THE POTENTIAL CONFLICT OF INTEREST ASSOCIATED WITH THE MANAGEMENT OF *ROSA RUBIGINOSA* L. (ROSEHIP) IN SOUTH AFRICA

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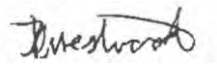
ABSTRACT

Rosa rubiginosa L. is a category 1b invasive plant species in South Africa and must be controlled according to NEM:BA. However, *R. rubiginosa* has the potential to provide economic benefit in South Africa due to the expanding market for the shrubs fruit, rosehips. The shrub is not permitted to be cultivated in South Africa due to legislation, limiting the economic potential as the rosehips are only able to be collected from wild *R. rubiginosa* shrubs. In order to expand the rosehip market in South Africa a downgrade or removal of *R. rubiginosa* from the invasive species list would be required, as wild harvest is limited. This study aims to assess the benefits and cost associated with *R. rubiginosa* in order to determine whether the legislation should be altered allowing for the cultivation of the shrub in South Africa.

Due to the limited literature surrounding *R. rubiginosa* three different questionnaires and a case study were used in order to assess the benefits and negatives associated with the shrub. Experts in the field of invasion biology were surveyed to bridge the gap in the *R. rubiginosa* literature. Landowners, where the shrub is abundant, were surveyed to determine the negative impacts of *R. rubiginosa.* Rosehip companies were surveyed in order to determine the current size and potential of the *R. rubiginosa* (rosehip) market. The case study looked at how a rosehip company would benefit if *R. rubiginosa* was allowed to be cultivated in South Africa. The study found *R. rubiginosa* to have great economic potential and market growth, with very little negative economic impact. The case study showed that one rosehip company would grow from 1500 tons of raw rosehip to 20 000 tons if cultivation was allowed, resulting in a growth in turnover from R57 million to R760 million ($1=R14.8). The findings in the study show that *R. rubiginosa* does not significantly affect landowners where it is abundant. Therefore, it is suggested that a change to the legislation should be considered allowing for the cultivation of *R. rubiginosa* should be implemented.

DECLARATION

This thesis has not been submitted to a university other than Rhodes University, Grahamstown, South Africa. The work presented here is that of the author, unless otherwise stated.



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Timothy Westwood Date

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LIST OF ABBREVIATIONS

CBD – Convention on Biological Diversity

ENM – Ecological Niche Modelling

GARP – Genetic Algorithm of Rule-set Prediction

GBIF – Global Biodiversity Information Facility

GDP - Gross Domestic Product

IAP – Invasive Alien Plant

IAS – Invasive Alien Species

NEM:BA – National Environmental Management: Biodiversity Act

NPV – Net Present Value

SANBI – South African National Biodiversity Institute

SAPIA – Southern African Plant Invaders Atlas

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CHAPTER 1

INTRODUCTION

1.1 INVASIVE ALIEN PLANTS

South Africa has a long history of invasive alien species (IAS) which dates back to the colonisation of the country by Europeans in the mid-17th century (Moran *et al.,* 2013) . The primary reasons for IAS introduction into foreign countries was to provide colonisers with food, raw materials, pets, erosion control, and recreational ornamentation (Zengeya *et al*., 2017). Today, IAS are still being introduced into countries all around the globe. Invasive alien plants (IAPs) are considered to be the most damaging of all IAS, having the greatest economic and environmental impacts (McGeoch *et al*., 2010; Spear *et al.,* 2011). The Convention on Biological Diversity (CBD) broadly defines and invasive alien species as:

> "a species whose introduction and spread threatens ecosystems, habitats or species with socio-cultural, economic and/or environmental harm, and/or harm to human health" (CBD, 2002: 2).

IAPs are an ever-growing threat to ecosystems across the globe (Van Wilgen *et al.,* 2004) and have therefore received increased attention from both governments and academics. This is due to the increased understanding relating to the severity of the consequences associated with IAPs (Early *et al*., 2016; Richardson *et al.,* 2004). Globalisation is regarded as the primary contributor to the increase of invasive plant species (Carbutt, 2012), due to non-native plants being introduced into a foreign range, either purposefully or accidentally (Simonsen *et al.,* 2008; Zengeya *et al.*, 2017). South Africa is no exception and is regarded as one of the most invaded countries on earth (Henderson, 2007; Van Wilgen *et al*., 2004).

Not all non-native plants are classified as invasive plants. A non-native plant is only a successful invasive if it causes a negative impact on human health, the native ecosystem and/or economic interests (Van Wilgen *et al*., 2004). IAPs have significant environmental and economic impacts; they spread at an extreme rate, produce a large number of seeds, form

dense stands, alter nutrient cycles and food webs, displace native vegetation, and alter water quality and quantity (Zimmermann *et al.*, 2004). IAPs cost the South African economy billions of Rands annually as a result of decreased economic production and control costs, which are additional costs that a developing country with significant inequality can ill afford (De Lange & van Wilgen, 2010). There is a significant scientific community in South Africa which focuses on evaluating ecological impacts of IAP's (Richardson & Van Wilgen, 2004; Zimmermann *et al.*, 2004; Hill & Coetzee, 2017), however there is still limited literature regarding the economic impacts of IAP's (De Wit *et al.,* 2001; Zengeya *et al.,* 2017).

IAPs impact economies in a variety of ways, both directly and indirectly. Research costs, reduction in agricultural yields, control costs and management programs, as well as physical environmental destruction are direct economic impacts caused by IAPs (Pimentel *et al*., 2005). Indirect economic impacts of IAPs include the loss of ecosystem services, changes to natural habitats, a decline in biodiversity, and various social impacts (Pimentel *et al*., 2005; Villamagna & Murphy, 2010). An IAP that impacts the environment and economy in both positive and negative ways create a conflict-of-interest, as to whether to eradicate the species or to use it for its beneficial qualities or find a balance between the two (Zengeya *et al.*, 2017). In South Africa *Rosa rubiginosa* L. is regarded as a conflict of interest species (Zengeya *et al*., 2017) as it is regarded as an invasive species but also known to have some beneficial attributes.

The following chapter provides a brief introduction and overview of *R. Rubiginosa* (1.2) and discusses the Rosehip Industry (1.3). The chapter further addresses the problem statement (1.4), the aims and objectives of the study (1.5), the method to be followed (1.6), and outlines the structure of the thesis (1.7).

1.2 *ROSA RUBIGINOSA* L. (SWEET BRIAR)

Rosa rubiginosa L., commonly known as Sweet briar or *Rosa Mosqueta* is an invasive compact, deciduous shrub native to Europe and Asia and has become naturalised in North America, South America, Australasia, and Africa (Ashmead, 2011; Henderson, 2007; Hirsch *et al*., 2011; Kissel *et al.,* 2018). *Rosa rubiginosa* is a highly invasive shrub, invading high altitude grassland, specifically moist valleys, rocky outcrops, watercourses, roadsides, as well as overgrazed land (Henderson, 2001). It is known to have a number of negative environmental and economic

impacts in non-native countries. The shrub is a threat to existing ecosystems as it spreads via a number of reproductive techniques including autonomous self-pollination. Baker (1955), put forward Baker's rule, which states that self-compatible plants, particularly those capable of autonomous self-pollination, have a higher invasive potential (Baker, 1955; 1967; Hao *et al.,* 2011; Ward., 2012). *Rosa rubiginosa* is also able to re-sprout subsequent to cutting or fire (Smulders *et al.*, 2011).

Rosa rubiginosa is one of the most frequent and prominent invaders in South Africa's high-altitude grassland biome (Carbutt, 2012; Henderson, 1991: Figure 1). The shrub is categorised as a 1b invasive species in South Africa under the National Environmental Management: Biodiversity Act, 2004 (AIS, Republic of South Africa, 2014). According to the most recently available SAPIA data, *R. rubiginosa* is most widespread and reaches the highest densities along the Drakensberg and Maluti mountain ranges which makes up the eastern part of the Great Escarpment (L Henderson, 1991, 2001). The shrub is also found in Lesotho, a landlocked country within South Africa. There are three South African provinces which border Lesotho, all of which contain *R. rubiginosa* infestations. The south eastern Free State is the most populated *R. rubiginosa* area in South Africa (L Henderson, 1991;Figure 1).

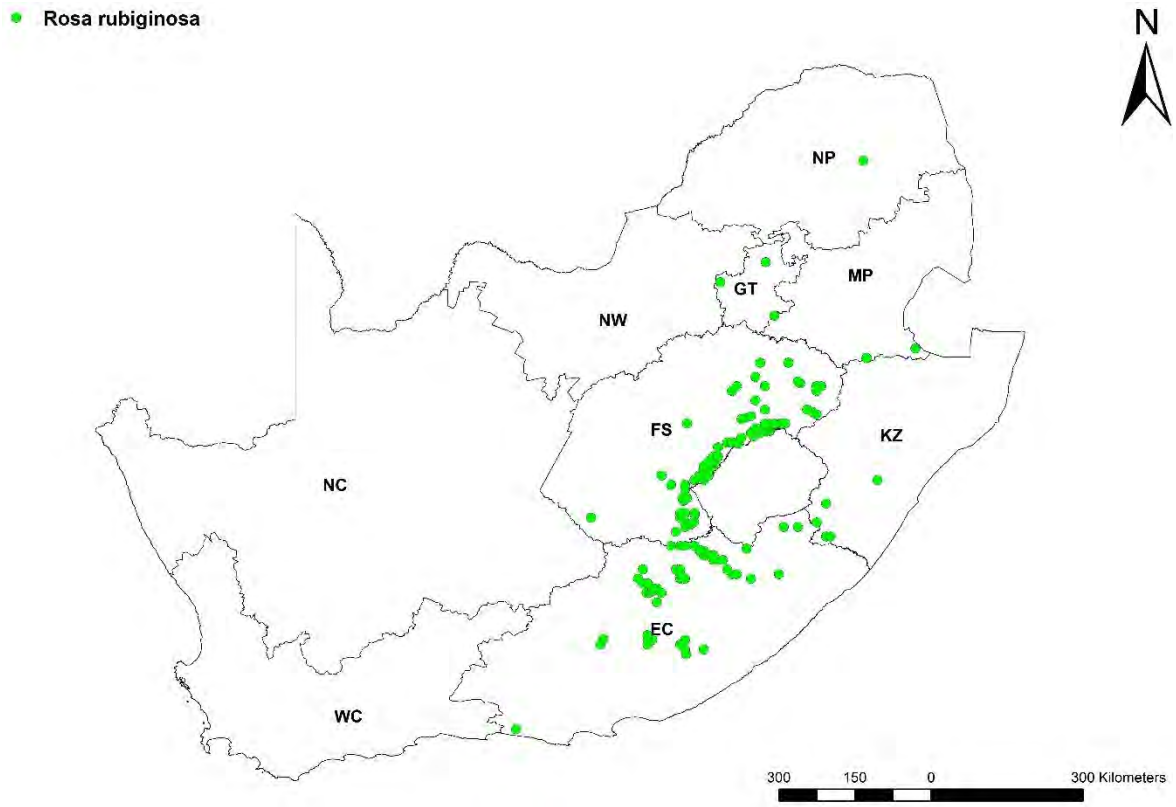

Figure 1. 1: Distribution records of *Rosa Rubuginosa* L. in South Africa. Provinces: Gauteng (GT), Mpumalanga (MP), Limpopo (NP), North West (NW), KwaZulu-Natal (KZ), Eastern Cape, Western Cape (WC), Northern Cape (NC) and Free State (FS)

R. rubiginosa, like all Rosa species, produce fruits known as rosehips. The rosehips have been used over the years to make various herbal teas and jams (Smulders *et al.*, 2011). It is also a growing product in the cosmetic industry, where there is a growing market for rosehips (Ramos *et al*., 2016).

1.3 ROSEHIP INDUSTRY

R. rubiginosa is an economically beneficial plant that's cultivation is prohibited by law in South Africa (NEM:BA, 2004). Originally wild harvested rosehips were used to produce teas and jams which contained high levels of vitamin C (Smulders *et al.*, 2011). In more recent years, the oil content and fatty acids obtained from the rosehips have been incorporated into cosmetics (Grundy *et al.,* 1989; De Pietri, 1992; Franco *et al.*, 2007; Barry *et al.,* 2008; Ramos *et al.*, 2016). There already appears to be a cosmetic market for rosehips in South Africa, as a large volume of rosehip is being exported out the country annually. This is possible due to legislation which

allows for the harvesting and selling of any 'wild' invasive plant's fruit (NEM:BA, 2004). Developed countries provide the largest markets for rosehip. Hills (2008), expressed the estimated size of the European rosehip market over a three-year period (2008-2010) to be between R120,7 and R144,84 million ($14,7 and $17,64 million).

1.4 PROBLEM STATEMENT

In South Africa, the National Environmental Management: Biodiversity Act (NEM:BA) regulations were promulgated in 2004, which legislates that all invasive plants must be contained and destroyed according to their stage of invasion (Poona, 2008). NEM:BA uses three legislated categories to describe the invasion stage and management options of identified invasive plant species. *Rosa Rubiginosa* L. falls under a 1b invasive species category which means the plant must be prohibited/destroyed, if in possession and kept under control. Invasive species that must be immediately prioritized for eradication as these species have high invasive potential. However, *R. rubiginosa* has the potential to provide economic benefits in South Africa as there is an expanding economic market for the shrubs fruits (rosehips). Previously, rosehips were used on a small scale for various teas and jams. However, more recently the market for rosehips has grown due to its use in the cosmetic industry (Jiménez-López *et al., 2017*). However, in South Africa, category 1b invasive species are not permitted to be cultivated and therefore would require a downgrading in order for the full economic potential of *R. rubiginosa* to be utilised in South Africa. Therefore, *R. rubiginosa* is a conflict-of-interest species which requires a decision as to whether the shrub's NEM:BA listing should be re-evaluated

1.5 AIMS AND OBJECTIVES

1.5.1 AIM

The aim of this study is to create a greater understanding of the impacts the invasive shrub *R. rubiginosa* has on South Africa. The study will assess the impact that the invasive shrub has on landowners and the benefit that the shrub provides companies in South Africa. This will allow for a conclusion to be drawn as to whether the current South African legislation should be downgraded to allow for the cultivation of *R. rubiginosa.*

1.5.2 OBJECTIVES

In order to achieve the aims of this study, certain objectives need to be fulfilled:

- Consult experts in the field of invasion biology in order to bridge the knowledge gap found in the limited available literature regarding *R. rubiginosa* in order to better understand the shrub's 1b categorisation.
- Assess the negative impacts *R. rubiginosa* has on landowners within *R. rubiginosa* infested areas of South Africa.
- Identify the functioning of wholesale *R. rubiginosa* (rosehip) companies and their economic benefits in South Africa.
- Conduct a case study to determine how a rosehip producing company would benefit from a *R. rubiginosa* categorisation downgrade.

1.6 METHOD TO BE FOLLOWED

This study attempts to better understand the conflict-of-interest associated with the invasive plant species *R. rubiginosa*, specifically looking to assess the benefits of allowing cultivation of the shrub in South Africa.

The study starts by bridging the gap in the academic literature with regards to the impacts imposed by *R. rubiginosa*. This was achieved by surveying experts within the field of invasive biology. In order to better understand the conflict-of-interest associated with *R. rubiginosa*, the impact that the shrub has on landowners in highly infested *R. rubiginosa* areas in order to understand the various negative impacts of the plant. The benefits of the shrub were also assessed by conducting a survey of the current rosehip companies in South Africa. A case study with one of the rosehip companies was conducted to gain an in-depth insight into the rosehip market and the potential benefit cultivation could provide.

1.7 STRUCTURE OF THE STUDY

This thesis is structured with the following chapters; Chapters two presents a literature review with specific focus on the economics of IAP's and the invasive shrub *R. rubiginosa*. Chapter three covers the methodological approaches conducted in the study. Chapter four provides

the results from the research conducted. Chapter five discusses the study's findings and the limitations and assumptions found within the study.

CHAPTER 2
LITERATURE REVIEW

2.1 INVASIVE ALIEN PLANTS

Invasive alien species are not a new phenomenon. IAS can roughly be dated back as far as 10,000 years ago, to the start of agriculture and with it the arrival of pests (Gren, 2008). IAS are animals, pathogens, and plants that are non-native to ecosystems which have the potential to cause economic or environmental harm or adversely affect human health (Pimentel *et al*., 2001). A species becomes invasive if it successfully out-competes native species and spreads through the new environment, increasing in population and harming the ecosystem into which it is introduced (Van Wilgen *et al.*, 2004).

The intentional and unintentional introduction of IAS into new ecosystems have a continued negative ecological, economic, human and social impact at national, regional and global scale. Biological invasions have disturbed natural habitats of native species, reduced the functionality of ecosystems, and impaired the aesthetics of natural environments (Marbuah *et al.,* 2014).

Despite the early recognition of IAS by ecologists and biologists in terms of environmental damages and social costs, environmental economic studies on IAS are scarce. Economic studies have focused on both *ex post* and *ex ante* assessments of costs associated with IAS or on cost-benefit analysis of programmes preventing, controlling or eradicating damages associated with IAS (Gren, 2008).

Pimentel *et al* (2001) estimated the total damages caused by IAS in six of the most invaded countries (Australia, United Kingdom, United States, South Africa, India and Brazil) to be more than $ 314 billion per year. South Africa loses an estimated R6.5 billion ($488 million) to IAPs annually, due to loss of water, grazing land and biodiversity (van Wilgen *et al*., 2017). Taking a number of assumptions into account, Pimentel *et al*, (2001) estimated the total global loss to IAPs to be around $1,4 trillion.

Within the literature surrounding IAPs, three key terms can be identified and need to be understood: ‘alien plants’, ‘naturalised plants’, and ‘invasive plants’. These terms are often mistakenly used as synonymous, however, they represent distinctive groups of plants.

Richardson *et al.* (2000) provides the distinction between the aforementioned three terms, suggesting that 'alien plants' are those plants that have either intentionally or accidently been introduced outside of their natural domain. The terms 'naturalised plant' and 'invasive plant' are both sub-groups of the term 'alien plant'. A 'naturalised plant' is an alien plant that is able to establish a sustainable population, meaning the plant is able to reproduce over several generations, and yet does not necessarily invade ecosystems (Richardson *et al*., 2000). An 'invasive plant' is a naturalised alien plant that invades ecosystems outside of its natural domain.

A biological invasion is a stochastic process that comprises of four stages; introduction, establishment, naturalisation, and damage creation (Marbuah *et al.*, 2014). The first stage, introduction, consists of the species being conveyed from their native range, either intentionally or unintentionally, into a new environment. The second stage is the species establishment in its new environment, this is where growth and reproduction gather pace and the populations size increases. The third stage of naturalisation is when the invasive species' reproduction is sufficient enough to maintain its population. The last stage of a biological invasion is the species ability to cause considerable ecological and economic damage to the native environment.

2.2 GLOBALISATION AS A DRIVER OF BIOLOGICAL INVASIONS

Biological invasions are strongly shaped by trends in human trade and transport (Hirsch *et al.*, 2011; Marbuah *et al.,* 2014). The trade of plant and animal species has been around for millennia. However, the 16th century was the first significant period in history which resulted in a drastic increase in IAS introductions (Preston *et al.*, 2004). This was a period of global exploration and the birth of colonialism, which saw drastic change in human demographics, agriculture, trade and industry (Preston *et al*., 2004). The industrial revolution was another significant period in invasive biology (Hirsch *et al*., 2011). The industrial revolution saw another increase in international trade facilitated by the construction of highways, railways and canals (Findlay & O'Rourke, 2007). Biological invasions have steadily increased over the last 200 years, increasing dramatically in the last 25 years (Hulme, 2009). In South Africa the introduction of alien invasive plants has been an ongoing process over the last 400 years (Moran *et al.,* 2013). The most intensive period of species introduction into South Africa was

between 1820 – 1899 with many of the introduced species being a direct result of the Dutch colonisation of the Cape peninsula (Henderson, 2007). Opuntia ficus-indica (sweet prickly pear) is the most prominent case of IAP in South Africa which was introduced in the early 20th century (Moran *et al.,* 2013).

