. robusta	*10*	-25.53722	31.20939	11	21	16	11	2	4	5	50	0	0	Natural
Field code	***Species name***	**Number**	**Invader**											
G10A	*Conostomium natalense var. glabrum*	23	no											
G10B	*Isoglossa delicatula*	17	no											
G10C	*Apodytes dimidiata*	3	no											
G10D	*Maytenus undata*	2	no											
G10E	*Diospyros whyteana*	5	no											
G. robusta	*11*	-25.53442	31.2114	16	21	13	13	4	0	6	31	0	0	Natural
Field code	***Species name***	**Number**	**Invader**											
G11A	*Diospyros whyteana*	5	no											
G11B	*Abrus precatorius*	2	no											
G11C	*Searsia chirindensis*	4	No											
G11D	*Hippobromus pauciflorus*	4	no											
G11E	*Vernonia oligocephala*	1	no											
G11F	*Acacia ataxacantha*	15	no											

G. robusta	*12*	-25.53396	31.21308	8.5	16	10	6	2	2	6	32	0	0	Natural
Field code	***Species name***	**Number**	**Invader**											
G12A	*Pellaea viridis var viridis*	8	no											
G12B	*Diospyros whyteana*	8	no											
G12C	*Pachystigma macrocalyx*	3	no											
G12D	*Bauhinia galpinii*	1	no											
G12E	*Asparagus virgatus*	8	no											
G12F	*Bridelia micrantha*	4	no											
G. robusta	*13*	-25.53381	31.21136	13	29.5	17.5	38	1	4	9	33	0	0	Natural
Field code	***Species name***	**Number**	**Invader**											
G13A	*Pearsonia sessilifolia*	1	no											
G13B	*Flemingia grahamiana*	3	no											
G13C	*Scolopia zeyheri*	1	no											
G13D	*Phyllanthus meyerianus*	2	no											
G13E	*Diospyros whyteana*	9	no											
G13F	*Senecio polyanthemoides*	8	no											
G13G	*Barlevia ovata*	2	no											
G13H	*Maytenus undata*	5	no											
G13I	*Smilax kraussiana*	2	no											
G. robusta	*14*	-25.53328	31.21117	7	29	18	50	2	0	7	22	1	4.545	Disturbed
Field code	***Species name***	**Number**	**Invader**											
G14A	*Helichrysum athrixiifolium*	4	no											
G14B	*Chromolaena odorata*	1	yes											
G14C	*Pearsonia sessilifolia*	4	no											
G14D	*Smilax kraussiana*	1	no											
G14E	*Abrus precatorius*	8	no											
G14F	*Diospyros whyteana*	1	no											
G14G	*Diospyros lycioide*	3	no											

G. robusta	*15*	-25.53234	31.21315	10	29	16	20	3	3	5	34	1	2.941	Disturbed
Field code	***Species name***	**Number**	**Invader**											
G15A	*Flemingia grahamiana*	9	no											
G15B	*Psidium guajava*	1	yes											
G15C	*Pellaea viridis var viridis*	18	no											
G15D	*Searsia chirindinsis*	1	no											
G15E	*Diospyros whyteana*	5	no											
G. robusta	*16*	-25.53217	31.21295	11	28	19	10	3	4	3	27	0	0	Disturbed
Field code	***Species name***	**Number**	**Invader**											
G16A	*Lippia javanica*	5	no											
G16B	*Euclea crispa subsp. crispa*	9	no											
G16C	*Diospyros lycioide*	13	no											
G. robusta	*17*	-25.53325	31.21267	10	19	14	13	2	0	5	19	0	0	Disturbed
Field code	***Species name***	**Number**	**Invader**											
G17A	*Smilax kraussiana*	5	no											
G17B	*Rapanea melanophloeos*	8	no											
G17C	*Pachystigma macrocalyx*	2	no											
G17D	*Diospyros whyteana*	1	no											
G17E	*Euclea crispa subsp. crispa*	3	no											
G. robusta	*18*	-25.53301	31.2115	15	45	26	95	1	0	7	56	0	0	Natural
Field code	***Species name***	**Number**	**Invader**											
G18A	*Crabbea hirsuta*	5	no											
G18B	*Athrixia phylicoides*	20	no											
G18C	*Lippia javanica*	2	no											
G18D	*Flemingia grahamiana*	11	no											
G18E	*Diospyros whyteana*	8	no											
G18F	*Ruellia cordata*	10	no											