It is therefore the opinion of many academics that globalisation is the primary driver for the increase in biological invasions *(*Hulme*,* 2009; McGeoch *et al.,* 2010*;* Carbutt*,* 2012*;* Early *et al*., 2016). Hulme (2009), showed a directly proportional increase in IAP with the increase in globalisation. Westphal *et al* (2008), demonstrated the positive relationship between merchandise imports and the number of invasive species, as well as the rate of species introduction. Hulme (2009) used Gross Domestic Product (GDP) to show the positive correlation between globalisation and biological invasions. GDP shows globalisation as it takes net exports into account, as well as private capital investments and government expenditure which reflects levels of infrastructure that can also facilitate invasions. A considerable increase in global GDP has occurred in recent years, along with an increase in the number of biological invasions, due to globalisation (Hulme, 2009). South Africa is no exception to the impact of globalisation and is regarded as one of the most invaded countries on earth (Henderson, 2007; van Wilgen *et al*., 2004).

2.3 *ROSA RUBIGINOSA* L.

Rosa rubiginosa L.*,* commonly known as *Rosa* Mosqueta in Argentina and Sweet briar in the rest of the world, is an invasive compact, deciduous shrub, part of the Rosaceae family. *Rosa rubiginosa* also goes by the ornamental name of "eglantine" (Hunter, 2014). *Rosa rubiginosa* is native to Europe and Asia (Figure 2.2). The shrub has become naturalised on four other continents (Africa, North America, South America, and Australasia), gaining invasive status on all four (Henderson, 2007; Ashmead, 2011; Hirsch *et al.*, 2011; Kissel *et al*., 2018). In most of the invaded countries *R. rubiginosa* was introduced for ornamental and hedging purposes (Henderson, 2001; Janakiram & Debner, 2008). The shrub, when fully grown, stands at 1-2 meters tall, has slightly arching branches with hooked thorns. The flowers blossom in the middle of summer and are pink in colour varying to white (Henderson, 2001). One of the defining characteristics of *R. rubiginosa* is the sticky glands on the underside of the leaflets which secretes a strong, sweet smelling fragrance (Zimmermann, 2012).

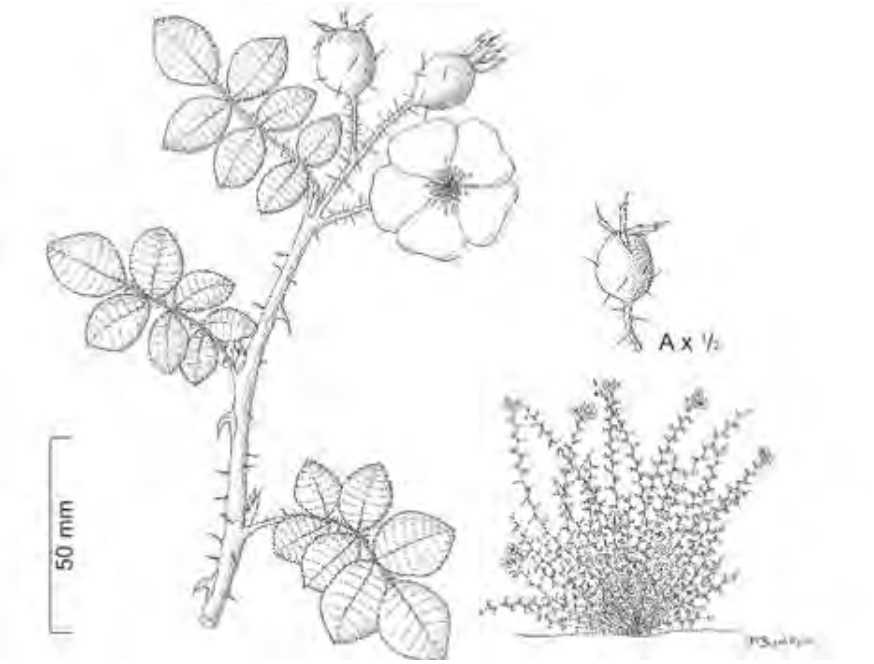

Figure 2. 1: Line drawing of *Rosa rubiginosa* L. leaves, flowers, hip, and shrub. Drawn by Sandie Burrows, first published in Henderson (2001).

Rosa rubiginosa is invasive in grasslands, specifically high altitude grasslands, in moist valleys, rocky outcrops, watercourses, roadsides, as well as overgrazed land (Carbutt, 2012; Henderson, 2001). The shrub also has the ability to invade dryland environments (Carbutt, 2012). *Rosa rubiginosa* is an early successional species and is able to rapidly invade open areas, due to the shrub's rapid growth rate and seed production, efficient seed dispersal (aided by animals), and form dense clusters altering vegetation physiognomy (Carbutt, 2012).

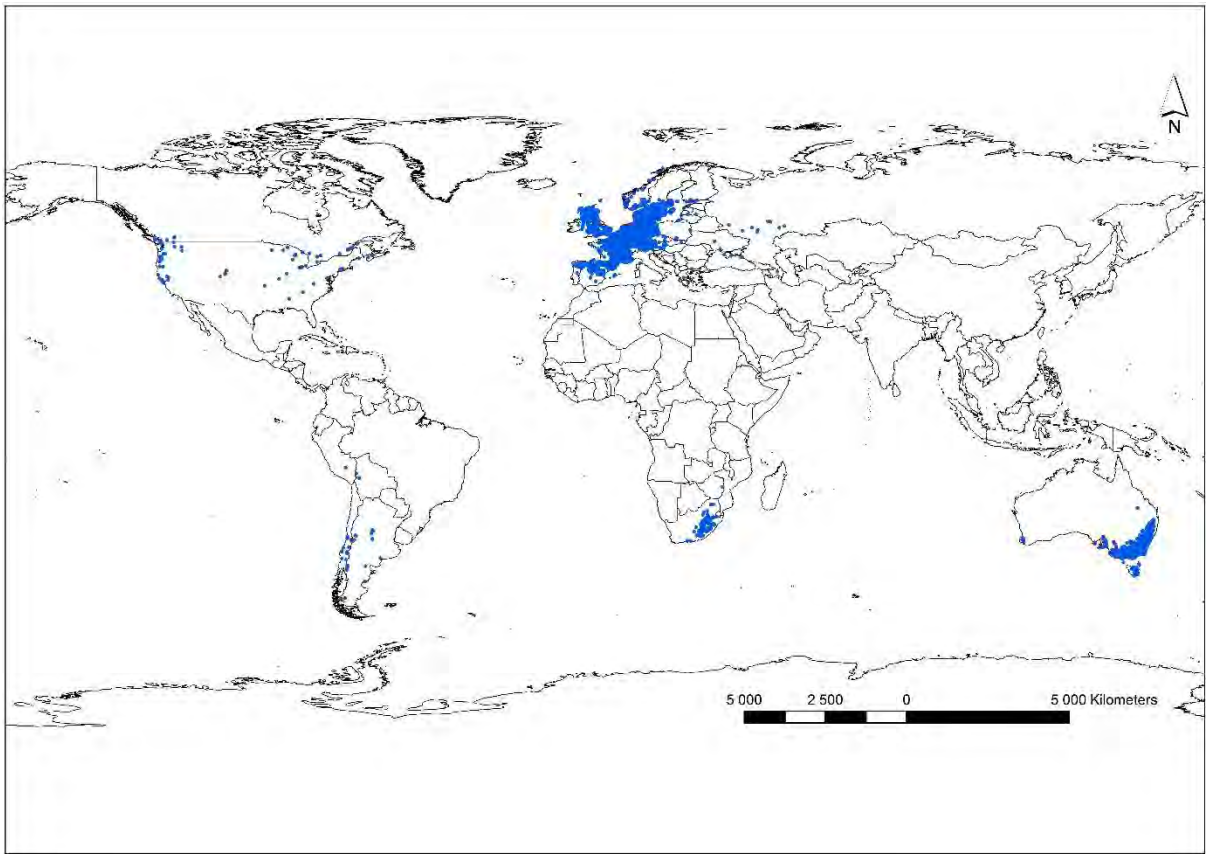

Figure 2. 2: The global distribution of *Rosa rubiginosa* L. Source: GBIF (2019).

A plant's invasive potential is largely influenced by its ability to reproduce rapidly (Mazzolari *et al.,* 2017). Plants display a great diversity of reproduction modes, dependency on which mode or modes a plant uses to reproduce will significantly impact the plant's ability to establish itself and invade a new area (Moodley *et al.*, 2016; Mazzolari *et al*., 2017). Baker (1955) put forward Baker's rule, which states that self-compatible plants, particularly those capable of autonomous self-pollination, have a higher invasive potential (Baker, 1955; 1967; Hao *et al.,* 2011 & Ward., 2012). *Rosa rubiginosa* has an array of reproductive techniques including autonomous self-pollination (Zimmermann *et al*., 2011). *Rosa rubiginosa* is also able to re-sprout subsequent to cutting or fire (Smulders *et al.*, 2011). The shrub is further spread through seed dispersal, birds and other animals eat the shrubs red fruit dispersing the seeds (Carbutt, 2012).

Rosa rubiginosa produce an orange-red to scarlet, fleshy achenes fruit, commonly known as rosehips. Rosehips are produced by the majority of Rosa species. Rosehips are formed when the tip of the stem swells up after the flower has faded. Rosehips vary between species in size, colour and shape (Janakiram & Debner, 2008). *Rosa rubiginosa* produces oblong shaped

hips, 1,4cm in length, are free of hairs (glabrous), and have 18 achenes per cluster on average (Janakiram & Debner, 2008). The biological purpose for rosehips is a means of seed dispersal.

The shrub is also perceived to be beneficial due to the various positive economic benefits associated with rosehips (Grundy *et al*., 1989; Franco *et al.*, 2007; Barry *et al*., 2008; Ramos *et al.*, 2016). Originally the rosehips were used to produce teas and jams (Smulders *et al*., 2017). More recently, rosehips have been incorporated into the cosmetic and natural oil industry (Nowak, 2005; Franco *et al*., 2007).

2.4 INVASIVE ALIEN PLANT LEGISLATION

The Department of Environmental Affairs (DEA) is responsible for the legislation regarding invasive alien species in South Africa. The National Environmental Management: Biodiversity Act (NEM:BA) is the primary legislative act on the management and control of IAPs in South Africa (NEM:BA, 2004). Invasive alien species are listed, along with their categories, in the Alien and Invasive Species regulations (AIS, Republic of South Africa, 2014) which falls under NEM:BA.

IAPs and their invasive tendencies are divided into three categories. Category 1 species are invasive plants that have the potential to cause considerable environmental and economic damage and are thus prohibited and must be controlled. Category 1 plants are further divided into 1a and 1b invasive plants. The 1a invasive plants cause considerable environmental and/or economic damage, but have not spread to the full extent of their potential range in South Africa. These species are deemed potentially eradicable and the DEA through South African National Biodiversity Institute (SANBI) spend money on managing these species within a National Management programme with the aim of eradication them. The 1b invasive plants also cause considerable environmental and/or economic damage, but have spread to such an extent that the likelihood of eradication is negligible and therefore they need to be managed through a National Management Programme. However, these species do not directly receive any government funding.

Category 2 listed invasive species are treated in the same way as 1b species, unless a permit has been granted to a landowner which allows for restricted activity within an area specified in the permit. These restricted activities include the cultivation of the category 2 species.

Even if a permit is granted to a landowner, the landowner still has the responsibility to ensure that the spread of the species does not occur outside of the land or area specified in the permit. Any category 2 invasive species which occurs in riparian areas must be considered to be a category 1b listed invasive species and managed accordingly.

Category 3 listed invasive species are predominantly ornamental plants. These species may no longer be planted. However, species that currently exist may remain, provided landowners take reasonable steps to prevent the species spreading. Any category 3 listed invasive species which occurs in riparian areas must be considered to be a category 1b listed invasive species and managed thus.

There are 373 listed invasive plants in South Africa. Of the 373 invasive plants, there are 50 1a invasive plants and 224 1b invasive species in South Africa, 23 category 2 species, 41 category 3 species, and 35 that fall under miscellaneous (AIS, Republic of South Africa, 2014).

In South Africa *R. rubiginosa* is categorised under the NEB:BA as a 1b invasive species (NEM:BA, 2004). No government funding has been dedicated to the eradication of *R. rubiginosa.* No official weed risk assessment has been done on *R. rubiginosa* in South Africa. The shrubs categorisation was determined, pre 2004, by various experts in the field of invasive biology.

In Australia, *R. rubiginosa* is categorised under the Natural Resources Management Act, 2004 as a category 2 invasive species (Hunter, 2014). The act is very similar to South Africa's NEM:BA with cultivation and transport of category 2 invasive species only being permitted with the correct permits. A state level risk assessment was conducted for *R. rubiginosa* using the Biosecurity SA Weed Risk Management System, which concluded that the impact the shrub has on both grazing land and native vegetation was low and that the feasibility of control was moderate, resulting in limited action on a state level. *Rosa canina* L. (dog rose) has a far greater impact on grazing land and natural vegetation in Australia than *R. rubiginosa* and therefore more attention is placed on *R. canina*. However, there are some management plans for *R. rubiginosa* within various mountain ranges (Hunter, 2014).

Rosa rubiginosa is also classified by the New Zealand Department of Conservation as an environmental weed and is restricted from sales, propagation and distribution (Howell, 2008).

2.5 *ROSA RUBIGINOSA* L. IN SOUTH AFRICA

Rosa rubiginosa has been identified in seven of the nine provinces in South Africa. Of the seven there are three provinces (Eastern Cape, Free State, and KwaZulu-Natal) that are significantly more populated by *R. rubiginosa*. These three provinces surround the land locked country of Lesotho where *R. rubiginosa* is well established as an invasive species (Carbutt, 2012). The predominant environmental biome of this area is the grassland biome. *Rosa rubiginosa* is a prominent invader within grassland biomes and was found to be one of the most frequent and prominent invader in the northern Eastern Cape and the eastern Free State (Henderson, 1991, 1992). Carbutt (2012) stated that *R. rubiginosa* is also capable of invading dryland environments and that the shrub is prevalent in high and low rainfall areas.

The first official recording in the SAPIA data base was in 1953 (Fig. 2.3). However, it was not until 1987 that SAPIA started collecting *R. rubiginosa* records. Records are recoded every few years as data is provided with data points by experts in the invasive field. There are currently 401 records of *R. rubiginosa* in South Africa on the SAPIA database (Fig 2.3).

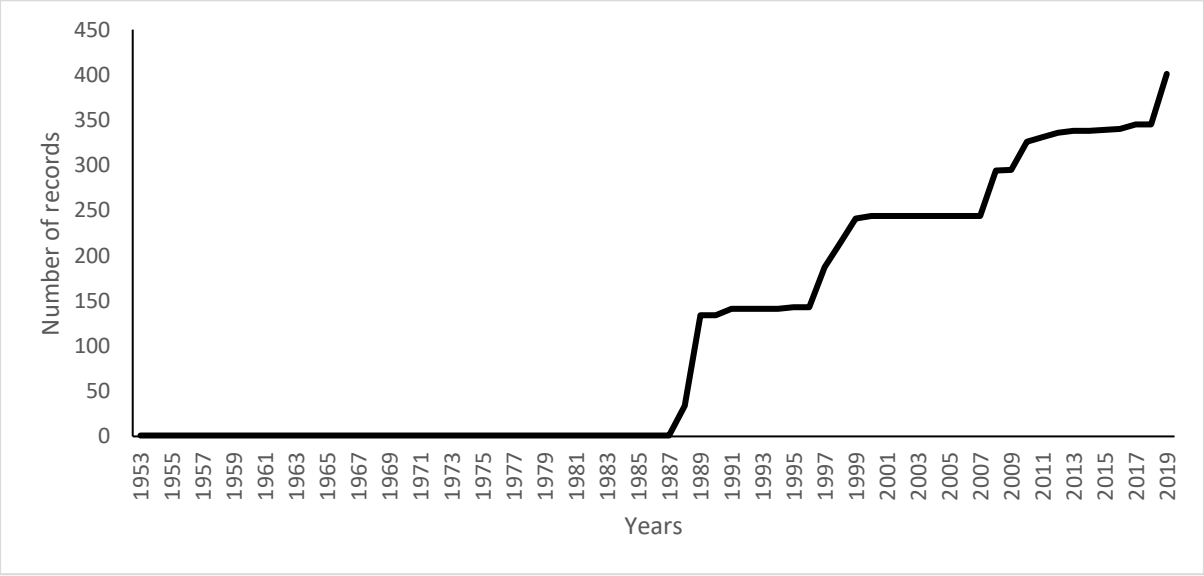

Figure 2. 3: The increase in the number of *Rosa rubiginosa* L. sightings in South Africa. (SAPIA database)

The majority of data points surround the landlocked country of Lesotho where it is well known that *R. rubiginosa* is in abundance (Carbutt, 2012; Henderson, 1991). The concentration of data points around Lesotho leads one to believe there must be a reason the shrub is only grows in that area. Henderson (1991) believes that the shrub only grows in areas that reach 5 degree Celsius or lower. The Drakensberg mountain range and Lesotho experience a large number of below freezing days and frost is a common occurrence (Carbutt, 2012).

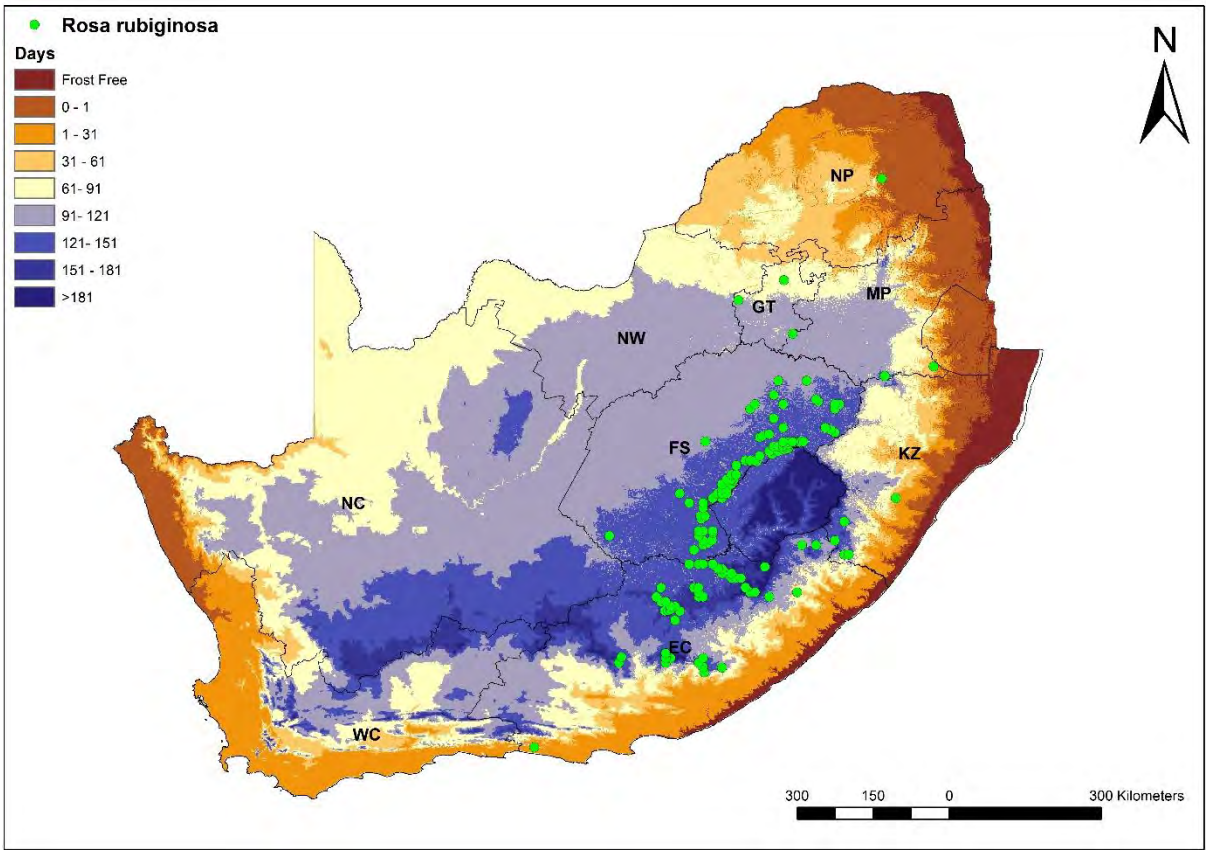

Figure 2. 4: The average annual number of frost days Schultz, 1997) overlaid onto the distribution of *Rosa rubiginosa* L. in South Africa.

Rosa rubiginosa falls within frost zones that experience well over 100 days of frost annually. The few data points that fall in zones with significantly less frost could be there due to the natural spread of the plant. However, these data points are around towns and cities and are therefore more likely ornamental shrubs which have been planted by humans who are able to induce seed germination artificially or plant by propagation.

As is found with many other members of the family Rosaceae, *R. rubiginosa* appears to require low winter temperatures in order to terminate seed dormancy. The requirement for

low winter temperatures may therefore limit the spread of *R. rubiginosa* to areas that perceive winter temperatures which fall below 5°C (L Henderson, 1991). The areas that are significantly more populated by *R. rubiginosa* (Eastern Cape, Free State, and KwaZulu-Natal provinces) experience the highest frequencies of below freezing minimum temperatures in Southern Africa (Henderson, 1992). The shrub is also found in Lesotho, a landlocked country within South Africa. There is therefore the potential that *R. rubiginosa* is only invasive in specific climate areas and is only found sporadically in other parts of the country due to ornamental cultivation of the shrub. This would lead to the potential that there is only a need to control *R. rubiginosa* in areas that have low winter temperatures. *Rosa rubiginosa* is regarded as an established, highly invasive, species in South Africa. *Rosa rubiginosa* is categorised as category 1b invasive and is the only noted invasive *Rosa* species in South Africa. There are several significant additional introduced *Rosa* species in South Africa, namely, *Rosa multiflora* Thumb*., Rosa x odorata* (Andrews) Sweet*., and Rosa sp. Rosa multiflora* is used as an ornamental plant. The shrubs rosehips do not provide any benefit and are not collected and sold in South Africa. *Rosa x odorata* are known to be used for their rosehips, however, there are very few records of the shrub in South Africa. There have only been three recorded *R. x odorata* species on the cost of KwaZulu-Natal and three in the Eastern Cape, all observed in urban areas. *Rosa sp.* is also not highly populated in South Africa with a total of 7 documented observations (SAPIA, 2019). None of these species are classified as invasive, however it was put forward by Lesley Henderson, a South African expert on invasive species, that *R. multiflora* should be classified as a category 3 invasive (Henderson, 2001). No action was taken. *Rosa rubiginosa* is the only Rosa species documented in areas where wild rosehip harvesting occurs in South Africa (SAPIA, 2019).

The 1b categorisation of *R. rubiginosa* in South Africa impacts various stakeholders. The categorisation prevents the cultivation of the shrub and therefore impacts the supply of rosehips to the various companies and requires them to gain their supply from inefficient wild picking, which is allowed under the 1b categorisation (NEM:BA, 2004). Various other stakeholders such as, farmers, potential employees of a larger market, and other participants in the sale of rosehip products in South Africa are impacted by the restrictive 1b categorisation. The categorisation should benefit landowners, as legislation states that landowners should control the spread of the shrub (NEM:BA, 2004). However, there is no

evidence of landowners controlling *R. rubiginosa* in South Africa. The 1b categorisation also means the shrub does not gain any government funding to aid the control and spread of the shrub in South Africa (NEM:BA, 2004). Executed efficiently, the 1b categorisation of *R. rubiginosa* should control the spread of the shrub however, both figure's 2.3 and 2.4 demonstrate the spread of the shrub.

2.6 ECONOMICS OF INVASIVE ALIEN PLANTS

The study of invasive biology has traditionally only been the domain of biologists. However, more recent times have seen economists studying invasive biology, with academics only focusing on the financial side of IAS in recent years, as their impact on economic systems has become more significant (Van Wilgen *et al.*, 2001; Cororaton *et al.,* 2009). IAPs cost South Africa billions of Rand annually and the world an estimated $1,4 trillion, almost 5% of the global economy (Pimentel *et al.*, 2001; De Lange & van Wilgen, 2010). It is important to have an economic understanding of invasive species so that their impacts on biodiversity can be quantified and compared between various species, allowing for an educated distribution of available resources so as to be most effective (Turpie, 2004; Fraser *et al*., 2016).

The traditional view of goods and services produced by firms is a basic economic concept. However, ecological economists have recognised the important impact made by ecosystems and have repacked ecosystem functions as valuable goods and services (Costanza *et al.*, 2014). This allows for an easier way of understanding the value of ecosystems and providing monetary values to invasions. An ecosystem good is a tangible product, such as timber. An ecosystem service encompasses benefits which are associated with ecosystem functioning, such as water purification (Turpie, 2004).

IAPs impact economies in a variety of ways, both directly and indirectly. Direct impacts are those changes in output, employment or income that represent the initial or first round of effects. Indirect, or secondary, impacts result from subsequent rounds of spending and respending within the economy (Bangsund *et al.,* 1999). Secondary impacts are not as easily identified as direct impacts, however secondary impacts often are significantly greater than direct impacts. Bangsund & Leistritz (1991) estimated direct and secondary impacts of Leafy Spurge infestations in Montana, South Dakota, and Wyoming in America to be $ 40,4 million and $ 89 million respectively.

According to Perrings *et al.* (2002), biological invasions are the external effects of market transactions as market prices do not reflect the total social and economic costs associated with an invasion (Jensen, 2012). It is the wider economy and not the individual or company who introduced the invasive species, that is impacted by the costs. Therefore, invasions show many characteristics of economic externalities, both positive and negatively (Jensen, 2012; Perrings *et al*., 2002). A conflict of interest arises when an IAP provides a positive environmental or economic externality coexisting with the invasive species negative externality, resulting from direct or indirect impacts. Positive externalities of IAPs include aesthetics, timber production, fruit production, fodder for livestock, carbon sequestration, and a form of biofuel (De Wit *et al.*, 2001; Van Wilgen and Richardson, 2014; Ramos *et al.*, 2016; Zengeya *et al.*, 2017). *Acacia mearnsii* (Black wattle), *Opuntia ficus-indica* (Mission prickly pear), and *Prosopis glandulosa* (Honey mesquite) are examples of IAPs within South Africa which are associated with both positive and negative externalities and therefore, are classified as conflict of interest species (Zengeya *et al*., 2017).

2.7 IMPACTS OF INVASIVE ALIEN PLANTS

Invasive alien plants have a significant negative effect on ecosystem services (Richardson & Rejmánek, 2011). Economic services are the benefits humans derive from ecosystems, such as, water supply, food, and the purification of air and water (Wallace, 2007). These impacts on ecosystem services have a ripple effect that impacts the production of economic goods and services and therefore impact negatively on a country's economy.

The effect IAPs exhibit on native ecosystems is mainly due to the fact that their characteristics are different to native species (Carbutt, 2012). Characteristics such as, reproduction techniques and climate adaptation allow for IAPs to rapidly spread and overwhelm areas where native species are found. The spread of IAPs and the reduction of native plants, pose a threat to ecosystem processes, which are fundamental to flora, fauna and human well-being (Gordon, 1998). Ecosystem processes are the transfer of energy and materials between biotic and abiotic elements in an ecosystem (Wallace, 2007), such as, evapotranspiration, water infiltration and storage, and nutrient cycles. Ecosystem processes directly influence ecosystem services.

However, IAPs may also provide beneficial characteristics creating a conflict-of-interest. This section looks at the general negative and beneficial characteristics of IAPs.

2.7.1 NEGATIVE IMPACTS ASSOCIATED WITH INVASIVE ALIEN PLANTS

The deliberate or accidental introduction of IAPs to a non-native environment has certain detrimental implications. These negative implications are derived from the invasive plant's characteristics, which give the species pre-adaptive advantages in the new non-native environment (Zimmermann *et al.,* 2004). These characteristics include faster growth rates, higher biomass, and higher net primary production (Ehrenfeld, 2003). These advantages often result in the displacement of native vegetation by the IAPs. Further implications associated with IAPs are a decrease in agricultural productivity and disruptions to ecosystem processes (Ehrenfeld, 2003; Eagle *et al.*, 2007).

Estimating the exact costs associated with IAPs is a complex process, with many academic estimates varying significantly. Pimentel *et al*, (2005) conducted a study that estimated the total loss to damages by IAPs in the US to be $120 billion/year. Another estimation of the US losses to IAPs amounted to a maximum of $185 billion in 1993 (Marbuah *et al.,* 2014). There is a significant difference between the two estimates, however, it is clear that the cost associated with IAPs are immense. Pimentel *et al*., (2001) estimated that the annual costs associated with IAPs worldwide, to be around $1.4 trillion per year, representing nearly 5% of the world economy.

The following cost associated with IAPs on ecosystem functioning will be discussed; water, climate, evapotranspiration, nutrient cycling processes, soil, fire, and cultural services.

a) Water

As a country, South Africa can be defined as a water stressed country, which will likely face water scarcity by the year 2025 (DWA, 2011: 1). Water was classified as an economic good in 1992 for the first time in a United Nations setting (ICWE, 1992). Water is a finite, vulnerable and essential resource and therefore needs to be used with caution (van der Zaag & Savenige, 2006). Water across the world is generally under-priced, resulting in the inefficient use of water (Rogers *et al,* 2002).

Generally speaking, IAPs use significantly more water compared to indigenous plants (Gorgens & van Wilgen, 2004). As a result, IAPs are adding to the ever-increasing stresses on the world's water supply, affecting both water quantity and quality. The reduction in water quality and quantity due to IAPs not only have negative environment and social impacts, but also have economic implications as water is regarded as an economic good (Rogers *et al.*, 2002). Simple supply and demand economics show that as the quantity and quality of water decreases the price of water will increase, especially as the demand for water is only rising. The growing water security issue make it very important to understand the cost-effectiveness of the removal of IAPs.

IAPs impact the quantity of water by reducing streamflow and having higher evapotranspiration rates than native plants. Research done by Dye and Jarmain (2004) on the impact black wattle *Acacia mearnsii* De Wild (Fabaceae) has on streamflow, found that the IAP reduced the amount of streamflow and increased evapotranspiration rates within water catchment areas compared to the natural indigenous vegetation. Marais and Wannenburgh (2008) provided evidence of how the removal of IAPs from riparian areas in South Africa is beneficial in terms of increased water yield. The increase in the estimate water yield in the Western Cape mountain catchment areas due to the removal of IAPs is around 34.4 million m^3/year (Marais & Wannenburgh, 2008).

Figures regarding the impact of IAPs and water quantity can vary dramatically between studies. Le Maitre *et al.,* (2000) initially estimated that IAPs use up to 3 300 million m^3 of water annually in South Africa. This estimation was made by aggregating estimates at a quaternary catchment scale, using the age-biomass-streamflow reduction model (Le Maitre *et al.,* 1996). However, in 2002, the draft National Water Resources Strategy of South Africa estimated the quantity of water used by IAPs to be 1 400 million m^3 annually (Marais & Wannenburgh, 2008). There is a large difference between the two estimates, however, both estimates are a significant amount of water loss due to IAPs.

b) Climate

The interaction between climate change and IAPs can be described as a positive feedback loop, as climate change increases potential habitats for IAP invasions increases, and IAPs subsequently make ecosystems more susceptible to climate change (Smith et al., 2012).

Climate change allows opportunities for new species, that have the potential to become invasive, to enter new regions. Climate change also has the potential to change species hierarchies in ecosystems, leading to new dominant species which may have invasive tendencies (Masters & Norgrove, 2010). IAPs have a tendency to thrive in disturbed habitats, which are becoming more common as global temperature rises (McNeely, 2000).

As IAPs replace and overtake native plant species in an ecosystem, the potential to alter the level of carbon dioxide released by the plant species is affected. This is due to the different carbon storage capacity of native and non-native species. A study which determined the net loss of carbon between invasive grass species and the native sagebrush ecosystem in the Great Basin region, USA, found there to be a net loss carbon sequestration of (-0,5 µmol m^{-2} s^{-1}) over a 12,7 million hectare area, had the potential to contribute to climate warming (Prater *et al.*, 2006). Hughes *et al.* (2006) studied invasive *Prosopis* species, in the southern Great Plains, found that the woody plants significantly increased ecosystem carbon storages which shows that IAPs can be beneficial in reducing climate warming.

c) Evapotranspiration

Evapotranspiration is the process by which water is transferred from the earth's surface into the atmosphere by means of evaporation from the soil and other surfaces, as well as by transpiration from plants. IAPs generally have much higher evapotranspiration rates than indigenous plants, resulting in more water usage in comparison to the plants they replace (Malan & Day, 2002). Ehrenfeld (2003) stated that the difference in a plants morphology (size, spatial extent of plant, and timing of growth) appears to hold more significance, in terms of evapotranspiration, than the differences in physical performance (water-use efficiency or transpiration rates per unit of leaf area).

Van Wilgen *et al.*, (2004) identified impacts associated with six IAP species in South Africa, of which four, *Sesbania punicea* (Cav.) Benth. (Fabaceae) (Red sesbania), *Acacia longifolia* (Andr.) Willd (Fabaceae) (Long-leaved wattle), *Acacia pycnantha* Benth. (Fabaceae) (Golden wattle), and *Hakea sericea* Schrad. & J.C. Wendl (Proteaceae) (Silky hakea), expressed "increased evapotranspiration" as a major negative impact. The impact of a higher evapotranspiration rate is that it can significantly alter hydrological regimes and lower water tables, thereby changing both the distance from the surface to the water tables and the rate

and direction of surface water flow (Gordon, 1998). Aquatic species, which sit on the top of waterbodies, have also been found to increase evapotranspiration rates. Water Hyacinth *Pontedaria crassipes* (Mart.) Solms (Pontederiaceae) and Water lettuce *Pistia stratiotes* L. (Araceae), have both been shown to have evapotranspiration rates that exceed open-water evaporation rates by as much as ten times (Gordon, 1998; Villamagna & Murphy, 2010).

Fraser *et al.* (2016) conducted a study on water hyacinth which included calculating the water loss in the New Year's Dam in the Eastern Cape province because of evapotranspiration through water hyacinth. The evapotranspiration rates were varied between low, medium, and high. With water loss per hectare varying from 19580m^3 (low), 45729m^3 (medium), and 97990m^3 (high). The study concluded that it was economically viable to justify the cost of biological control on Water hyacinth when evapotranspiration rates were medium and high (Fraser *et al*., 2016).

d) Nutrient Cycling Processes

The introduction of IAPs has the potential to change nutrient cycling processes, such as, nitrogen (N), carbon (C), potassium (P), water, and other cycles of ecosystems (Chengzhang *et al.*, 2007; Dassonville *et al.*, 2008; Jo *et al.*, 2017). Nutrient cycling processes are natural recycling systems, which impact ecosystem processes and therefore ecosystem services, sustaining and contributing to the well-being of human societies (Allison & Vitousek, 2004). IAPs impact nutrient cycling processes in a variety of ways, IAPs increase biomass and net primary production, raise N availability, alter N fixation rates, produce leaf little with higher decomposition rates, as well as impacting other nutrient cycling processes (Ehrenfeld, 2003; Dassonville *et al*., 2008).

Physiological traits that are commonly associated to the spread and establishment of IAPs, such as, increased leaf area, rapid growth rates, and elevated leaf nutrient concentration, impact ecosystem processes (Allison & Vitousek, 2004). Generally, these traits improve litter quality and should increase the rate of decomposition and nutrient cycling (Allison & Vitousek, 2004; Dassonville *et al*., 2008).

The most studied nutrient cycling process concerning IAPs is the nitrogen cycle. Jo *et al.* (2017) examined how IAPs species alter ecosystem N dynamics in forest in the eastern states

of the USA. It was found that invasive species increased N cycling by enhancing the flow if N to the soil through increased litter N content and litter N production, as well as by increased uptake of available soil N, via greater specific root length and litter N production (Jo *et al*., 2017). Nitrogen fixation rates also play a significant role in altering N cycling. Allison and Vitousek (2004) tested the impact on nutrient cycles of 11 understory plants from the Hawaiian Islands, and found that invasive species lost N and P more rapidly and in larger quantities than comparable native litter types. Allison and Vitousek (2004) concluded that invaders have the potential to increase nutrient cycling rates by a significant amount due to rapid decomposition and nutrient release from invasive litter. Other academics, however, have found that IAPs do not necessarily have a negative impact of nutrient cycling. Wang *et al* (2015) described how there is evidence that *Myrica faya* Ait. (Myricaceae), invasive to Hawaii, increased the mean N soil input. Ehrenfeld, (2003); Dassonville *et al.*, (2008) and Jo *et al*, (2017) all stated examples of how IAPs positively effect nutrient cycles.

e) Soil

As explained in the previous section, IAPs impact nutrient cycles, such as nitrogen cycles, within the soil (Jo *et al.*, 2017). However, some IAPs have a more straightforward impact on soil, as they impact soil by increasing the rate of erosion. The increase in erosion rates has negative impacts on both ecosystems and the economy (Eagle *et al*., 2007; Chamier *et al.,* 2012). The main impact is the effect soil erosion has on water quality, due to the increase in sediment load in waterbodies (Smith *et al.*, 2011). Increase in soil erosion affects water turbidity and salinity, increases nutrient loads, decreases pH levels, increases water temperatures which accelerates eutrophication processes; and increases the concentration of pollutants such as toxic heavy metals and the number of disease-carrying micro-organisms (Smith *et al.*, 2011; Chamier *et al*., 2012). There have been cases where IAPs have been introduced deliberately to reduce soil erosion rates, however, many of these scenarios have resulted in unintended negative impacts associated with IAPs and therefore discontinued as an erosion control technique (Forseth & Innis, 2004; Phillips *et al*., 2013). Forseth & Innis (2004) investigated the introduction of Kudzu *Pueraria montana* (Lour.) Merr. (Fabaceae) into the United States of America to reduce soil erosion in the early 20th century. Over 85 million seedlings were provided to landowners by government agencies to reduce erosion. In 1953, Kudzu was removed from the list of appropriate erosion control, was classified as a weed in

1970, and was placed on the Federal Obnoxious Weed List in 1997 due to the tree's invasive characteristics. Kudzu now covers 3 million hectares in eastern United States, spreading by 50000 ha per year.

f) Fire

IAPs have the potential to increase the intensity of fires in invaded areas. IAPs alter fuel properties and fire regimes by changing the distribution, size and plant chemistry of the biomass (Chamier *et al.*, 2012), as well as, impacting the frequency, intensity, type, extent, and seasonality of fire (Brooks *et al.*, 2004). Altered fire regimes due to IAPs, pose a threat to native vegetation, increase soil erosion, and pose a danger to humans and other species (Brooks *et al.*, 2004; Chamier *et al.*, 2012). In South Africa's mountain catchments, both *Hakea* species and *Pinus* species increase fire intensity, which induces water repellence which further increases erosion rates (Richardson & Van Wilgen, 2004).

g) Cultural Services

The impact IAS have on cultural services can be defined as, "those attributes of an ecosystem that are non-consumptive (i.e. hold value for recreation, tourism, history, education, science, heritage, inspiration, spiritually and aesthetics), and are difficult to assess because they are based on personal and local value systems" (Pejchar & Mooney, 2009: 501). The most impacted cultural services by aquatic and terrestrial IAPs are recreation and tourism. In Florida USA, the invasive tree *Melaleuca quinquenervia* (Cav.) S.T.Blake (Myrtaceae) has a positive impact on honey production, which results in a gain of $15 million annually. However, *Melaleuca quinqienervia* poses a threat to ecotourism of losses up to $168,6 million annually (Serbesoff-King, 2003).