G. robusta	*19*	-25.53345	31.21112	16	38	19	64	4	3	4	22	0	0	Disturbed
Field code	***Species name***	**Number**	**Invader**											
G19A	*Helichrysum athrixiifolium*	3	no											
G19B	*Pellaea viridis var viridis*	11	no											
G19C	*Smilax kraussiana*	5	no											
G19D	*Euclea crispa subsp. crispa*	3	no											
G. robusta	*20*	-25.53481	31.21078	7	17	10.5	28	2	0	6	41	0	0	Natural
Field code	***Species name***	**Number**	**Invader**											
G20A	*Acacia ataxacantha*	5	no											
G20B	*Helichrysum athrixiifolium*	21	no											
G20C	*Barlevia ovata*	3	no											
G20D	*Ruellia cordata*	2	no											
G20E	*Maytenus undata*	8	no											
G20F	*Diospyros whyteana*	2	no											
S. chirindensis	*1*	-25.53691	31.21158	18	41	35	104	2	0	10	48	0	0	Natural
Field code	***Species name***	**Number**	**Invader**											
S1A	*Acacia ataxacantha*	8	no											
S1B	*Pellaea viridis var viridis*	18	no											
S1C	*Athrixia phylicoides*	6	no											
S1D	*Englerophytum magalismontanum*	1	no											
S1E	*Flemingia grahamiana*	2	no											
S1F	*Searsia pentheri*	3	no											
S1G	*Senecio polyanthemoides*	5	no											
S1H	*Apodytes dimidiata*	1	no											
S1I	*Bauhinia galpinii*	2	no											
S1J	*Lippia javanica*	2	no											

S. chirindensis	*2*	-25.53483	31.21106	12	16	15.5	79	2	0	7	29	1	3.448	Natural
Field code	***Species name***	**Number**	**Invader**											
S2A	*Grevillea robusta*	1	yes											
S2B	*Euclea crispa subsp. crispa*	4	no											
S2C	*Apodytes dimidiata*	3	no											
S2D	*Helichrysum athrixiifolium*	9	no											
S2E	*Senecio polyanthemoides*	3	no											
S2F	*Lippia javanica*	2	no											
S2H	*Diospyros whyteana*	7	no											
S. chirindensis	*3*	-25.53498	31.21123	16	29	20	123	2	1	8	58	10	17.24	Natural
Field code	***Species name***	**Number**	**Invader**											
S3A	*Pellaea viridis var viridis*	19	no											
S3B	*Diospyros whyteana*	5	no											
S3C	*Flemingia grahamiana*	3	no											
S3D	*Abrus precatorius*	7	no											
S3E	Ageratum conyzoides	10	yes											
S3F	*Diospyros whyteana*	3	no											
S3G	*Searsia pentheri*	2	no											
S3H	*Senecio polyanthemoides*	9	no											
S. chirindensis	*4*	-25.53309	31.2121	10	12	8	50	1	0	5	39	0	0	Disturbed
Field code	***Species name***	**Number**	**Invader**											
S4A	*Helichrysum athrixiifolium*	13	no											
S4B	*Smilax kraussiana*	5	no											
S4C	*Diospyros whyteana*	12	no											
S4D	*Gymnosporia heterophylla*	7	no											
S4E	*Ficus sur*	2	no											

S. chirindensis	*5*	-25.53849	31.21056	5	13.5	10	28	1	1	6	34	11	32.35	Natural
Field code	***Species name***	**Number**	**Invader**						0					
S5A	*Diospyros whyteana*	6	no											
S5B	*Psidium guajava*	11	yes											
S5C	*Helichrysum athrixiifolium*	9	no											
S5D	*Diospyros lycioide*	2	no											
S5E	*Bridelia micrantha*	1	no											
S5F	*Flemingia grahamiana*	5	no											
S. chirindensis	*6*	-25.53653	31.21158	14	29	18	50	2	1	4	18	13	72.22	Disturbed
Field code	***Species name***	**Number**	**Invader**											
S6A	*Senecio polyanthemoides*	2	no											
S6B	*Ageratum conyzoides*	11	yes											
S6C	*Maytenus undata*	3	no											
S6D	*Chromolaena odorata*	2	yes											
S. chirindensis	*7*	-25.53525	31.21133	18	45	38	143	5	0	6	48	0	0	Disturbed
Field code	***Species name***	**Number**	**Invader**											
S7A	*Rapanea melanophloeos*	8	no											
S7B	*Smilax kraussiana*	5	no											
S7C	*Bauhinia galpinii*	20	no											
S7D	*Diospyros whyteana*	6	no											
S7E	*Bridelia micrantha*	4	no											
S7F	*Mimusops zeyheri*	5	no											
S. chirindensis	*8*	-25.53633	31.21031	6	11	9.5	5	2	0	7	75	4	5.333	Natural
Field code	***Species name***	**Number**	**Invader**											
S8A	*Flemingia grahamiana*	25	no											
S8B	*Searsia pentheri*	18	no											
S8C	*Acacia ataxacantha*	13	no											