A large part of tourism, especially in Africa, is made up of wildlife safaris. Witt *et al.,* (2017) conducted a study on the Serengeti-Mara ecosystem in East Africa, where the Serengeti National Park, Masai-Mara National Reserve, and other surrounding conservation areas have been impacted by IAPs. Two hundred and forty-five alien plants were considered in the study, 23 were identified as invasive, of which 6 were focused on as they posed the highest risk. The findings showed that these species impacted the size of rangelands, which impacted large

mammal's (wildebeest, zebra and gazelles) migration patterns, which in turn negatively impacted national parks and the tourism they provide (Witt *et al*., 2017).

2.7.2 BENEFITS OF INVASIVE ALIEN PLANTS

Invasive species are predominantly studied for their negative impacts and not for their beneficial characteristics. However, IAPs were often originally introduced into non-native areas due to the beneficial attributes of the species, without the consideration of the species negative impacts (Zengeya *et al*., 2017). This resulted in a conflict-of-interest as the species imposed their invasive characteristics. A conflict-of-interest arises when an IAP provides a positive environmental or economic externality coexisting with the invasive species negative externality (Zengeya *et al*., 2017). Positive externalities of IAPs include; aesthetics, erosion control, shade, fodder, timber, food, medicinal purposes, nitrogen fixation, increase in carbon sequestration, and firewood (De Wit *et al.,* 2001; van Wilgen & Richardson, 2014; Ramos *et al.*, 2016; Zengeya *et al.*, 2017).

For example, blackberries are commercially produced as an economic good around the world. In South Africa, there are 100 hectares of blackberry cultivation (Strik *et al*., 2007). All blackberry producing Rubus species in South Africa are classified as alien according to the Alien and Invasive Species List, with 6 of them classified as invasive (Henderson, 2011). Therefore, the invasive blackberries pose a conflict-of-interest due to their beneficial economic value.

Zengeya *et al.*, (2017) assessed the beneficial attributes associated with *Jacaranda mimosifolia* D.Don (Bignoniaceae) in South Africa. Jacaranda's are iconic trees in the city of Tshwane adding aesthetic value. The conflict-of-interest between stakeholders was resolved by not listing jacarandas as invasive species in urban areas and farm houses in specific provinces (Gauteng, Limpopo, North-West, KwaZulu-Natal, and Mpumalanga) (Zengeya *et al*., 2017).

De Wit *et al.* (2001) calculated the benefits associated with black wattle in South Africa. Black wattle was introduced into South Africa for its beneficial tannins, which is used in the production of soft leather (De Wit *et al*., 2001). Tannins extracted from black wattle produced a net present value (NPV) of $363 million. Firewood and building material produced a NPV of

$143 million and $22 million respectively. The NPV gained from an increase in carbon sequestration was valued at $23 million. Black wattle also provides other benefits such as wood chips, pulp, timber, and charcoal however, these were not assigned NPVs. The total NPV estimated for black wattle in 1998 was over $552 million (De Wit *et al.,* 2001). However, black wattle is regarded as one of South Africa's most damaging and wide spread invasive species.

Non-native plants have been used to prevent for soil erosion due to their favourable root characteristics (Phillips *et al.*, 2013; Gordon *et al*., 2001). Kudzu (*Pueraria montana*) was introduced in the US in 1876 to aid in soil control (Forseth & Innis, 2004). Kudzu was successful in limiting soil erosion, reducing land sliding, the rate of earthflow movement, and improving soil retention all over the eastern parts of the US.

Prosopis species were introduced into South Africa as a means of shade and fodder for livestock. It is now also used for timber, honey, and medicinal purposes which has resulted in an estimated net economic value ranging from $3,5 - 15,3 million. However, if mesquite continues to spread at the rate it currently is, the net present value will become negative within 4-22 years (Wise *et al*., 2012).

2.8 IMPACT OF *ROSA RUBIGINOSA* L.

This section reviews the known impacts of *R. rubiginosa*. There is very limited research covering the impacts of *R. rubiginosa,* especially in South Africa.

From the available literature it was determined that *R. rubiginosa* has a rapid growth rate and seed production rate, along with various other beneficial reproduction techniques, which allow the shrub to rapidly invade open areas (Zimmermann *et al*., 2011; Carbutt, 2012). The invasion of the shrub often results in dense thickets, altering native vegetation physiognomy (Carbutt, 2012). These dense thickets of *R. rubiginosa* pose negative environmental and economic impacts. The dense thickets reduce farm land which negatively impact both cultivated and grazing land, due to the reduction in the land's carrying capacity and area suitable for cultivation (Carbutt, 2012). The thickets have the potential to block livestock from water sources (Grundy *et al.,* 1989). These negative impacts caused by *R. rubiginosa* on

farmland have the potential to significantly impact the agricultural sectors in invaded countries (Grundy *et al.*, 1989).

Le Maitre *et al.,* (2016) conducted a study that estimated the impact that various invasive plants, including *R. rubiginosa*, had on water supply in South Africa. It was assessed that *R. rubiginosa* had an estimated annual flow reduction factor of 72% of the mean annual runoff. Of the dryland invaders assessed, *R. rubiginosa* was considered to have a relatively moderate water-use level (Le Maitre *et al*., 2016). Most of South Africa's surface water originates from the high-altitude grasslands, such as the Lesotho Highlands where *R. rubiginosa* is most prevalent (Turpie *et al.,* 2008). The mountain catchments within the grassland biome occupy a mere 8% of the surface area of South Africa, but yield 49% of the runoff (Wilson, 1984). A further study has appraised the concentrated area of *R. rubiginosa* in South Africa to be 11 801 ha, resulting in an estimated 8,75 million m^3 of mean annual surface water runoff reduction, which is the equivalent of 74mm of rainfall (van Wilgen *et al*., 2017).

Correspondence with various experts in the field of invasion biology has identified several other negative impacts of *R. rubiginosa*. The first being the loss of native biodiversity in grassland areas. Secondly, the shrub can be harmful to animals. The shrub is thorny and dense which can cause physical injuries to livestock and block access to grazing and water sources. A large consumption of the shrub's rosehips by livestock can lead to obstruction of the gut and potentially fatalities. Lastly, is the threat to eco-tourism revenue due to biodiversity loss and the high visual impacts of IAP's in conservation areas (L Henderson SANBI 2018, personal communication).

2.8.1 BENEFITS OF *ROSA RUBIGINOSA* L.

R. rubiginosa provides a number of positive economic impacts, due to the shrub's beneficial properties (Grundy *et al.*, 1989; De Pietri, 1992; Franco *et al.*, 2007; Barry *et al*., 2008; Ramos *et al.*, 2016). Most of the economic benefit associated with *R. rubiginosa* is procured from the plant's fruit (rosehip). The initial beneficial use of rosehips was in the form of rosehip tea and jam, due to the taste and the high vitamin C content (Smulders *et al*., 2011). Edible *R. rubiginosa* rosehips, contain approximately 500-2200 mg/100g of vitamin C within the fresh fruit (Aguirre *et al*., 2016). Vitamin C content in rosehips can be up to 15 times greater than the vitamin C content in citrus fruits (Barry *et al*., 2008). Rosehips also contain other beneficial

vitamins; A, B1, B2, E, and K, as well as, minerals such as phosphorus, magnesium, iron, sodium, and calcium (Moure *et al.*, 2001; Barry *et al.*, 2008).

In more recent years, rosehips have been incorporated into the cosmetic industry as an increased understanding in the fruit's properties has been attained. The oil content and fatty acids obtained from rosehip provide the shrubs cosmetic economic benefit of accelerating the regeneration of scar tissue damage, antioxidant activity, and anti-inflammatory properties (Moure *et al*., 2001; Nowak, 2005; Jiménez-López *et al.*, 2017).

Rosehip oil provides the greatest monetary benefit. Rosehip oil is extracted from the fruit's seeds via the process of cold-pressing. The market for cold-pressed oils has significantly increased due to the oils specific characteristics, flavours and various bioactive substances (Prescha *et al.*, 2014). These oils are most commonly known for their valuable unsaturated fatty acids and their natural antioxidants (Prescha *et al.*, 2014). Cold-pressing is a process in which a steel press extracts oil through pressing fruit or seeds. The cold-pressing procedure does not involve any external heat or chemical treatments, which is beneficial in maintaining high compound levels (Siger *et al*., 2008). The oils extracted from cold-pressing are unrefined and do not require either heat or chemical treatment in the oil extraction process (Siger *et al*., 2008). Unrefined oils contain more nutrients than refined oils and therefore possess more beneficial properties, making for better cosmetic products.

Still Pure, a company that sell rosehip oil, state that the rosehip oil contains high levels of vitamin C, antioxidants and fatty acids (linoleic 47,4% and linoleic 33%). These beneficial properties help the skin to heal as well as speed up tissue regeneration. Rosehip oil is particularly suited to healing scars, burns, stretch marks and reduces the signs of aging.

Nowak (2005) compared 11 Rosa species with regards to their oil and fatty acid content. *Rosa rubiginosa* was found to be the 6th greatest producer of oil and 2nd with regards to the percentage of unsaturated fatty acids extracted per rosehip. *Rosa rubiginosa's* rosehips have an 8% oil content. In contrast *Rosa canina* var. *dumalis* has approximately 11% oil content. In terms of unsaturated fatty acids, *R. rubiginosa* has approximately 78% of unsaturated fatty acids extracted per rosehip, while *Rosa dumalis* var. *besseriana* is the only species that was tested to have more, with approximately 79% of unsaturated fatty acids extracted per rosehip.

The anti-inflammatory properties of rosehips are attributed to Galactolipids. Galactolipids are a pure active substance that is extracted from the plasma membrane of rosehips (Larsen *et al.*, 2003; Rein *et al.,* 2004; Mármol *et al.*, 2017). Due to the anti-inflammatory properties, rosehips are being used for its beneficial effect on inflammatory diseases such as rheumatoid arthritis (Larsen *et al.*, 2003; Mármol *et al*., 2017).

There have been several clinical trials focused on the effects rosehip powder has on arthritis. Trials have been done on the effectiveness of rosehip powder on both osteoarthritis and rheumatoid arthritis. Rheumatoid arthritis is a chronic systemic autoimmune disease in which the body attacks the lining of any bodily joint (synovial membrane), leading to erosion of the cartilage and deformity of bone and joints (Mármol *et al.*, 2017). Osteoarthritis is the most common form of arthritis impacting millions of humans across the globe. Osteoarthritis occurs when the protective cartilage in a joint wears down over time, resulting in inflammation and pain (Cohen, 2012). Rosehip powder has been shown to reduce arthritic symptoms in a number of clinical trials (Kharazmi & Winther, 1999; Warholm *et al*., 2003; Rein *et al*., 2004; Cohen, 2012).

Cohen (2012) discussed a number of randomised controlled trials which assessed whether rosehip powder reduces pain and increases flection within various joints. The trials compared two groups, one group received rosehip powder and the other received a placebo. The first trial saw 100 patients suffering with osteoarthritis of the knee or hip. The first group received 2,5g standardised rosehip powder twice a day for 4 months and the second control group received a placebo. Results showed that rosehip powder significantly reduced pain in 64.6% of patients and there was also a significant improvement in hip flexion. A similar trial, involving 112 patients with various osteoarthritic complications and covering 3 months, experienced significant reductions in pain and stiffness. Further benefits included improved moods, wellbeing and sleep quality. Sixty-six percent of patients receiving active rosehip powder treatment reported improved pain levels compared to only 36% of the placebo patients. A third trial discussed by Cohen (2012) involved 94 patients, 35 years and older suffering with osteoarthritis of the hip or knee. A similar 3-month period where half the patients received 5g of rosehip powder a day and the other half received a placebo. Patients who received rosehip powder perceived a significant pain reduction, according to WOMAC (Western Ontario and McMaster Universities Osteoarthritis Index), and decreased their

consumption of 'rescue medication' after 3 weeks (Winther *et al.*, 2005). Willich *et al,* (2010) conducted a 6 month double blind placebo-controlled trial which also found benefits for patients suffering from rheumatoid arthritis. Participants who took the rosehip powder indicated significantly improved scores on the Health Assessment Questionnaire Disability Index (HAQ-DI).

All the above trials saw significant reduction in pain scores from patients who were treated with rosehip powder. Patients who received treatment were twice as likely to report pain reduction (Cohen, 2012). It was noted by Cohen (2012) that the herbal remedy of rosehip powder is a far safer treatment in comparison to other medical treatments in terms of side effects.

Another potential benefit of *R. rubiginosa* is the recovery of degraded native forests, as the shrub behaves as a nursing plant. De Pietri (1992) conducted a study in Los Alerces National Park, Argentina on whether *R. rubiginosa* could help in the recovery of natural degraded forests. The study found that *R. rubiginosa* behaved as a nursing plant by creating a protective microenvironment for the establishment of native woody species. The shrubs thorns prevent cattle grazing and contributes to soil structure recovery, allowing for woody species growth within the microenvironment. The native woody species would eventually grow through and become taller than the *R. rubiginosa* shrubs, as was found in areas of the National Park (De Pietri, 1992).

Ramos *et al.,* (2016) assessed the chemical nature of *R. rubiginosa's* seeds, pulp, and leaves to determine whether the shrub could be used for biodiesel production. The findings of the study showed that in terms of thermal stability, the shrubs raw seeds, seed oil and rosehip pulp all showed potential as a biomass feedstock for conversion into biofuels (Ramos *et al*., 2016).

2.9 CONTROL OF INVASIVE ALIEN PLANTS

The damages associated with IAPs cause billions of dollars worth of damages. In 1996, the estimated extent of invasive alien plant cover in South Africa was approximately 1.736 million condensed hectares, greater than the size of the Gauteng province (Le Maitre *et al*., 2000). The estimated extent of the IAP cover increased to 1.813 million hectares by 2008 (van Wilgen

et al., 2012). In order to counteract the damages, management programs are set up in order to control and decrease the spread of IAPs.

There are three main techniques which are used in the controlling of IAPs; mechanical, chemical and biological. It is also common for the different controls to be integrated to affectively reduce the amount of IAP's (Van Wilgen *et al.*, 2001). Mechanical control is the physical removal of the invasive plant by humans and the use of machines (Van Wilgen *et al.*, 2001). Chemical control is the use of chemicals (herbicides) to poison and kill the invasive plants (Curtis & Bidart, 2017). Biological control is the introduction of an invasive plant's natural enemy into the invaded area (Moran *et al.,* 2013).

Kettenring & Adams, (2011) conducted a systematic review of the academic literature covering IAP control between 1960 and 2009. A total of 355 published articles that evaluated IAP control were considered in the systematic review. Chemical control (herbicides) was the most covered control technique with it being studied in 55% of the articles. Employed cutting techniques, burning, and hand pulling were covered in 34%, 24%, and 20% of academic papers respectively (Kettenring & Adams, 2011). It is important to note that biological control of IAPs was not considered in the systematic review and has since become the forerunner in academic research concerning the control of IAPs.

2.9.1 CONTROL TECHNIQUES

a. Mechanical Control

Mechanical control is the physical destruction or removal of invasive plants (van Wilgen *et al.,* 2001). Mechanical control includes the felling or uprooting of plants and is often integrated with the use of fire. The tools used range from hand-held tools, such as slashers and saws, to power-driven tools such as chainsaws and bulldozers. Mechanical control requires a large labour force and therefore can be quite costly, especially in dense infestations or remote areas (van Wilgen *et al.,* 2001).

b. Chemical Control

Chemical control involves the use of herbicides (plant poison) to kill off the invasive plants (Curtis & Bidart, 2017). The use of herbicides can be harmful to ecosystems, especially when

used close to fresh water sources (van Wilgen *et al.,* 2001). It is common for the use of chemical control to leave undesirable residue, contaminate fresh water supplies, impact human health and non-target species (Bangsund *et al.*, 1999). Van Wilgen *et al.,* (2001) stated that the use of chemical controls is often governed by government legislation in an attempt to hinder any negative impacts caused by herbicides. Herbicides are non-specific to the targeted invasive plant and therefore have to be used very carefully in order to not negatively impact native species. Herbicides are not self-sustaining in the long term and will need constant reapplication.

c. Biological Control

Biological control, is the reduction and control of invasive species by identifying and introducing a natural enemy from the species' native environment into the invaded environment (Zimmermann *et al.*, 2004). Insects, weeds, mites, fungi, bacteria and viruses are all types of biological controls (Van Wilgen *et al*., 2001). However, it is not as simple as locating and introducing the natural enemy. It is crucial that the biological control agents are host specific, meaning the natural enemies are completely dependent on the invasive species and thus have the potential to rapidly increase in population size across the target species, reducing and controlling its spread (Moran *et al.,*2013). The host specific nature of a biological control agent is equally important in the sense that it will not harm any native species.

Biological control is consistently the most economically beneficial control technique (Van Wilgen *et al.*, 2001; De Lange & van Wilgen, 2010; Hill & Coetzee, 2017). Unlike mechanical and chemical control, biological control is not labour intensive and does not require periodic follow ups (Van Wilgen *et al*, 2001; Hill & Coetzee, 2017). Environmental conditions may negatively impact the biological control agent and another release of the agent may be required. Benefit-cost ratios can be used to determine whether it makes economic sense to establish a specific control technique by comparing the costs against the benefits of removing the invasive species. Benefit-cost ratios, looking at the use of biological control on *Acacia longifolia* and *Acacia pycnantha* where calculated to be 1465:1 and 4433:1 respectively (van Wilgen *et al.*, 2004).

The most significant cost that is associated with biological control is the research and experimental process that precedes the release of the biological control agent (Culliney,

2005). Before there can be any release of a biological control agent, rigorous safety tests need to be conducted under strict quarantine conditions. This is because it needs to be determined that the agent is sufficiently host-specific and thereby feeding and maintains its populations on only the invasive species (Zimmermann *et al.*, 2004). A suitable agent cannot survive on any species other than the target species, and will die if there are no host plants available (Zimmermann *et al.*, 2004).

When considering biological control, it is important to be aware that the natural enemies are not contained by borders, both local and national. The natural enemies' ability to spread from the initial release area is what makes it so effective as a control technique. However, it is possible that the natural enemy can spread into areas (states or countries) that do not want the natural enemy to attack the specific plant. Often this is because an economic benefit is being exploited from the plant (Simonsen *et al.*, 2008; van Wilgen & Richardson, 2014).

This was seen in the case of *Cactoblastis cactorum* (Berg.) (Pyralidae), commonly known as the cactus moth. The moth was introduced as a biological control for the pest *Opuntia* spp. (prickly pear) in the Caribbean (Johnson & Stiling, 1998). The moth has made its way from the Caribbean to Southwest America, where it is attacking native cactus plants (Hight *et al.*, 2002; Simonsen *et al.,* 2008). The cactus moth is heading for Mexico where it has the potential to cause serious economic damage, as cactus production is one of Mexico's main agricultural revenue stream (Simonsen *et al.*, 2008).

d. Integrated Control

Integrated control is the combinational use of at least two of the above three primary elements of IAS control (mechanical, chemical, and biological) (van Wilgen *et al.,* 2001). Various IAPs have been managed by the use of integrated control, such as the Black wattle (*Acacia mearnsii*), Yellow star-thistle (*Centaurea solstitialis*) and Triffid weed (*Chromolaena odorata*) (van Wilgen *et al.,* 2001). The use of controlled fire is often a management technique used in conjunction with one or more of the primary control techniques.

Acacia mearnsii, commonly known as Black Wattle, is one of the most prominent IAPs in South Africa. According to van Wilgen *et al.*, (2012), Black Wattle alone costs South Africa R561.9 million (expressed as 2008 Rands) in clearing costs between 1995 and 2008. This amounted

for approximately 17,56% of the total cost of alien plant control in South Africa. *Acacia mearnsii* invades shrublands, grasslands and savanna biomes, especially along water courses (Van Wilgen *et al.*, 2001). The seeds are spread by water courses and through the transportation of soil (van Wilgen *et al.*, 2001). *Acacia mearnsii* is a good example of integrated control as all three primary control techniques (mechanical, chemical and biological) are used in the attempt to control *Acacia mearnsii* populations. The mechanical technique of felling occurs with the resulting stumps being treated with herbicide. A follow up is required to remove any seedlings. The use of biological control is used in dense areas of *Acacia mearnsii* infestation in South Africa (Van Wilgen *et al.*, 2001). Two biological control agents are used to control *Acacia mearnsii*, *Melanterius servulus* and *Dasineura dielsi* (Impson *et al.*, 2011). *Melanterius servulus* is a seed feeder while *Dasineura dielsi* is a flower galler.

Along with being one of South Africa's most invasive plants, *Acacia mearnsii* bestows economic potential and is therefore a conflict of interest species (van Wilgen *et al*., 2012; Zengeya *et al*., 2017). The wattle growers were able to block the use of biological control for a number of years, before reluctantly accepting the release of *Melanterius servulus* which reduced seed output but does not harm the vegetation part of the plant (Impson *et al.,* 2011; van Wilgen *et al.,* 2012; Zengeya *et al.*, 2017). De Wit *et al.*, (2002) conducted a benefit-cost analysis in *Acacia mearnsii* which resulted in a benefit-cost ratio of 0.4. Although benefits were calculated to be in excess of R3,3 billion (expressed in 1998 Rands), the costs were more than double, primarily due to the reduction in surface water. De Wit *et al.*, (2002) suggested that the best integrated control technique would be a combination of physical clearing and plant-attacking biological controls.

2.9.2 CONTROL TECHNIQUES OF *ROSA RUBIGINOSA* L.

There have been a variety of techniques used to control *R. rubiginosa* over the last century. Prior to 1930, the only control used to manage *R. rubiginosa* was mechanical control, via hand pulling and using horses to pull out severely dense thickets (Grundy *et al.*, 1989). The first records of chemical control were in 1976, the use of picloram spray was successfully used on mature *R. rubiginosa* shrubs (Molloy, 1976). Biological control for *R. rubiginosa* was considered as early as 1960, however no action was taken (Grundy *et al.,* 1989). The burning

of shrub weeds is a common form of control, however *R. rubiginosa* was found to not burn readily and burning failed to affect deep-seated crown and root buds (Grundy *et al*., 1989).

Syrett (1985), tested a variety of insect biological controls for *R. rubiginosa,* which concluded that gall wasp, *Dipolepis rosae* as the best biological control option. However, it was never released on the shrub as the gall wasp also attacked other Rosa species, such as garden roses and horticultural crops (apples, plums, apricots, and raspberries) which are closely related to *R. rubiginosa*. Bruun (2006) assessed the potential for the release of a biological control agent for *Rosa rugosa* Thunb. in Europe and North America. There were a number of potential biological control agents, among them the gall wasp *Diplolepis fukudae*. However, it was concluded that there were concerns with the host specificity of the biological controls. The use of grazing animals as biological control has been studied, with results showing promise within the first 9 months of the shrubs life, after which the thorn defensive mechanism of the shrub becomes too strong for grazing animals (Holgate, 1987; Popay & Field, 1992). Another potential control of *R. rubiginosa* is the Rose Rosette Disease, which comes from the Rose Rosette Virus (Epstein & Hill, 1999; Windham *et al.*, 2014). However, the virus has not been used as it causes damage to non-target vegetation.

2.10 SOUTH AFRICAN MARKET FOR *ROSA RUBIGINOSA* L. (ROSEHIP)

As it currently stands, there is a market for rosehips in South Africa, even though *R. rubiginosa* is an invasive 1b species. This is due to the legislation that allows for the picking and selling of any 'wild' invasive plant's fruit (NEM:BA, 2004). Although rosehips can be sourced from a variety of Rosa species, from the data available only *R. rubiginosa* is documented to be located in areas where wild rosehips are known to be picked in South Africa (SAPIA, 2019). If cultivation were to be considered, a risk assessment would need to be conducted, regardless of the Rosa species chosen to be cultivated, due to the fact that an introduced species that is so closely related to *R. rubiginosa* would be of risk. If cultivation were allowed, cultivating a plant that is already established in South Africa would be of far less risk than introducing a new unknown species.

Rosa rubiginosa is not cultivated within South Africa, however the rosehips are being picked in the wild and sold to companies and exporters. Earthoil, a Kenyan cosmetics company, estimates that over 1200 rural community members from the Lesotho region collect rosehips

for their company alone (Earthoil, 2017). The fact that the rosehips are picked in the wild allows for companies to advertise their rosehips and rosehip products to be organic.

The rosehips in South Africa and Lesotho are categorised under organic wild collected products (Censkowsky *et al.*, 2007). Censkowsky *et al.* (2007) estimated the total global quantities of organic wild collected products, and found that rosehip was the 5th largest organic wild collected product globally. The reported collected area amounted to 11,8 million hectares with a global total of 7,782 tons of rosehip harvested. Of the global total of 7,782 tons, 1000 tons of rosehips were harvested in the Lesotho area (Censkowsky *et al.*, 2007). Rosehip is the second most organic wild collected product in Africa, and greatest in Sub-Saharan Africa. Censkowsky *et al.,* (2007), classified rosehips as *R. canina* in the study which was most likely done for simplicity as there are a number of rosehip producing species.

In the past, organic wild products, such as honeybush (*Cyclopia spp*), rooibos (*Aspalathus linearis*), and shea butter (*Butyrrospermum parkii, fructus*) were sauced from the wild only. However, due to increased demand a movement towards cultivated areas has occurred to increase the supply required for the products (Censkowsky *et al.*, 2007). It may be that South Africa is reaching a similar point where a move towards cultivation of Rosa species is required, however, due to the invasive nature of *R. rubiginosa* there are barriers to the cultivation of the plant that did not exist with any of the above three plants.

The supply for the current rosehip market comes from informal pickers who pick wild rosehips in South Africa near the Lesotho boarder as well as in Lesotho. The demand for the wild picked rosehips comes from companies in South Africa who refine the product further. These companies mainly supply international markets with the various separated components that make up a rosehip (seed, shell and oil). The overseas demand for rosehip is far greater than what South Africa produce. Due to the supply being solely from wild plants climatic conditions can significantly impact supply in South Africa.

The market for rosehip inevitably creates employment, aiding in one of South Africa's most pressing socio-economic challenges. South Africa has the 5th highest unemployment rate in the world, standing at 25.9 percent of the labour force (The World Bank, 2016). There is evidence to suggest that historically there has only been seasonal informal employment within South Africa's rosehip industry (Henderson, 1991). There are, however, companies that

are processing and selling rosehips and rosehip products, creating formal employment opportunities. Although informal employment in not necessarily seen as bad, formal employment is regarded as superior due to the protection it provides through wage and labour laws (Van der Berg, 2014). These employment opportunities may have the potential to increase in numbers if *R. rubiginosa* is downgraded, allowing for the cultivation of rosehips (permit required) and potentially an increase in the rosehip market size.

2.11 GLOBAL ROSEHIP MARKET

There is very little available information regarding the global market for *R rubiginosa* (rosehips). There are a limited number of global market reports on the rosehip oil market that cover a significant number of countries and provide an array of global market figures and forecasting. However, these reports are inaccessible due to their significant costs, ranging from $1500 to $4200. One of these reports, Rosehip Oil Market 2019 Industry Size by Global Major Companies Profile, Competitive Landscape and Key Regions 2025, provided a short summary of information. It reported that the growth of the rosehip global market was mainly driven by the increasing demand for skin care products and the emerging e-commerce industry. The report estimated that the rosehip industry is expected to grow at a compound annual growth rate of 10,49% from the year 2018 to 2025. This would see the market size grow from $102 million in 2018 to roughly $205 million by 2025. An increase of over 100% in the market size in just 7 years. Zion Market Research believes the global cosmetic market to already stand at $532 billion in 2017 and is forecasted to reach $863 billion by 2024.

According to Statistics SA (2019) the rosehip market has grown at a rate of 4,37% between 2008 and 2018, with the market growing 5,5% in 2018. The cosmetic market is broken down into five categories skincare (39%), haircare (21%), make-up (19%), perfumes (11%), and hygiene products (10%) (Statista, 2019). In South Africa, the cosmetic industry amounted to $3,8 billion and had seen an average annual growth of 12% per annum between 2005 and 2010 (Department of Trade and Industry, 2012).

The Chile market for rosehip is the only country that has multiple studies covering the size of the market in terms of economic figures. Chile supply the greatest amount of rosehips into the global rosehip market (Censkowsky *et al.*, 2007). The following will provide an understanding how the market for rosehips has developed over recent years.

A significant number of Rosa species, including *R. rubiginosa* were introduced to Chile by Spanish colonizers. These Rosa species have established themselves among the native flora. Chile has taken advantage of the foreign Rosa species and is thus regarded as one of the largest rosehip exporting countries in the world (Hirsch *et al*., 2011). As is seen in Lesotho and South Africa, the rosehips are collected in the wild by local families and are therefore classified as a certified organic wild product (Joublan & Rios, 2005; Espinoza *et al.,* 2016). Most of the rosehip products are exported to Europe, with Germany the main import country, importing 73% of Chile's rosehip export (Joublan & Rios, 2005; Hirsch *et al*., 2011). Sweden and the USA are also significant importers of rosehip products from Chile (Joublan & Rios, 2005). The processing industries have developed certification programs so as to meet the requirements of the international market.

Joublan & Rios, (2005) provided data on the rosehip market in Chile. There are three products exported out of Chile; dried rosehip peel, whole dried rosehips, and seed oil. Between the years 1991 and 2003 the average yearly export from Chile amounted to 6786 tons of dried rosehip peel with a mean average of $15 502 (Joublan & Rios, 2005). Joublan & Rios (2005) further found that from 2000 to 2004 the total amount of exported rosehips from Chile increased from 4807 tons to 7457 tons, this was attributed to recent economic agreements with the European Union (EU) and the USA. This study on the rosehip market in Chile concluded that in order to successfully satisfy market demand, the cultivation of rosehip producing species needs to be implemented (Joublan & Rios, 2005).

A more recent study on the Chilean rosehip market stated that Rosa mosqueta (which is a grouped name given to three rosehip producing plants including *R. rubiginosa*) covers 58 440 ha (Espinoza *et al.,* 2016). The study expressed that in 2013 just over 77 tons of dried rosehip were exported out of Chile, amounting to $373 726. In the same year 89 tons of rosehip oil was exported, amounting to $1 942 338. A further 96,4 tons of rosehip husks were exported at a value of $486 144 (Espinoza *et al.,* 2016).

Although the two above studies are not directly comparable. It is evident from the work by Joublan & Rios (2005) that the rosehip market, especially in Chile, has significantly increased since 1991. What is significant between the two studies is the fact that the mean average economic gain from rosehips between 1991 and 2003 was $15 502. However, as rosehips

have been incorporated into the cosmetic industry, it was found that a significantly smaller tonnage of rosehips was making an economic gain of over $2.5 million (Espinoza *et al.,* 2016).

No cultivation of *R. rubiginosa* has been documented thus far. Therefore, the global market for rosehip is nearly entirely made up of wild picked rosehip products (Censkowsky *et al*. 2007). The size of this market in 2007 was 7,782 tons. Three countries dominate the market; Chile (3514 tons), Romania (3051 tons), and Lesotho (1000 tons).

2.12 CONCLUSION

There have been a large number of alien plant invasions across the globe. Which result in negative economic and environmental impacts to native ecosystems. There have been significant efforts to control the spread of IAPs. However, in certain situations, IAPs have an economic or environmental benefit that coincides with the negative impacts, resulting in a conflict-of-interest. Often conflict-of-interest species are overlooked by invasion biologists who are solely focused on control the IAP. However, some IAPs have the potential to contribute more to the economy than they take away and therefore should be considered as a beneficial species. This is especially in a developing country were unemployment is low and poverty is high.

Rosa rubiginosa L. is an IAP that seems to have significant economic benefit. However, this economic benefit has significantly grown in recent years as the beneficial properties of the shrub's fruit (rosehips) have been discovered. This study aims to assess whether the shrub's benefits have significantly increased enough in order to challenge the invasive status in South Africa. The study has the potential to aid in the reconsideration of invasive species categorisations which is assessed every five years (NEM:BA, 2004).

CHAPTER 3
METHODOLOGY

3.1 INTRODUCTION

When assessing the impact an invasive species has on an area/country, benefit-cost analyses have been one of the prevailing methods used. However, there hardly any literature on the costs and benefits associated with *Rosa rubiginosa* L. in South Africa, even though, various stakeholders namely; landowners, farmers and rosehip companies are directly impacted by the species. Making the use of a benefit-cost analysis implausible. Therefore, a survey of these stakeholders was thought to be the most appropriate approach to bridging this knowledge gap.

Given the social context of the research problem, the best means to assess the studies goals would be to conduct a survey with the population of interest. The individuals within the sample groups are part and parcel of the population of interest as it would be irrelevant surveying a population that has no interest or understanding of *R. rubiginosa*. From a statistical perspective it was not possible to incorporate the entire population when conducting the expert opinion and landowner surveys. Therefore, samples of the population were thus regarded as representatives of the populations (Gujarati, 2009).

There are two broad ways to conduct surveys: Self-administered and administered surveys. Self-administered surveys do not require the aid of an interviewer. Survey examples that fall under self-administered are drop-off pick-up, mail surveys and internet surveys (Smyth *et al.,* 2010; Allred & Ross-Davis, 2011; Israel & Lamm, 2012; Dillman, 2016). Alternatively, administered surveys are conducted with the interviewer present. Survey examples that fall under administered include face-to-face interviews and telephone surveys (Smyth *et al.,* 2010; Allred & Ross-Davis, 2011; Hillier *et al.*, 2014). Each of the methods have both positive and negative attributes. These attributes make the methods more or less applicable to different research problems.

The selection of a survey method is dependent on the conditions under which the research is being conducted. The main influencing factor is the financial budget applied to the research.

If the research has a large budget the best method to conduct extensive face-to-face interviews (Allred & Ross-Davis, 2011). This method results in the best response rates and allows for an interaction between respondents and researchers, allowing for the information actually being sought by the questionnaire to be defined, clarified and collected with as much clarity as possible. However, if a small budget is given to the project, the most optimal method of surveying would be the internet survey method. This survey method is regarded as the least expensive (Lesser *et al*., 2011). Internet surveys have limitations such as, low response rates, loss of participant traceability and emails are often ignored or treated as spam mail (Dillman, 2016).

Four different surveys were conducted in order to answer the four main objectives of the study. To bridge the knowledge gap surrounding *R. rubiginosa* (objective 1), a survey was conducted with experts within the field of invasion biology. This survey attempted to specifically determine how invasive the shrub is and whether experts still agree with the original 1b categorisation of *R. rubiginosa*, made by experts, pre 2004. A second survey was conducted with landowners within *R. rubiginosa* infested areas in order to determine the negative impact of the shrub on the landowners (objective 2). The landowner survey determined how much of a direct impact *R. rubiginosa* has on landowners' economic activity and day to day activities. The 3rd survey attempted to determine the economic benefit of *R. rubiginosa* to South Africa (objective 3) by surveying the wholesale companies involved in the sale of *R. rubiginosa*. The last survey conducted was a case study with one of the wholesale companies which determined how the rosehip market could benefit from a categorisation downgrade of *R. rubiginosa* (objective 4).

3.2 ETHICAL CONSIDERATIONS

While conducting this research, it was ensured that all requirements of the Rhodes University Research Ethical Standards Policy were observed. The survey instrument (questionnaire) was given ethical clearance by the Rhodes University Ethical Standards Committee (RUESC) – Human Ethics sub-committee. This ensured that the rights, privacy and anonymity of any participants were acknowledged and respected, with no subject being offended or harmed in any manner. A consent form was provided to each participant with consent forms giving precise details of the study's aim and objectives and how data would be used. Participants

reserved the right to exit participation at any point in the study. Feedback will also be provided to all participants in the form of a summary report. The higher degrees ethical board of Rhodes University approved this research project.

3.3 DATA COLLECTION AND SOURCES

The research used both primary and secondary data in a complementary approach in order to satisfy the data requirements.

3.3.1 PRIMARY DATA COLLECTION

Surveys and Questionnaires

Primary data was used in the research to acquire detailed information regarding *R. rubiginosa* and the rosehip market in South Africa. The primary data collected took place in the form of questionnaires and interviews (see appendices) (approved by the ethics committee at Rhodes University, 0323, May, 1019 and 0558, Apr, 2019). All questionnaires were proofed by colleagues from both the Department of Economics and Economic History and the Entomology Department at Rhodes University. They were also checked by the Rhodes University ethics committee.

a) *Rosa rubiginosa* Literary Gap

The invasive categorisation of *R. rubiginosa* was originally determined, in 2004, by expert opinion (no official assessment) under the Conservation of Agricultural Resources Act, 1983 (Act No. 43 of 1983). The are no available publications or studies that directly assess any impact associated with the species in South Africa. Therefore, to bridge the knowledge gap surrounding *R. rubiginosa* (objective 1), experts within the field of invasion biology were surveyed. This served as a good sample group as expert opinion is what was used to categorise the shrub originally. The data collection for the expert opinion questionnaire took place in May 2019 at the National Symposium on Biological Invasions in Tulbagh, Western Cape. Various other experts (not present at the symposium) who were identified through networking, were emailed the questionnaire, only two email recipients provided feedback. In order to qualify for the sample group, participants either needed to have achieved a doctorate within the invasive biology field or had to have worked within the field for a minimum of 5

years. In total twelve invasive biology experts took part in the questionnaire (more than who were consulted for the first categorisation). The qualitative data collected was converted into quantitative data, as yes/no answers were turned into 1's and 0's. This was done so the data could be represented in the form of graphs and tables. The rest of the qualitative data was interpreted.

The questionnaire was divided into four sections. The first section covered various particulars of the respondents. This was done for administrative purposes in case of any follow up requirements. The second section covered plant identification. The questionnaire had various pictures of *R. rubiginosa*, to assess whether participants could identify the specific species. The third section covered the positives and negative environmental and economic aspects of *R. rubiginosa.* The fourth section allowed for any additional comments the experts wished to raise.

b) *Rosa rubiginosa's* Negative Impact on Landowners in Infested Areas

To determine what impact *R. rubiginosa* has on South African landowners, a questionnaire surveying landowners in infested *R. rubiginosa* areas was conducted. The majority of the sample group came from farmers, as farms cover large amounts of land and due to the fact farms are commonly impacted by IAPs. The study defines the negative impact *R. rubiginosa* has on landowners as the observable negative impacts faced by landowners in *R. rubiginosa* infested areas. Monetary data on the direct loses associated with the control techniques implemented and loss of agricultural land due to *R. rubiginosa* was collected in order to provide some form of insight into the costs experienced by landowners. The cost to landowners associated with the control of *R. rubiginosa* was calculated by adding the cost of labour and the money spent on fuel, chemicals or machinery in order to control the shrub on an annual basis. The monetary loss associated with agricultural land was estimated by the landowner.

Face-to-face semi-structured interviews were conducted. The data collection for the landowner questionnaires was undertaken during the month of June 2019 in the Eastern Cape, Free State and KwaZulu-Natal provinces in South Africa. A number of areas in each province were surveyed however, in certain areas there were no suitable people to interview. Sampling was not random as only interested and affected parties took part in the study.