S8D	*Lantana camara*	4	yes											
S8E	*Hippobromus pauciflorus*	3	no											
S8F	*Bridelia micrantha*	7	no											
S8G	*Diospyros whyteana*	5	no											
S. chirindensis	*9*	-25.53658	31.21167	15	51	35	38	3	1	5	25	22	88	Disturbed
Field code	***Species name***	**Number**	**Invader**											
S9A	*Ageratum conyzoides*	20	yes											
S9B	*Senecio polyanthemoides*	2	no											
S9C	*Psidium guajava*	1	yes											
S9D	*Rhoicissus tridentata*	1	yes											
S9E	*Mimusops zeyheri*	1	no											
S. chirindensis	*10*	-25.53525	31.21131	7	15	12.5	44	1	0	10	32	2	6.25	Disturbed
Field code	***Species name***	**Number**	**Invader**											
S10A	Rubiaceae conostomium natalense var glabrum	2	no											
S10B	*Acacia ataxacantha*	4	no											
S10C	*Athrixia phylicoides*	5	no											
S10D	*Lantana camara*	2	yes											
S10E	*Nidorella auriculata*	3	no											
S10F	*Euclea crispa subsp. crispa*	2	no											
S10G	*Diospyros whyteana*	2	no											
S10H	*Searsia chirindensis*	4	no											
S10I	*Smilax kraussiana*	5	no											
S10J	*Bridelia micrantha*	3	no											

S. chirindensis	*11*	-25.53328	31.21397	12	18	11	28	2	2	5	20	0	0	Natural
Field code	***Species name***	**Number**	**Invader**											
S11A	*Triumfetta pilosa*	8	no											
S11B	*Ruellia cordata*	3	no											
S11C	*Acacia ataxacantha*	3	no											
S11D	*Euclea crispa subsp. crispa*	2	no											
S11E	*Diospyros whyteana*	4	no											
S. chirindensis	*12*	-25.53394	31.2132	10	38	29	87	0	2	6	33	5	15.15	Natural
Field code	***Species name***	**Number**	**Invader**											
S12A	*Rubus crataegifolius*	5	yes											
S12B	*Mimusops zeyheri*	3	no											
S12C	*Canthium inerme*	4	no											
S12D	*Diospyros whyteana*	10	no											
S12E	*Maytenus undata*	8	no											
S12F	*Asparagus virgatus*	3	no											
S. chirindensis	*13*	-25.53285	31.21365	8	28	22	13	1	3	5	27	8	29.63	Natural
Field code	***Species name***	**Number**	**Invader**											
S13A	*Tricalysia lanceolata*	5	no											
S13B	*Hippobromus pauciflorus*	3	no											
S13C	*Rubus crataegifolius*	8	yes											
S13D	*Diospyros whyteana*	10	no											
S13E	*Flemingia grahamiana*	1	no											
S. chirindensis	*14*	-25.53572	31.21106	14	22	21	50	0	1	6	56	0	0	Disturbed
Field code	***Species name***	**Number**	**Invader**											
S14A	*Diospyros whyteana*	15	no											
S14B	*Euclea crispa subsp. crispa*	21	no											
S14C	*Apodytes dimidiata*	4	no											
S14D	*Scolopia zeyheri*	7	no											

S14E	*Maytenus undata*	8	no											
S14F	*Phyllanthus meyerianus*	1	no											
S. chirindensis	*15*	-25.53216	31.21654	7	32	20	64	3	0	4	12	0	0	Disturbed
Field code	***Species name***	**Number**	**Invader**											
S15A	*Diospyros whyteana*	4	no											
S15B	*Mimusops zeyheri*	2	no											
S15C	*Psydrax obovata*	2	no											
S15D	*Flemingia grahamiana*	4	no											
S. chirindensis	*16*	-25.53288	31.21421	7	21	9.5	10	2	0	7	37	0	0	Natural
Field code	***Species name***	**Number**	**Invader**											
S16A	*Diospyros whyteana*	3	no											
S16B	*Flemingia grahamiana*	5	no											
S16C	*Apodytes dimidiata*	6	no											
S16D	*Pellaea viridis var viridis*	10	no											
S16E	*Phyllanthus meyerianus*	3	no											
S16F	*Smilax kraussiana*	8	no											
S16G	*Mimusops zeyheri*	2	no											
S. chirindensis	*17*	-25.5316	31.21353	13	23	17	20	1	2	6	42	0	0	Natural
Field code	***Species name***	**Number**	**Invader**											
S17A	*Acacia ataxacantha*	1	no											
S17B	*Hippobromus pauciflorus*	5	no											
S17C	*Pellaea viridis var viridis*	20	no											
S17D	*Diospyros whyteana*	5	no											
S17E	*Dalbergia armata*	6	No											
S17F	*Eugenia natalitia*	5	no											