Although this sample method may be considered biased, parties who have not come across *R. rubiginosa* before would not be aware of the effects of the shrub and this would cause the results to be skewed. The sample group that took part in the study were selected on their knowledge and/or experience of dealing with *R. rubiginosa.* Door-to-door sampling followed by networking was used to create the sample group. Ten landowners partook in the questionnaire with the majority of participants coming from the eastern Free State where *R. rubiginosa* is most prolific in South Africa (Henderson, 2001).

The red dots in figure 3.1 depict the regions that were surveyed. In these regions an attempt was made to locate stakeholders who were impacted by *R. rubiginosa.* The surveys were extensive, however so few interviews were conducted due to the lack of *R. rubiginosa* found on various properties.

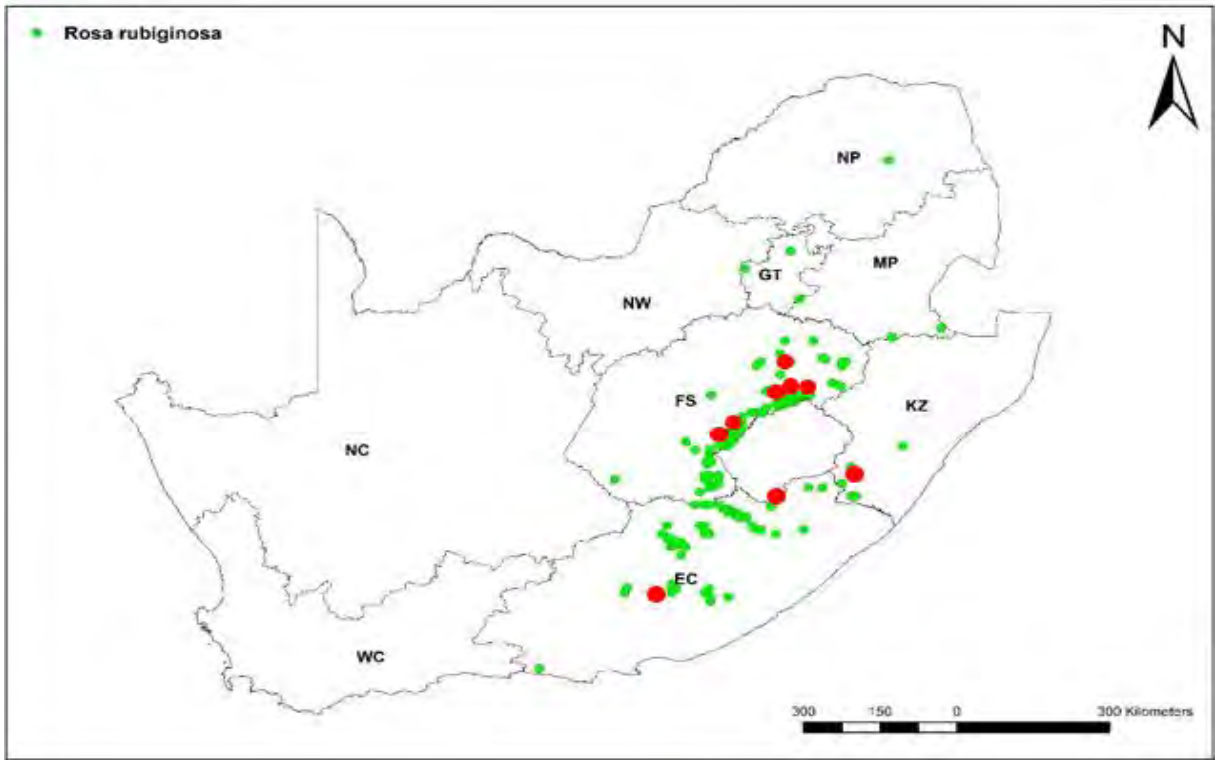

Figure 3. 1: *Rosa rubiginosa* L. distribution in South Africa (green dots) and sites where landowner surveys were conducted (red dots).

Both quantitative and qualitative data was collected in the landowner questionnaires. The quantitative data was used to determine the cost to landowners in terms of *R. rubiginosa* control and lost agricultural land. Basic statistics were used in order to present findings in

figures and provide an overall understanding of the impacts. Some of the qualitative data collected was converted into quantitative data, as yes/no answers were turned into 1's and 0's. This was done so the data could be represented in the form of graphs and tables. The more in-depth qualitative data feedback was interpreted by personal interpretation.

The landowner questionnaire was divided into five sections. The first section covered various particulars of the respondents. This was done for administrative purposes in case of any follow up requirements. The second section covered plant identification, assessing whether participants could identify the specific species. The third section covered the containment of *R. rubiginosa.* This section assessed the extent of the infestation and impact of *R. rubiginosa* and ascertained the control techniques and cost sustained by landowner. The fourth section covered legislation so that participants could indicate their understanding of the legislation regarding *R. rubiginosa* in South Africa, as well as, whether the landowners believed the current categorisation of the shrub was reasonable. The fifth section allowed for any additional comments to be voiced by the participants.

c) Rosehip Company Functioning and Benefits

The functioning and benefits associated with *R. rubiginosa* were determined through surveys with wholesale rosehip companies in South Africa. The study attempted to sample the entire wholesale market for rosehips in South Africa to depict the benefit of *R. rubiginosa* to South Africa. This was possible as the rosehip market is an oligopoly. No data is available depicting the financial side of the rosehip industry in South Africa. Therefore, questionnaire surveying of the companies was the best possible way of understanding the rosehip market and gain an understanding of the size and growth of the market. The companies do not work together in anyway or means and do fall under a larger organisation or group.

The study defines the South African rosehip market size as the turnover generated by wholesale rosehip companies which sell in bulk, refined *R. rubiginosa* rosehips (seed, shell and oil). Turnover is a key measurement in measuring a business or markets performance. In cases where companies were not willing to provide turnover figures, best possible estimations were used. These estimations were done by using the number of rosehips processed by the company and the average turnover generated from the other rosehip companies.

Face-to-face semi-structured interviews were conducted and when time did not allow for the interview to be completed a follow up phone interview was conducted. The data collection for the company questionnaire took place between the month of June and August 2019. Interviews were conducted in the Free State and KwaZulu-Natal provinces. Sampling covered three of the four significant wholesale rosehip companies in southern Africa. The one company that was not involved in the study did not respond to any contact attempts. Some inferences were made about the company from information gathered in the literature and from the other companies surveyed.

Both quantitative and qualitative data was collected. The quantitative data was used in order to determine the monetary costs and profits associated with the rosehip companies. Basic statistics were used in order to depict the results in figures and provide an understanding of the data. Qualitative data provided an understanding into the relatively unknown rosehip market. A basic thematic analysis was conducted along with personal interpretation of the qualitative data.

The company questionnaire was divided into five sections. The first section covered various particulars of the respondents. This was done for administrative purposes in case of any follow up requirements. The second section covered rosehip as a product. This section assessed whether the rosehips sold are from *R. rubiginosa* species as well as the beneficial characteristics associated with rosehips. The third section looks at the various company's production statues. This covers both the types of rosehip products being sold, as well as their quantities and turnover statistics. It also covers the way in which raw rosehip product are attained and the various costs. The fourth section covered the rosehip market. This was done by determining where the companies sold their products, both in South Africa and abroad. It also covered how the sale of rosehip products has changed over the years. The fifth section allowed for any additional comments to be voiced by the participants.

d) Company Case Study

The company case study was conducted in order to determine how the rosehip companies are limited by working with a category 1b invasive plant, *R. rubiginosa*, and how companies would change if the shrub was downgraded allowing for cultivation. As all the companies function in very similar ways, determined during the company surveys. We believe this data to be representative of the other two companies as well. Face-to-face semi-structured interview was conducted with the owner of one of the companies. Both quantitative and qualitative data was collected. The qualitative data was interpreted personally and any white noise feedback was filtered out. The interview was conducted in a semi-structured format and was recorded in order not to slow the flow of conversation. The recoding was then converted into text and a basic thematic analysis was conducted.

The case study was split into two main questions. What is the company's present states and how would it potentially change if cultivation of *R. rubiginosa* was allowed? In order to determine the present states, general questions were asked on the current running of the company, what the company's costs and revenue were, and how the company was limited by the 1b categorisation of R. rubiginosa. To determent the potential changes to the company if a downgrade was implemented, questions were asked regarding what limitations would be removed and how their removal would benefit the company, how the running of the company would be altered, and a hypothetical change to cost and revenue were discussed.

The case study allows for an understanding as to how the rosehip market could potentially expand. As there is no way to run an experiment to determine what would happen if cultivation was allowed, due to cultivation being illegal, a hypothetical scenario was the best way to understand the potential of the companies.

3.3.2 SECONDARY DATA COLLECTION

In order to determine the extent of the population and the potential spread of *R. rubiginosa* population data was taken from various sources including; the South African Plant Invaders Index (SAPIA) and the Global Biodiversity Information Facility (GBIF) (Booth *et al.,* 2014). SAPIA provided distribution data for *R. rubiginosa* in South Africa (Henderson, 1998). GBIF provided distribution data of *R. rubiginosa* on a global scale.

Distribution records of *R. rubiginosa* arising from the field surveys, GBIF and SAPIA were overlaid onto a map incorporating the number of frost days in South Africa (Schultz, 1997), using ArcView v.10.4., to visually show the influence and importance of frost in driving the distribution of *R. rubiginosa* populations in South Africa.

CHAPTER 4
RESULTS

4.1 BRIDGING THE *ROSA RUBIGINOSA* L. KNOWLEDGE GAP

The *Rosa Rubiginosa* L. literature review identified two key points. Firstly, there is a significant gap in the literature surrounding both the benefits and negative impacts of the shrub, locally and abroad. Secondly, the current 1b categorisation of *R. rubiginosa* in South Africa was not determined by a risk assessment but rather by the opinion of experts in the field of invasion biology many years ago. Therefore, the use of an expert opinion questionnaire was used to gain an improved understanding of the impacts of *R. rubiginosa* in South Africa and bridge the cap in the literature.

4.1.1 IDENTIFICATION

Twelve experts in the field of invasion biology, all of which were aware of the shrub's invasive presence in South Africa, took part in the survey. Ten of the twelve experts were aware of the fact that *R. rubiginosa* is a category 1b invasive species. Eight of the twelve experts classified *R. rubiginosa* as a conflict generating species. The remaining four experts were unsure of whether the shrub is a conflict generating species. None of the experts replied 'no' as they were aware that many invasive species do possess some form of benefit. The eight participants who believe the shrub to be a conflict generating species were aware of its commercial and ornamental benefits along with the invasive characteristics. The other four experts were not aware of any particular benefits related to the shrub. However, one expert stated that Rosa species have many benefits and it is therefore likely that the shrub has both beneficial and negative impacts. A respondent commented that she is very aware of the conflict associated with the shrub in Argentina but not in Sub-Saharan-Africa.

4.1.2 INVASIVE CHARACTERISTICS

In order to better understand the invasive characteristics of *R. rubiginosa* experts were asked to state whether various highland invasive species, found in the same regions of Sub-Saharan Africa as *R. rubiginosa*; were more invasive, had the same invasiveness or less invasive.

In all cases, *R. rubiginosa* was not seen as being more invasive than any of the five highland invasive species. *Robinia pseudoacacia* and *Cirsium* species were seen to be significantly less invasive. *Rubus fruticoses* and *Pyracantha angustifolia* were viewed by the experts to be of similar to less invasive in comparison to *R. rubiginosa* (Fig 4.1). The majority of experts believed *Contonester* species to be of the same invasive level as *R. rubiginosa*

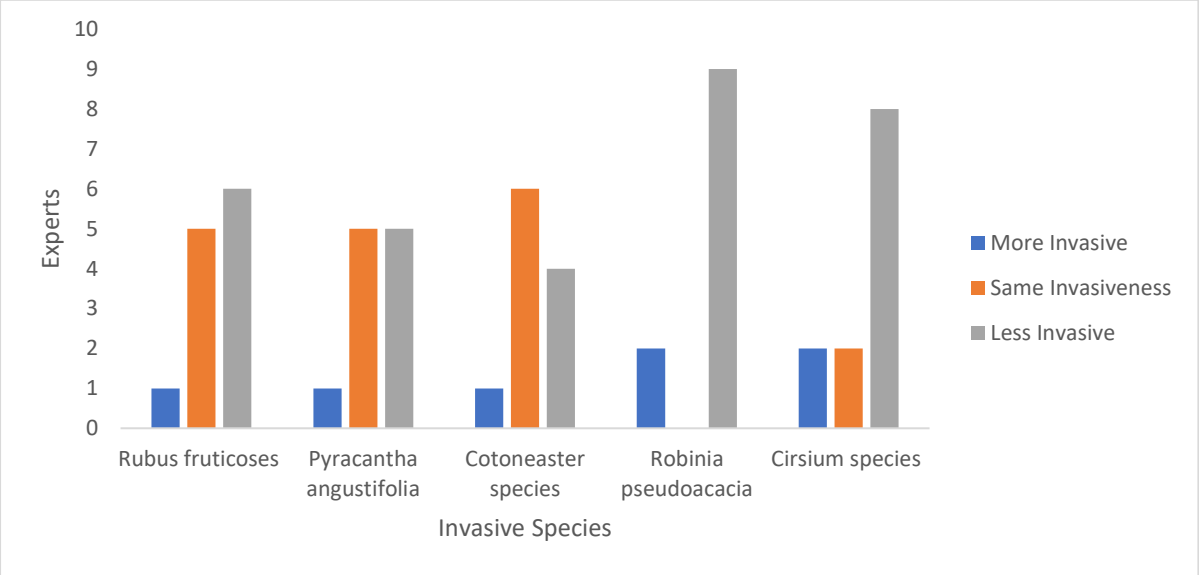

Figure 4 1: Whether *Rosa rubiginosa* L. is more, the same, or less invasive than five other highland invasive species located within the grassland biome of South Africa.

International studies have suggested various negative impacts associated with *R. rubiginosa.* The invasive biology experts were asked to provide their sentiments towards whether they agree or disagreed with the various negative impacts of *R. rubiginosa*.

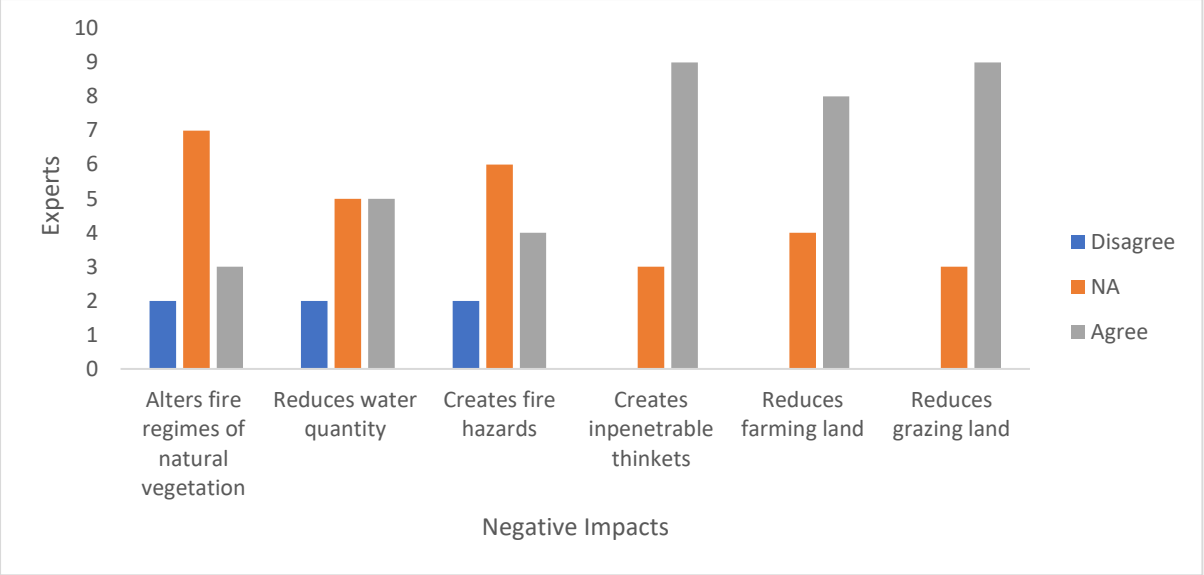

Figure 4 2: Expert's sentiments towards negative impacts associated with *Rosa rubiginosa* L. derived from several international studies.

A number of experts were not aware (NA) of the negative impacts associated with *R. rubiginosa* (Fig 4.2). Three of the impacts have NA as the highest expert response. For each of the negative impacts stated more experts were in agreement than not. There was a strong agreement by experts that *R. rubiginosa* creates impenetrable thickets, reduces farming yields by decreasing farming land, and reduces the amount of grazing land available to livestock (Fig 4.2).

The experts where asked if they had any additional negative impact to the ones listed. The impact on biodiversity was brought up. A respondent stated that "Large stands of *R. rubiginosa* may outcompete native species (in terms of space, nutrients, pollinators and seed dispersers). In Argentina it was found that invaded stands of the shrub provided new habitat for rodents. These rodents, in turn, can carry the hantavirus which can be dangerous to humans (e.g. Andreo *et al.*, 2014)".

4.1.3 BENEFICIAL CHARACTERISTICS

In order to better understand the beneficial characteristics as well as the awareness of experts, a table was provided in order to determine their sentiments (agree or disagree) towards various benefits of *R. rubiginosa* (rosehips).

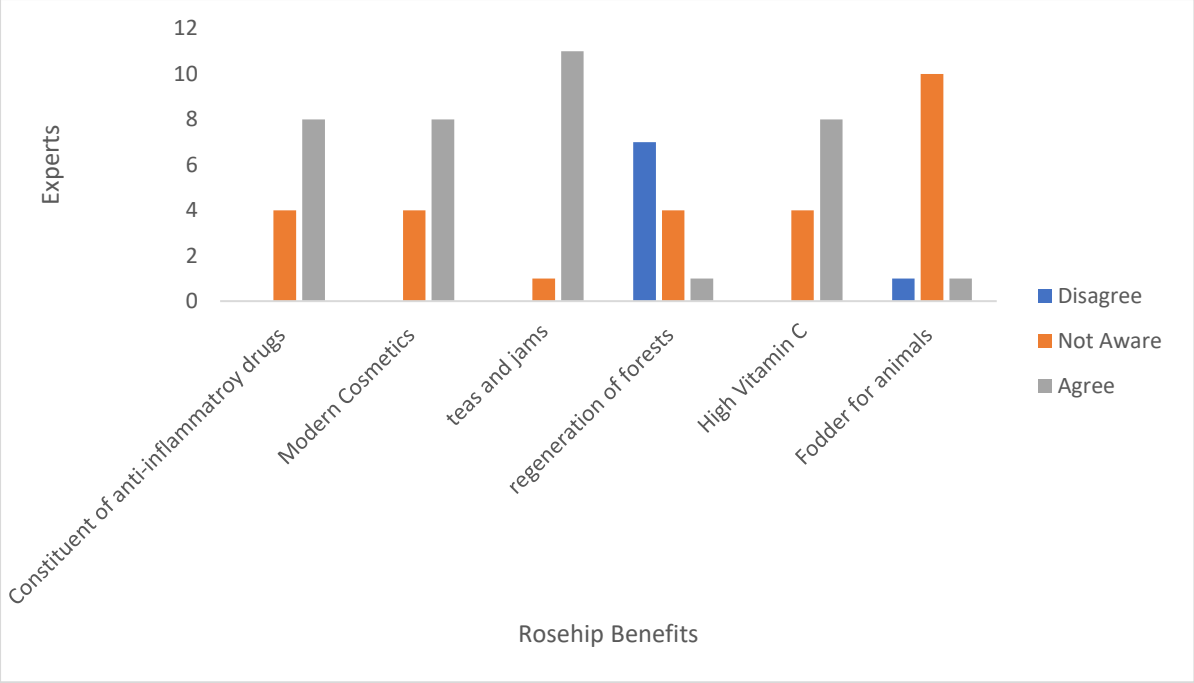

Figure 4 3: Expert opinions to various economic benefits associated with *Rosa rubiginosa* L. and its fruit rosehip.

Of the six rosehip benefits presented to the experts the majority agreed with four of them (Fig. 4.3). Two of these benefits have been around for centuries, the use of teas and jams to take advantage of the fruit's high vitamin C content. Experts were also aware of more recent benefits found on the cosmetic and medicinal industry. The majority of experts disagreed with De Pietri (1992) who conducted a study that stated *R. rubiginosa* can behave as a nursing plant in order to facilitate natural forest regeneration (Fig. 4.3). Ten of the 12 experts were not aware of the ability for rosehips to be used as fodder for animals. Additional benefits were stated by experts, such as job creating in rural communities, rosehips are a possible food source for wild animals, and the aesthetic benefit of the plant.

The majority of experts are aware that there is a conflict of interest associated with *R. rubiginosa* and are aware of the recently discovered benefits of the rosehips. However, the details of the conflict of interest does not seem to be very well understood and therefore making a judgement on the plants invasive status may not be completely accurate. In saying that only two of the experts confidently agreed with the categorisation with eight of them being unsure and two experts disagreeing with the categorisation, believing the shrub should be downgraded.

4.2 *ROSA RUBIGINOSA* L. IMPACT ON SOUTH AFRICAN LANDOWNERS

The impact of *R. rubiginosa* on South African landowners provides an indication of the extent of the negative impacts imposed by the invasive shrub. Ten interviews were conducted with South African landowners living in areas which have the highest *R. rubiginosa* infestations, according to the SAPIA distribution data (Fig. 3.1). These areas were along the Lesotho boarder in the Eastern Cape, Free State and KwaZulu-Natal. Eight of the 10 questionnaires were completed, with two landowners unable to provide any information regarding *R. rubiginosa* as they did not have the shrub on their land and were unaware of the species. These two participants were both from KwaZulu-Natal. Due to the specificity of the research, only landowners who had the species on their land would be able to partake in the questionnaire.

Seven of the participants had various farming practices on their lands. This is beneficial to the study as it covers a number of different land types, such as, cultivated, grazing, marginal and gardens. The last participant is a conservation manager in KwaZulu-Natal. The landowners had lived on their various properties for an average of 26 years. This provided good historical data of how the invasive shrub would have spread over the years.

4.2.1 IDENTIFICATION AND IMPACT

landowners were shown the photographs bellow (Fig. 4.4) to determine if they knew what the shrub was and whether they could identify it. All eight were confident in being able to identify the shrub and stated it was found on their land.

Figure 4 4: Photos depicting *Rosa rubiginosa* L. flower, leaves, rosehips and shrub.

The landowners indicated the extent as to which *R. rubiginosa* covered their land. The majority of landowners (62,5%) have low coverage of the shrub and that the shrub has not dominated their lands over the various years it has been there (Fig. 4.5). Two landowners stated they experience medium coverage, with one landowner stating they experience a high coverage of *R. rubiginosa* on their land. However, of the eight landowners, seven regarded the invasive shrub to be problematic. Only one respondent, based in KwaZulu-Natal province, stated that the shrub was not problematic, but did warn against the shrub becoming a problem in the next 20-25 years.

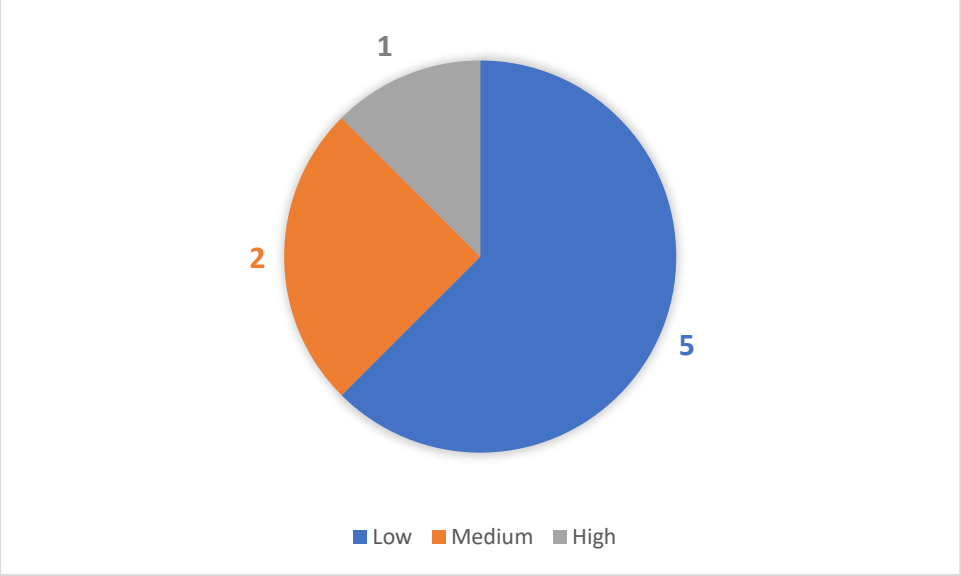

Figure 4 5: Amount of *Rosa rubiginosa* L. on landowners' land.

Invasive plants have a number of common negative impacts, such as, choking fence lines, reducing water, blocking animal access, and decreasing available farming land.

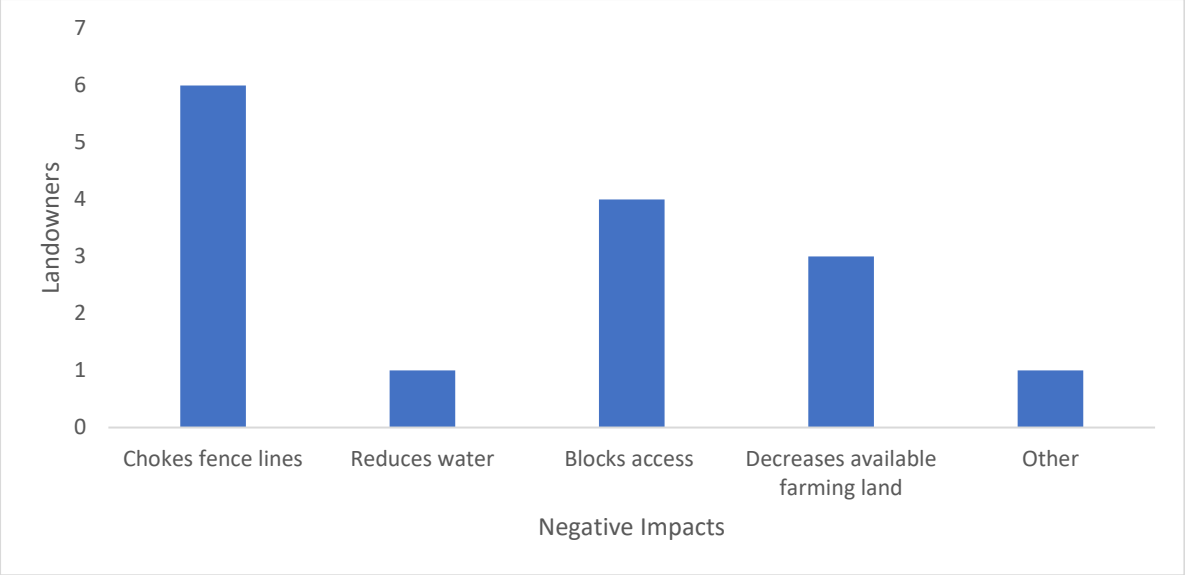

Figure 4 6: A diagram indicating the negative impacts associated with *Rosa rubiginosa* L. experienced by landowners.

The most common negative impact to landowners is that the shrub chokes fence lines. This is a result of birds consuming the seeds and dropping them while they sit along the fence line (Fig 4.6). One of the landowners who has owned his property for 46 years, stated that as *R. rubiginosa* has established itself on his land, which has resulted in the bird life changing. Four landowners stated that the shrub blocks animal access and three said it decreased available farm land (Fig 4.6). However, it was only able to decrease farm land if the land was not maintained for a period of time. Grazing animals are able to stop the spread of the shrub if they are grazing in a field the shrub is trying to establish itself. Only one participant stated that the shrub reduces water quantity. One landowner stated that the shrub increases fire intensity and that when the shrub is found along a fence line it increases the chances of the fence breaking during a fire.

The extent of *R. rubiginosa* in the most highly infested areas of South Africa are seen to be relatively low. However, the landowners clearly do experience various negative impacts commonly associated with IAPs.

4.2.2 LANDOWNERS CONTROL OF *ROSA RUBIGINOSA* L.

Half of the landowners interviewed have attempted to control the *R. rubiginosa* found on their land. Two landowners have attempted mechanical control and three have attempted chemical control techniques. No landowners have attempted to use fire to control the shrub.

There is currently no biological control for *R. rubiginosa* and therefore no landowners have attempted this form of control. In one case, integrated control was used by a landowner, combining mechanical and chemical control. Control techniques where implemented roughly once a year by each landowner, some of the landowners indicated that some years there would be no need for any control.

The annual amount of money spent by landowners on the control of *R. rubiginosa* averaged R9562,50 per landowner. There was great variation among the amount spent by landowners. One landowner's annual spending on the control of the shrub was R30 000, while another landowner only spent R250 annually. The full extent as to how much landowners annually spend on the control of *R. rubiginosa* is hard to determine as not all landowners feel the need to control the shrub. However, from the data acquired, it can be stated that R4,07 is spent per hectare of land in an attempt to control *R. rubiginosa*. This figure was derived by taking the amount spent on control and divided by the area of the land the control took place on. The most money spent on control was in the Free State near the town of Clarens

The losses endured by landowners due to the negative impact of *R. rubiginosa* were hard to determine for the landowners. One landowner, in an attempt to try give some sort of feedback, estimated that in infested areas (20 shrubs or more per ha) he would sustain R100 worth of losses. On his property of his 520ha of grazing land, he estimated that 30ha is infested land, resulting in R3000 lost to the shrub's negative impacts annually. In order establish the total impact the shrub has on South Africa's agricultural sector, one would need to determine the amount of infested land.

The monetary losses vary significantly between areas. If correct farming practices are applied *R. rubiginosa* is not able to outcompete the agricultural processes on the land. The results do show that in marginal lands the shrub spreads rapidly outcompeting the native vegetation within the highly invaded areas that were identified in figure 3.1.

4.2.3 INVASIVE CHARACTERISTICS

A comparison was made between *R. rubiginosa* and various other invasive species found within the same infestation area identified in figure 3.1. A number of invasive species were considered to be more damaging by the landowners, namely, *Robinia pseudoacacia* L. (Black

locust), Populus species, Rubus species, *Gleditsia triacanthos* L. (Honey locust), *Acacia mearnsii* De Wild. (Black wattle), *Salix babylonica* L. (Weeping willow) and Pyracantha species (firethorn). Only one landowner saw *R. rubiginosa* as a real concern compared to the other invasive in the area, rating it as the second worst after *Robinia pseudoacacia*. This is the landowner that spend R30 000 annually on the control of *R. rubiginosa.*

Almost all of the landowners stated that *Seriphium plumosum* L. (Slangbos or Grey bush) is the worst invasive species they deal with in their area. However, this species is in fact not an IAP and is an invasive native to South Africa. Slangbos is an aggressive encroacher endangering grasslands, often outcompeting and covering land that has been over-grazed (Snyman, 2009).

Five of the landowners have witnessed a constant increase in the spread of the shrub across their lands and that the spread is continuing to increase (Fig.4.7). Two of the landowners stated that the number of shrubs has increased over the years but in recent times the spread has slowed. Only a single landowner reported no increase in the quantity of *R. rubiginosa* across their land.

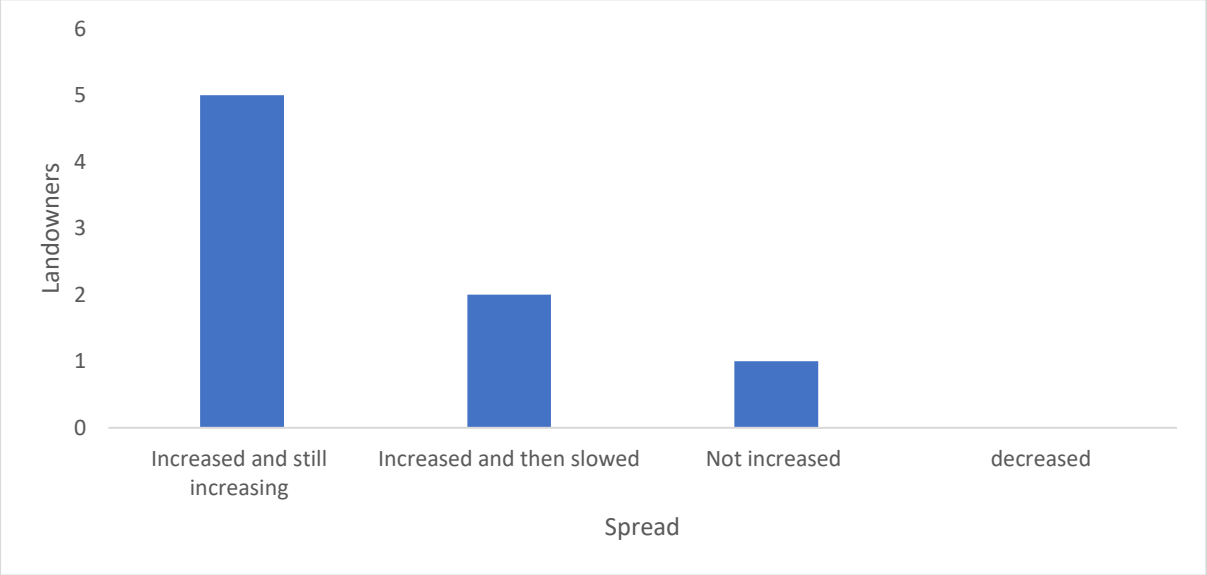

Figure 4 7: Spread of *Rosa rubiginosa* L. witnessed by landowners.

The figure above evidently shows there is increasing concern for *R. rubiginosa.* However, in comparison to other invasive species, efforts are better served controlling species such as *R. pseudoacacia*, Pyracantha species and various others.

4.2.4 LEGISLATION

Five of the eight were aware that the shrub is listed as a 1b invasive in the Alien Invasive Species List of 2014, in accordance with the NEM:BA. The remaining three participants were not aware of the specifics, only that it was invasive.

All participants were then told that the shrub was a category 1b invasive and what that meant according the NEM:BA legislation. They were then asked what their sentiment was towards whether the categorisation of the shrub was reasonable (Fig. 4.8).

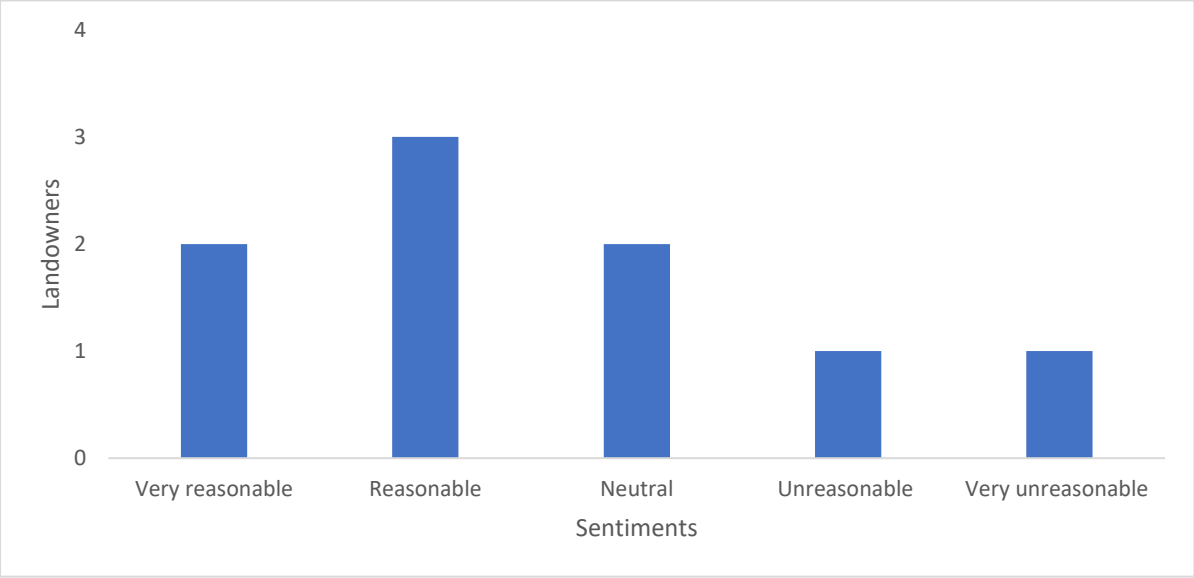

Figure 4 8: Landowners sentiments towards the 1b categorisation of *Rosa rubiginosa* L.

The responses were well spread between being reasonable and unreasonable with a slight majority being on the side of the legislation being reasonable (Fig. 5.8). The landowner's opinions are influenced by the effect the shrub has on their farming practices and land. It is important to them that if there is to be any suggested changes to the legislation that there is evidence that the benefits will significantly outweigh the costs and be socioeconomically beneficial to the country.

Landowners in the Free State were far more aware and concerned about *R. rubiginosa* than anywhere else in the country. There was some concern shown towards *R. rubiginosa* by landowners although various other invasive species were of greater concern.

4.3 ROSEHIP COMPANY FUNCTIONING AND BENEFITS IN SOUTH AFRICA

In southern Africa there are four main companies that are involved in the sale and distribution of rosehip. The companies are based in the South Africa (Free State and Kwa-Zulu-Natal provinces) and Lesotho. The research was only able to cover three of the companies with the fourth not responding to various contact attempts. The companies that were interviewed were able to provide various information about the missing company, allowing for educated estimations of the rosehip industry in Southern Africa. For the sake of confidentiality companies will be referred to as company A, B and C.

The rosehip market in South Africa is very much an emerging market. From the three company's interviewed, a total of 11 years has been spent in the rosehip industry. Company A had been in the business for six years. Companies B and C have been in the industry for three and two years respectively. All three companies are based in and around Lesotho. This is due to the high population of invasive *R. rubiginosa* in this area of southern Africa.

4.3.1 COMPANY LIMITATIONS

All three companies stated that they were not limited by the demand for rosehip as the international demand for rosehip is so great that there is ample room for expansion. In addition, all the companies stated that they had plans to expand in the other global markets to include the Asian market which has not yet been supplied. This high demand makes the limitations faced by the company a significant issue.

The companies stated that they face a number of limitations due to market restrictions and the fact they are dealing with an invasive species. The supply of rosehip is a limitation faced by the companies as it is dependent on environmental factors. The restriction of cultivation in southern Africa means that all supply comes from wild shrubs which are predominantly dependent on environmental factors which fluctuate on a yearly basis.

Most of the rosehip picking takes place in Lesotho, a poor country with many subsistence farmers. Often, the end of the rosehip picking season overlaps with their spring cultivation, resulting in a decrease in the supply of rosehips.

One of the companies that is relatively new to the market has trouble with access to pickers. The company's owner stated that the restriction to pickers was due to corruption, which sees small companies within Lesotho partnering with the local police to block the companies' access. All of the company owners interviewed used the phrase "guns and rosehips" to describe the on goings within the market in Lesotho. This phrase is eluding to the competitive and sometimes violent competition when accessing the rosehips within an unregulated market.

Transport of the rosehips from Lesotho to South Africa is another limitation and cost faced by the companies. The companies are also required to have permits to transport the rosehips across borders. These permits are not expensive but need to renewed often, which is a time-consuming process.