S. chirindensis	*18*	-25.53137	31.21364	18	38	32	50	3	0	8	37	0	0	Natural
Field code	***Species name***	**Number**	**Invader**											
S18A	*Euclea crispa subsp. crispa*	7	no											
S18B	*Athrixia phylicoides*	5	no											
S18C	*Carissa bispinosa*	4	no											
S18D	*Hyperacanthus amoenus*	3	no											
S18E	*Acacia ataxacantha*	8	no											
S18F	*Diospyros whyteana*	7	no											
S18H	*Asparagus virgatus*	1	no											
S18I	*Rapanea melanophloeos*	2	no											
S. chirindensis	*19*	-25.53141	31.21499	9	14	12	13	2	2	6	18	2	11.11	Disturbed
Field code	***Species name***	**Number**	**Invader**											
S19A	*Tenrhynea phylicifolia*	6	no											
S19B	*Lantana camara*	2	yes											
S19C	*Olea europaea subsp. africana*	1	no											
S19D	*Smilax kraussiana*	3	no											
S19E	*Asparagus asparagoides*	1	no											
S19F	*Ruellia cordata*	5	no											
S. chirindensis	*20*	-25.53167	31.21528	6	18	10	3	2	2	3	6	0	0	Disturbed
Field code	***Species name***	**Number**	**Invader**											
S20A	*Acacia ataxacantha*	3	no											
S20B	*Searsia pentheri*	2	no											
S20C	*Scolopia zeyheri*	1	no											

13. Appendix G: Seed viability and dispersal data

Rabelani Marikhele		**Data collection**		**10-Jun-17**	
Seed viability and dispersal data					
Seed no	Seed mass	Time Rep1 (s)	Time Rep2 (s)	Time Rep3 (s)	Viability
1	0.0099	9	8	8	yes
2	0.0066	9	9	8	no
3	0.0071	9	9	10	yes
4	0.0062	10	10	9	yes
5	0.0067	8	9	9	yes
6	0.0078	9	9	9	no
7	0.0061	9	11	13	no
8	0.0075	9	10	10	yes
9	0.0068	9	9	10	yes
10	0.0053	11	9	11	no
11	0.0053	10	10	11	no
12	0.0093	8	9	10	yes
13	0.0090	9	9	9	yes
14	0.0081	9	12	11	yes
15	0.0073	9	10	7	no
16	0.0044	13	18	19	no
17	0.0044	15	10	12	no
18	0.0063	8	9	9	yes
19	0.0102	10	7	8	yes
20	0.0108	8	10	8	yes
21	0.0040	15	13	12	no
22	0.0062	10	10	10	yes
23	0.0052	9	9	8	yes
24	0.0103	11	11	9	yes
25	0.0046	12	13	15	no
26	0.0074	9	10	9	yes
27	0.0034	14	16	13	no
28	0.0079	9	10	8	yes
29	0.0039	13	12	16	no
30	0.0100	9	8	8	yes
31	0.0038	15	17	15	no
32	0.0050	10	12	11	no
33	0.0053	11	13	13	no
34	0.0091	8	8	8	yes
35	0.0072	9	8	9	yes
36	0.0079	9	7	8	yes
37	0.0083	8	9	8	yes
38	0.0087	7	8	7	yes
39	0.0095	8	8	9	no
40	0.0032	16	19	15	no
41	0.0059	8	8	8	yes
42	0.0062	10	9	10	yes
43	0.0064	9	9	9	yes
44	0.0076	8	8	8	yes

45	0.0061	10	10	11	yes
46	0.0022	17	19	19	no
47	0.0048	11	11	12	yes
48	0.0096	8	11	10	yes
49	0.0104	7	7	8	yes
50	0.0065	10	10	9	yes

14. Appendix H: Age estimate data

Sample No	Location	Diameter (cm)	Height (m)	Number of rings
1	Ground Level	58	24	41
1	1.5 Above ground	42.5	24	41
2	Ground Level	28	15	27
2	1.5 Above ground	19.5	15	27
3	Ground Level	29.3	15	24
3	1.5 Above ground	24	15	24
4	Ground Level	31	17	20
4	1.5 Above ground	19.5	17	20
5	Ground Level	25.5	12	19
5	1.5 Above ground	23.5	12	13
6	Ground Level	19.7	11	17
6	1.5 Above ground	15.5	11	17
7	Ground Level	17.5	13	14
7	1.5 Above ground	13.6	13	14
8	Ground Level	15.5	9	13
8	1.5 Above ground	13	9	13
9	Ground Level	16.3	11	10
9	1.5 Above ground	10.2	11	10
10	Ground Level	8.5	8	7
10	1.5 Above ground	5	8	7
11	Basal	29	9.9	20
11	1.5m	20	9.5	14
12	Basal	39	12	27
12	1.5m	26	12	22
13	Basal	17	5	16
13	1.5m	9	5	9
14	Basal	36	12	15
14	1.5m	23	12	13
15	Basal	16	5	14
15	1.5m	10	5	8
16	Basal	24	10	14
16	1.5m	20	10	11
17	Basal	17	5	12
17	1.5m	10	5	8
18	Basal	31	11	18
18	1.5m	24	11	11
19	Basal	28	8	12
19	1.5m	12.5	8	9
20	Basal	17	9	16
20	1.5m	12	9	12

15. Appendix I: Observations of *Grevillea robusta* in South Africa, obtained from: (Rebelo, 2008; Dehnen-Schmutz, 2011; Moodley *et al*., 2014; iSport, 2017)

Date	Lat Degs	Long Degs	Locality\Route	Province
1980	22.57.0	30.28.24	Louis Trichardt - Sibasa	Limpopo
1981	25.58.28	26.05.08	Ottoshoop - Zeerust - Swartruggens	North West
1982	23.38.58	30.12.58	Duiwelskloof - Magoebaskloof	Limpopo
1982	23.35.30	30.5.51	Tzaneen - Modjadji - Duiwelskloof - Mooketsi	Limpopo
1982	23.49.23	30.9.31	Blydepoort - Tzaneen main rd; turnoff to Modjadji	Limpopo
1982	24.17.48	28.6.44	Nylstroom - Vaalwater	Limpopo
1982	24.56.0	30.50.39	Graskop - Blydepoort main Rd	Mpumalanga
1982	24.22.0	27.44.0	Atlanta - Brits	North West
1982	25.39.6	28.20.4	Pretoria - Roodeplaat - Enkeldoring	Gauteng
1982	25.22.55	30.32.0	Schoemanskloof - Montrose - Elandshoek	Mpumalanga
1982	25.5.42	30.47.12	Nelspruit - Sabie	Mpumalanga
1982	25.43.35	30.39.57	Elandshoek - Ngodwana - Kaapsehoop	Mpumalanga
1982	25.35.21	30.45.58	Kaapsehoop - Barberton - Nelspruit	Mpumalanga
1982	25.46.34	31.2.41	Kaapsehoop - Escarpment - Barberton	Mpumalanga
1982	25.57.35	30.32.22	Lekkerdraai - Badplaas - Carolina	Mpumalanga
1986	29.9.4	3.4.01	Stanger - Mapumulo - Kranskop	Kwazulu-Natal
1986	29.20.45	31.19.24	N2 (Stanger) - Greytown	Kwazulu-Natal
1986	30.19.3	30.44.1	Umzinto - Park Rynie	Kwazulu-Natal
1987	29.33.23	30.55.09	Pietermaritzburg, Chase Valley	Kwazulu-Natal
1990	33.59.41	22.36.47	Wilderness East - Langvlei	Western Cape
1990	33.57.20	23.9.13	Kom Se Pad; Diepwalle to Gouna	Western Cape
1993	24.59.33	30.48.47	Sabie & Mac-Mac Rivers, Goudstroom, Malieveld Sprt	Mpumalanga
1994	24.10.01	30.21.38	Legalameetse N R, Ofcolaco	Limpopo
1994	24.35.00	30.20.09	Elands River upstream of 5 arches bridge	Mpumalanga
1994	24.30.00	30.35.00	Lupelule catchment; opposite Elandshoek	Mpumalanga
1994	24.56.50	31.46.01	Railway/SPOORNET: Empangeni - Felixton - Mtunzini	Kwazulu-Natal
1994	24.2.53	31.31.56	Railway: Fairbreez - Eshowe North - Amatikulu	Kwazulu-Natal
1995	24.28.0	30.56.0	Riverside Farm, Mataffin, Nelspruit	Mpumalanga
1995	24.32.3	31.19.1	N4 Kaapmuiden - Nelspruit	Mpumalanga
1995	24.29.33	30.23.15	Otto's Bluff to New Hanover; railside (SPOORNET)	Kwazulu-Natal
1995	24.15.56	30.37.13	Harden Heights, Greytown, Mollisina - Ahrens; rail	Kwazulu-Natal
1995	24.46.40	29.58.55	Henley - Ncwadi; rail (SPOORNET)	Kwazulu-Natal
1995	29.30.32	30.21.37	Rail/SPOORNET: PMB - Merrivale; PMB - Otto's Bluff	Kwazulu-Natal
1996	24.35.0	30.45.00	Graskop - Blyde R Canyon R532, near Bourkes Luck	Mpumalanga
1996	24.40.0	30.45.00	Graskop - Blyde R Canyon R532, Treur River Valley	Mpumalanga
1996	24.50.0	30.30.00	R533 & R36, Pilgrims Rest - Lydenburg	Mpumalanga
1996	24.54.0	30.45.00	Pilgrims Rest	Mpumalanga
1996	25.26.0	30.57.00	Nelspruit; Botanical Garden and entrance road	Mpumalanga
1996	25.20.0	30.50.00	R37, Rosehaugh - Nelspruit	Mpumalanga
1996	25.30.0	30.50.00	Nelspruit - Kaapsehoop	Mpumalanga
1996	25.35.0	30.50.00	Kaapsehoop - Barberton	Mpumalanga
1996	25.00.0	31.00.00	R536, Sabie - Hazyview, Sabie River Valley	Mpumalanga
1996	25.25.0	31.05.00	N4, Kaapmuiden - Nelspruit	Mpumalanga
1996	25.40.0	31.15.00	Shiyalonguba Dam - Louw's Creek	Mpumalanga

1996	25.45.0	31.00.00	R40, Nelspruit - Barberton - Bulembu	Mpumalanga
1997	22.55.0	29.50.00	Louis Trichardt Dist; Mountain Inn - Bluegum Poort	Limpopo
1997	22.55.0	30.5.00	Louis Trichardt via Tshifhire to Thohoyandou	Limpopo
1997	22.55.0	30.20.00	R523, Mandala - Thohoyandou	Limpopo
1997	23.25.0	29.55.00	Groot Spelonke - Spelonken Plantation - Soekmekaar	Limpopo
1997	23.05.00	30.00.00	Albasini Dam - Elim - Bandelierkop	Limpopo
1997	23.00.0	30.00.00	Louis Trichardt Dist; Sterkstroom - Hangklip	Limpopo
1997	23.00.0	30.05.00	Louis Trichardt Dist; Piesanghoek - Sterkstroom	Limpopo
1997	23.10.0	30.00.00	Elim - Bandelierkop	Limpopo
1997	23.40.0	30.10.00	Modjadji - Tzaneen; Selokwe River Valley	Limpopo
1997	23.55.0	30.50.00	Tzaneen - New Agatha - Die Akkers picnic site	Limpopo
1997	23.48.51	30.01.44	Debengeni Falls, Magoebaskloof	Limpopo
1997	23.45.0	30.00.0	R71 Tzaneen - Magoebaskloof	Limpopo
1997	23.45.0	30.50.0	R36 & R71; Westfalia - Magoebaskloof	Limpopo
1997	23.45.00	30.00.0	R71 De Hoek - Debengeni Falls - Woodbush	Limpopo
1997	29.33.51	30.20.22	Ferncliffe; western side of Pietermaritzburg	Kwazulu-Natal
1997	29.34.45	30.22.19	Chasedene, Pietermaritzburg	Kwazulu-Natal
1998	23.58.0	28.41.0	Ga-Motlana - Potgietersrus R518; along Sterk River	Limpopo
1998	24.50.0	27.40.0	Leeuwpoort Mine and Warmbaths to Thabazimbi	Limpopo
1998	24.15.45	28.5.48	Culmpine Estate; Vaalwater; Mokolo River	Limpopo
1998	24.38.51	28.40.5	Nylsvley Nature Reserve, Naboomspruit	Limpopo
1998	24.15.0	29.45.0	Burgersfort to Pietersburg	Limpopo
1998	24.50.0	30.15.0	Lydenburg to Burgersfort	Limpopo
1998	29.30.0	30.20.0	Pietermaritzburg; Chase Valley and Chase Stream	Kwazulu-Natal
1998	30.58.0	30.16.0	Mpenjati Nature Reserve; Mpenjati River	Kwazulu-Natal
1998	31.2.40	29.21.48	Bomvini Location, Lusikisiki District	Eastern Cape
1999	23.59.0	29.59.0	Haenertsburg	Limpopo
1999	27.44.26	30.47.33	Vryheid Hill Nature Reserve	Kwazulu-Natal
2001	25.35.0	28.30.0	Premier Mine Nature Reserve, Cullinan	Gauteng
2004	26.0.0	27.40.0	R563 - N14; Krugersdorp District	Gauteng
2004	31.35.01	28.47.17	Umtata River, Umtata, former Transkei	Eastern Cape
2004	31.35.0	29.31.0	Cremorne Estate, Mzimvubu River, Port St Johns	Eastern Cape
2005	24.48.53	28.20.38	Between Klein Kariba and Nylsvley	Limpopo
2005	24.50.57	28.20.2	Klein Kariba between entrance and river; opp. golf course	Limpopo
2005	24.45.39	30.32.57	Farm near Ohrigstad	Limpopo
2006	24.16.52	27.44.45	Vygeboomfontein - Buffelsfontein	Western Cape
2006	24.24.13	28.7.34	Vaalwater - Nylstroom	Limpopo
2006	24.45.0	28.10.0	Frischgewaagd to Elandsfontein	Gauteng
2006	24.50.0	28.19.0	Klein Kariba Pleasure Resort near Bela-Bela (Warmbaths)	Limpopo
2007	23.54.0	29.56.0	Haenertsburg Dist; Veekraal - Cheerio	Limpopo
2007	23.50.0	30.5.0	Tzaneen District; Pigeon Hole (Agatha area) - Tzaneen	Limpopo
2007	24.54.0	30.39.0	R533 Pilgrims Rest - Ohrigstad	Limpopo
2008	25.20.0	30.25.o	N4 Bambi to Schoemanskloof	Mpumalanga
2008	25.20.0	30.35.0	Wonderkloof to Sudwala	Mpumalanga
2008	29.0.0	30.50.0	Krantzkloof Nature Reserve	Kwazulu-Natal
2008	33.55.0	22.45.0	Ruigtevlei - Karatara	Western Cape
2008	33.55.0	25.0.0	N2 Humansdorp - Port Elizabeth	Eastern Cape
2008	33.50.0	25.15.0	N2 turnoff to Uitenhage	Eastern Cape
2009	31.35.0	29.30.0	Port St Johns; main entrance road and surroundings	Eastern Cape
2009	31.30.0	29.30.0	Lusikisiki - Port St Johns R61; former Transkei	Eastern Cape
2010	25.30.0	30.20.0	N4 Waterval Boven - Ngodwana	Mpumalanga
2010	25.35.0	30.55.0	R40 Barberton - Nelspruit	Mpumalanga
2010	25.36.37	30.52.34	Kaapsehoop - Barberton	Mpumalanga

2010	25.5.0	31.5.0	R538 Manzini - Hazy View	Mpumalanga
2010	24.2102	30.5647	Tokai A10	Western Cape
2010	25.25.0	31.5.0	R538 Karino - Plaston (Manzini and Numbi)	Mpumalanga
2010	25.30.0	31.10.0	Bouldersberg to Krokodilpoort	Mpumalanga
2010	25.40.0	31.15.0	Shiyalongubu Dam to Louw's Creek	Mpumalanga
2010	24.2102	30.5647	Matumi Game Lodge,near Hoedspruit; 537	limpopo
2011	24.50.42	28.19.48	Bela Bela, Klein Kariba private nature reserve	Limpopo
2011	25.40.22	28.6.12	Pretoria North, Brits road	Gauteng
2011	33.22.0	25.44.0	Addo to Suurberg to Ann's Villa R335	Gauteng
2011	34.05442	18.425389	Tokai service avenue Painters Cottage	Western Cape
2011	34.05398	18.425917	Carletonville	Gauteng
2012	30.43.0	30.27.0	Umtentweni	Kwazulu-Natal
2012	30.40.0	30.20.0	Oribi Flats to the N2	Kwazulu-Natal
2012	26.365	27.3897	Somerset East	Eastern Cape
2013	23.58.16	28.41.46	Waterberg; Marken to Mokopane R518; Sterk River	Limpopo
2013	24.5.0	28.20.0	Waterberg; Olivenfontein to Koperfontein	Limpopo
2013	24.25.0	28.15.0	Waterberg; Donkerhoek - Heuningfontein - Bakovenkrans	Limpopo
2013	24.15.0	28.25.0	Bokpoort Pass to Vaalwater	Limpopo
2013	24.5.0	28.35.0	Waterberg; Bastersnek to Jonkmansdrif	Limpopo
2013	24.5.0	28.40.0	Waterberg; Sterkrivier to Swartkop	Limpopo
2013	24.10.0	28.45.0	Waterberg; Rooiwal to Mooiwater	Limpopo
2013	24.25.0	28.35.0	R520 Mookgopong/Naboomspruit to Marken	Limpopo
2013	24.30.0	28.20.0	Waterberg: Bakovenkrans - Doornfontein; Swaershoekberge	Limpopo
2013	24.35.0	28.15.0	R33 Vaalwater to Nylstroom	Limpopo
2013	33.56.48	23.37.37	Start of Bloukrans Pass; Lottering plantations	Limpopo
2013	33.56.1	25.1.30	N2 near Gamtoos River crossing	Eastern Cape
2013	34.0.0	21.10.0	R323 Ladismith to Riversdale	Eastern Cape
2013	32.714	25.647	A16c Tokai	Western Cape
2013	34.05137	18.430513	Bibbeyshoek, Goudveld, Knysna	Western Cape
2013	33.9285	22.96556	Tokai Park - Service Road opp Lions gate	Western Cape
2013	34.054	18.425877	M42 Tokai	Western Cape
2013	26.2041	28.0473	De Tweede Spruit Conservancy	Gauteng
2014	25.56298	28.5278	De Tweede Spruit Conservancy	Gauteng
2014	25.5484	28.569266	Dassie St, Rheenendal	Western Cape
2014	33.92806	22.963611	N2, Greater Plettenberg Bay	Western Cape
2014	34.03806	23.226389	Winterberg Inn	Western Cape
2014	25.4.14	30.51.13	Sabie; Bergvliet plantation (KLF)	Mpumalanga
2015	22.55.00	30.5.0	Piesanghoek to Tshitiva; Soutpansberg district	Limpopo
2015	22.47.0	30.21.0	Tshandana to Nzhelele	Limpopo
2015	23.0.0	30.5.0	Piesanghoek to Welgevonden	Limpopo
2015	33.42292	19.265356	Mankele	Mpumalanga
2015	25.3898	30.7131	Outeniqua Nature Reserve	Western Cape
2015	25.46.53	28.11.37	Fountains Valley	Gauteng
2015	33.9219	22.262	Klaasenbosch Trail	Western Cape
2016	25.5.0	31.0.0	White River to Hazyview R40	Mpumalanga
2016	34.00746	18.439287	Kloof Rd, Sea Point	Western cape
2016	24.86712	28.324257	Ronwill holiday resort, R101	limpopo
2016	33.92673	18.381063	Carwash alien spotting	Western cape
2016	33.9698	18.458047	R335 (3)	Eastern cape
2017	33.36592	25.73747	R331 (4)	Eastern cape
2017	33.75449	24.79776	R331 (3)	Eastern cape
2017	33.7943	24.87279	R331 (5)	Eastern Cape
2017	25.677	28.5383	Pretoria	Gauteng

2017	25.7423	28.292	Pretoria	Gauteng
2017	25.7415	28.2896	Pretoria	Gauteng
2017	25.7566	28.2944	Pretoria	Gauteng
2017	25.7533	28.2884	Pretoria	Gauteng
2017	25.75329	28.28843	136, Taj St	Gauteng
2017	25.78001	28.103772	Greyton House trees	Gauteng
2017	34.05309	19.604051	Greyton	Western cape
2017	34.05136	19.606336	Greyton	Western cape
2017	34.05366	19.604372	Greyton	Western cape
2017	34.04484	19.61053	Greyton	Western cape
2017	34.0465	19.60973	Greyton	Western cape
2017	34.04537	19.616338	Greyton	Western cape
2017	34.04853	19.61008	Greyton	Kwazulu-Natal
2017	28.4182	32.1834	Mtubatuba	Kwazulu-Natal
2017	28.4247	32.1847	Mtubatuba	Kwazulu-Natal
2017	28.43359	32.18582	Riverview	Kwazulu-Natal
2017	28.43595	32.18292	Riverview	Kwazulu-Natal
2017	28.43829	32.18095	Riverview	Kwazulu-Natal
2017	28.43527	32.18236	Mtubatuba	Kwazulu-Natal
2017	28.4343	32.1826	Mtubatuba	Kwazulu-Natal
2017	28.42716	32.18157	Mtubatuba	Kwazulu-Natal
2017	28.4264	32.1818	Mtubatuba	Kwazulu-Natal
2017	28.42614	32.18305	Mtubatuba	Kwazulu-Natal
2017	28.4208	32.1836	Mtubatuba	Kwazulu-Natal
2017	28.4115	32.1885	Mtubatuba	Kwazulu-Natal
2017	28.41358	32.19029	Mtubatuba	Kwazulu-Natal
2017	28.4144	32.1943	Mtubatuba	Kwazulu-Natal
2017	28.41544	32.19588	Mtubatuba	Kwazulu-Natal
2017	28.41545	32.19287	Mtubatuba	Kwazulu-Natal
2017	28.41509	32.1924	Mtubatuba	Kwazulu-Natal
2017	28.37939	32.4099	St Lucia	Kwazulu-Natal
2017	34.04856	19.60697	Greyton	Kwazulu-Natal
2017	34.04882	19.609778	Boston st, Elarduspark,	Gauteng
2017	25.82396	28.25826	Stander st, Moreletapark	Gauteng
2017	25.81883	28.29262	Moreletapark, Pretoria Eas	Gauteng
2017	25.82401	28.29398	Swellendam	Western cape
2017	34.02358	20.435819	35 George road	Western cape
2017	26.57.25	26.40.27	At Anglogold Ashanti Vaal River Operations near Orkney	Gauteng