4.3.2 PRODUCTION

Company A did not provide production data requested in the questionnaire. Company's B and C did supply the data required. Educated assumptions will be used when required as well as assistance from the other company owners who have a rough idea of the missing company's production statistics. Assumptions regarding company A will be made in order to estimate the market size within South Africa.

a) Purchasing of rosehips

According to the companies, the vast majority of rosehips harvested were all wild picked from Lesotho with a small minority from South Africa. Lesotho has a large poor, unemployed population and the picking and selling of rosehips provides an opportunity for them to meet their basic needs. The purchasing of the hips in Lesotho is not regulated and therefore the price paid by the various companies is relatively low. The price paid for the rosehips varies between R6 and R15 per kilogram. All payments are made in cash, which is almost always the medium of exchange used within informal markets (Van der Berg., 2014). The variance of price is dependent on several factors. The main factor is moisture level within the rosehips. The higher the moisture content the greater the weight of the rosehips and therefore the less rosehips per kilogram. The later in the season, the dryer the rosehips and the more the companies are willing to pay as they do not have to dry the rosehips themselves artificially,

which comes with its own expense. The reason the pickers do pick the rosehips in the early season and do not wait until they are dry is due to the need for money. According to the companies some pickers attempt to dry the rosehips themselves in order to be paid more, however, this is more work and often not worth their time. Supply is another factor that fluctuates the price paid to the pickers for the rosehips. The more rosehips being supplied by the locals in Lesotho the less the companies pay for them. This falls under the simple economic framework of supply and demand, as supply increases, price decreases and *vice versa*. Supply is influenced by environmental factors and time of season. Finally, price is also dependent on whether the pickers have followed the correct procedures in order for the companies to sell their products with an organic label. Pickers are provided with training and various packaging materials in order for organic certification companies to provide the rosehip companies with organic certification.

A very limited supply of rosehips is obtained by company C from pickers in South Africa. As in the case of Lesotho, these pickers are part of the informal market and are picking from wild shrubs. They are also paid in cash. According to the companies, the reason for such a small number of rosehips picked in South Africa is due to the significantly less rosehip and due to South Africans not believing it is worth their time. South Africans are also restricted by access to rosehips as the country has strict property rights and fence lines which restrict the ability for pickers to get to the rosehip shrubs, unlike in Lesotho. Poor South Africans are given welfare grants from the government which lowers the desire for them to do the hard work of picking wild rosehips. The limited and variable supply of wild picked rosehips has resulted in company B import roughly 20% of its rosehip seeds from South America.

b) Rosehip quantity

In 2019, Company A saw approximately 1800 tons of rosehip go through production with approximately 1500 and 300 tons go through companies B and C respectively (Fig. 4.9). This puts the total quantity of rosehips between the three companies at 3600 tons (Fig. 4.9). This is far greater than the size of the market in 2007 which was assessed to stand at 1000 tons (Censkowsky *et al*., 2007). There is currently one other large company in the rosehip market in southern Africa which is, according to the three companies that did partake in the research, the longest and biggest standing player in the market. It is believed by the companies

interviewed, that they work with in excess of 1000 tons of rosehips annually. This would put the quantity of rosehips in southern Africa in excess of 4600 tons.

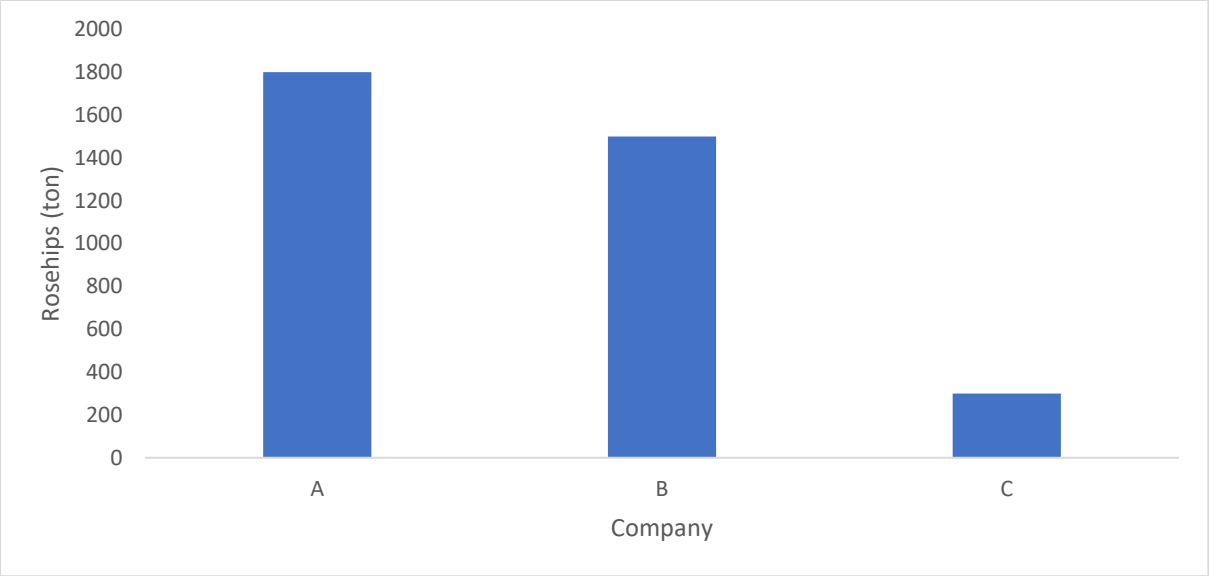

Figure 4 9: The quantity of rosehips which went through production in each company in 2019.

c) Products

All three companies have a different business plan in terms of the types of products they sell. The common practice that all companies attempt is to produce as many organic products as possible due to the significantly greater economic benefit that is ascertained from them.

Company A sells the basic primary products. They sell the dried rosehip shells and seeds. They do not refine their products any further than separating the hips into shell and seed. The sale of these products will not create a large turnover but the costs will be significantly less than companies that refine the products further.

Company B looks to refine the rosehip into teas and oil and powder. There is a larger cost to refining the products further, especially pressing the oil from the seed. The seed oil does however, sell for significantly more than the seed. Therefore, company B will have a higher cost than company A but the company's turnover will be far greater for the same quantity of rosehips.

Company C is similar to company B in terms of refining products. However, the company is also willing to sell less refined products to parts of the market that require them.

4.3.3 COMPANY TURNOVER

Only companies B and C provided turnover figures. Company B's turnover for 2019, in terms of rosehip sales, was R56 million. The company's rosehip sales have grown significantly over the three years the business has been selling rosehips. The company's rosehip turnover grew 62,5% from R6,4 million in 2017 to R10,4 million in 2018. The company's turnover grew an enormous 439% from R10,4 million to R56 million in 2019 (Fig. 4.10).

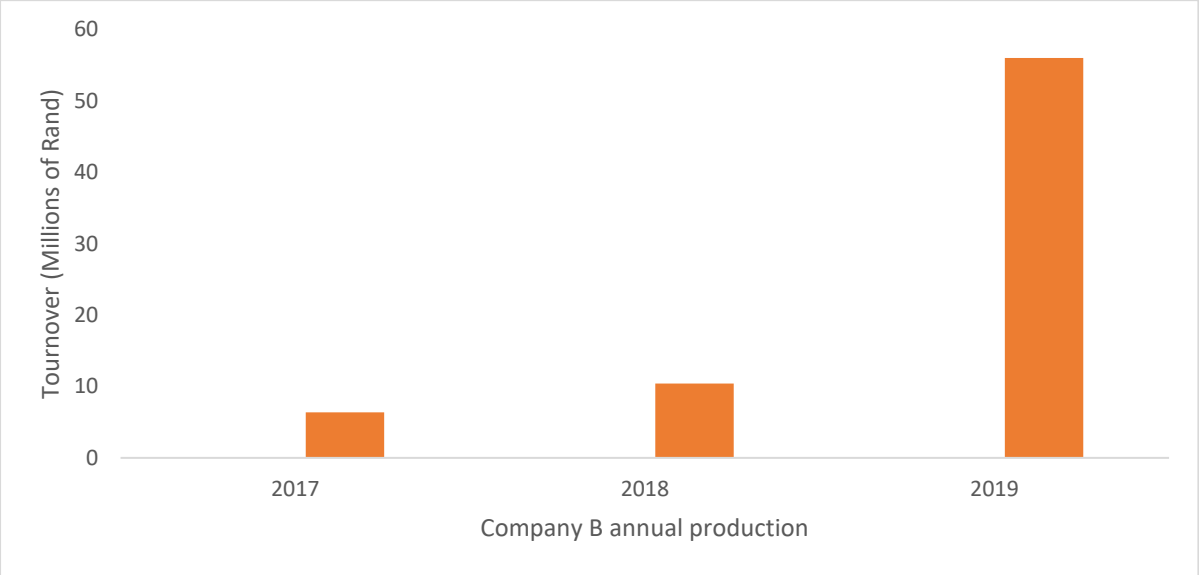

Figure 4 10: Company B's annual turnover over the past 3 years.

Company B's turnover comes from two product categories rosehip seed oil (75%) and rosehip shells (25%). It is possible to refine the rosehip shell further into teas and powders however, this company does not believe these value adding processes are economically beneficial.

Company C has grown from a turnover of just under a million rand in 2018 to R8,64 million in 2019. The company C makes most of its profits off rosehip organic oil and organic rosehip shells. However, unlike company B, company C looks to gain every possible profit out of each rosehip by selling multiple refined products such as, rosehip tea and powder. Company C also sells less refined products such as whole rosehips and seed.

Using the estimated combined quantity of 4600 tons of rosehips sold by the companies and the average turnover per ton between companies B and C, a rough estimation of R153,64 million in turnover for the year 2019 is calculated.

4.3.4 THE ROSEHIP MARKET STRUCTURE

The sale of rosehip from the companies is both local and overseas. However, the majority of sales are made to overseas markets as this is where the greatest demand is. The main overseas market is in Europe with the USA, Canada and Asia as alternative markets. Company A exports 76% of their rosehips to overseas markets in Germany, United Kingdom, USA, Canada and Japan. The remaining 24% are sold to a local company Cape Natural, which is situated in the Western Cape Province of South Africa. Company A sells relatively unrefined products. Their products fall under three product categories whole rosehips, rosehip shells and rosehip seeds. They sell both organic and nonorganic products. Their local sales to Cape Natural are of whole rosehips which get refined and the shells are used by to produce teas. The seeds are sold back to company A and exported to the overseas market.

Company B sells refined products that fall under two product categories organic rosehip seed oil and organic rosehip shells. All of the products are exported out of South Africa. The products exported to Europe go to a single company in Germany that distributes the products within the European market. This is due to the simplicity of dealing with one company instead of multiple companies. Company B also exports to Australia and New Zealand and has plans to move into the Asian market in the coming years.

Company C makes use of all possible sale options from conventional whole rosehips to organic rosehip oil. The company's greatest turnover comes from organic rosehip oil with sales being split between overseas (76%) and locally (24%). Rosehip organic powder is spilt 64% overseas and 36% local. The sale of rosehip shells is almost entirely local (98%). Local sales are made to companies in the Free State, Gauteng, KwaZulu-Natal and Western Cape. Overseas sales are only to European countries (United Kingdom, Germany, Switzerland and Italy).

Company owners were asked how the sale of rosehip has changed over the years. In terms of local sales, two of the companies said growth is slow but the market is stable. Company B was not able to provide any information as they only work with overseas markets. In terms of the overseas market all companies see room for growth especially in the organic products. There has been a large jump in the demand for the organic oil in recent years due a decrease in supply from Argentina due to wild fires. Furthermore, all companies believe there are other

overseas markets that they could export into, with expressed interest in expanding into the Asian market.

In South Africa, all three companies foresee the potential for market expansion and some have plans in order to implement expansion. Company C is the newest to the market and is currently processing their products in a small warehouse. However, they have plans to move into a larger warehouse in Lesotho where they will be looking to expand from 300 tons to 2500 tons on an annual basis. Company B believe there is potential to grow in the rosehip oil market but are not so sure about the shell side of production. In saying that company B would look to expand to as much as 20 000 tons of rosehips annually if the supply was possible. Company A believes there is no shortage in demand from the overseas market and with an increase in supply there will be no issue in the selling of the product.

4.3.5 JOB CREATION

The rosehip industry provides formal, seasonal and informal employment. Between the three companies there are 77 full time employees. The number of full-time employees increased as the quantity of rosehips that go through production increased. Seasonal employment among the three companies amounted to 111 employees. Seasonal employment ranged from six employees in company C to 75 employees in company B. Seasonal employment is beneficial to these companies as the picking and processing of rosehip is seasonal and does not require full time employment. Therefore, the seasonal employment is beneficial as it supplements the performance capacity of the regular employees.

The exact number of informal employees is not known. The informal employees mainly come from Lesotho, with a few also in the eastern Free State Province of South Africa. The informal employees are the ones who pick and sell the rosehips to the companies. They are provided some training in order to make sure the way the rosehips are picked in line with organic certification requirements. The total estimated number of informal employees is 31 500 between the three companies. This may not be exactly correct as informal employees could sell rosehips to multiple companies resulting in them being recorded more than once. However, there is clearly a large informal employment rate associated with the rosehip market. The large number of informal employees is due to the illegality of growing the invasive shrub *R. rubiginosa* in South Africa.

All the companies are relatively new and growing which means that employment should grow in the future. Company C is looking to increase production from 300 to 2 500 tons, while company B is looking to increase production to 20 000 tons of rosehip annually. Such increases in production would result in a significant increase in employment figures. These plans are not possible through wild picked harvest alone and are therefore dependent on a legislation change to allow for cultivation of the shrub.

According to the companies, if *R. rubiginosa* is downgraded to allow for cultivation there may be a shift away from the informal employment to a formal employment of farmers in South Africa. This will be dependent on the relative costs associated with the two harvesting approaches. The market may potentially be big enough to incorporate both formal and informal suppliers.

4.3.6 CULTIVATION BENEFITS

Additional information was provided by one of the participants regarding the possible benefits of cultivation. The information provided was drawn from a though experiment using his own knowledge. No physical attempts to cultivate *R. rubiginosa* was attempted.

If one estimates 2000 plants per hectare and 750g of hips per fully matured plant, one would get 1500kg of rosehip. Roughly 300kg of shells is acquired from 1500kg of rosehip. The shells can be sold at R40 per kg, resulting in R12 000 worth of rosehip shells per hectare. Roughly 500kg of seed is acquired per 1500kg of rosehip. The seed is pressed and results in 12kg of oil. At non-organic prices you could get R1000 per kg of oil, according to the landowner. Therefore, R12 000 per hectare. The turnover per hectare would roughly be around R24 000. If picking is still done by humans it would cost roughly R9000 (1500kg @ R6 a kg). Under organic certification the turnover could rise to R37 800 per hectare (shell = R21 000; oil = R16 800). This would then make it one of the most profitable crops available to be farmed in South Africa per hectare.

4.4 ROSEHIP COMPANY CASE STUDY

Invasion biologists and environmentalists are often bias when investing and categorising invasive species, such as *R. rubiginosa*. Often any beneficial attributes are neglected, not considered or intentionally omitted. It is the main focus of academics to look at the invasive

side of species like *R. rubiginosa* and often look past the beneficial characteristics they bring to foreign countries. The aim of this case study was to further investigate a potential positive attribute of *R. rubiginosa*.

A case study was conducted with one of the prominent South African rosehip companies. The company is a wholesale company which focuses on a number of African plant based natural products. The company's main focus is on rosehip, with roughly 80% of the company's sales coming from various rosehip products. The case study was conducted to understand the limitations faced by the company due to working with a category 1b invasive species *R. rubiginosa* and how the company would benefit from a potential downgrading of the shrub to a category 2 invasive species under the South Africa NEM:BA legislation. The study took the form of an interview with the company's owner with structured questions.

4.4.1 PRESENT COMPANY INFORMATION

The company in the case study is the same company as company B in the previous chapter. The company is based in South Africa with two processing facilities. According to the owner, the majority of the company's rosehip supply comes from Lesotho as the plant is in abundance and can be freely collected from the wild, whereas it is difficult to collect in South Africa due to property fence lines and the need for the landowner's permission. The company employs 40 full time South African employees and 30 to 40 seasonal employees. The seasonal employees are employed to help with the physical labour required. The company also works with thousands of informal employees in Lesotho who source the wild harvested rosehips.

a) Background and Production Process

The current production process is heavily influenced by the limitations of working with a category 1b invasive species. All rosehips are picked in the wild and come from the mountainous country of Lesotho, a country with about 40% of the population living below the international poverty line. The rosehips are hand-picked in the winter by informal pickers and taken to collection sites where they are paid in cash. The income generated from the rosehip sales are highly beneficial for sustaining the people of Lesotho in the winter season. Once the collection site has enough rosehips, they contact the company truck drivers who go to these sites and pay cash for the rosehips. The rosehips are then brought through the Lesotho-South

Africa border to a processing facility in Wepener, Free State province. A general permit from the Department of Agriculture and Fisheries is required to transport the rosehips across the border. This is the same permit that is required to bring any fruit or berry across a border into South Africa. In South Africa, the fresh rosehips are dried at 40 degrees Celsius to ensure the integrity of the bioactive ingredients is maintained. The rosehips then go through a milling process where the seed is separated from the flesh. The fruit flesh is either exported from the site for teas or it is milled up and sold into the nutraceutical industry. The seeds are trucked to a facility in KwaZulu-Natal where they are pressed and the oil is extracted and shipped to overseas markets. All products are sold in bulk and further refined into branded products by various other companies.

In addition to the Lesotho supply, company B sources seed from Chile. The company has a relationship with a leading supplier in the Chilean rosehip industry. The relationship is a mutualistic relationship. The Chilean company supply rosehip seed to company B so that it may be pressed in South Africa and exported into the European market. The extra supply provides additional safety in terms of supply, which is limited from Lesotho. The seed that is imported from Chile comes from three different Rosa species grouped under the general term *Rosa mosqueta* which includes *Rosa moschata, Rosa rubiginosa* and *Rosa canina* (Joublan & Rios, 2005). The oil that is extracted from these seeds is not as economically beneficial for company B compared to the Lesotho seed. This is due to the oil from the seed not being as high yielding as the *R. rubiginosa* seeds from Lesotho. A small profit margin was made from these seeds in 2019. Due to the lack of economic value procured from the Chilean rosehip seed. The shells that come from Chile are not economically viable for company B to process.

Company B aids the Chilean company by subsidising their rosehip supply to Europe. Chile's GDP growth is strangling their rosehip industry as harvesters are asking for significantly more pay and are looking elsewhere for greater income, which is resulting in Chile struggling to supply the 20 000 tons into the overseas market. Therefore, company B is helping the Chilean company reach the annual 20 000 ton supply. This is highly beneficial to company B as it provides a secure supply into the European market.

b) Company's Goals with Current Legislation

The company's overall goal in terms of the rosehip market expansion is to reach a quantity of 20 000 tons of raw rosehips annually. Without a change in legislation the company will need to dominate the wild picked harvest supply from Lesotho in order to achieve the volume the company requires. However, even if the company is able to dominate the roughly 4000 – 5000 tons Lesotho market, it will still be significantly lower than the goal of 20 000 tons. The company is therefore looking elsewhere for supply. Even with the company taking over some of the Chilean supply there is still a shortage in supply and therefore they are looking at various other options such as cultivation and foreign imports. The possibility of cultivation outside of South Africa is a potential option. A country like Swaziland has no legislation against the cultivation of *R. rubiginosa* and could potentially be a cultivation option for the company. This however would come with its own form of additional limitations and extra costs.

c) Company Revenue

Company B had a rosehip turnover in 2019 of R57 million. This R57 million came from 1500 tons of dried rosehips. The goal for 2020 is to reach 2000 tons of rosehips that will amount to a turnover of roughly R76 million. If the company was to reach their ultimate goal of 20 000 tons of rosehips the turnover would amount to roughly R760 million worth of trade.

d) Company Costs

There are a number of costs associated with the company. Common costs such as salaries and transport contribute a significant amount to the total costs of the company. The company pays around R350 000 a month on salaries. It costs R3.50 per kg when shipping rosehip products overseas. This is a standard shipping price and is not seen as excessive by the company. There is also the small cost of transporting the rosehips from Lesotho and around South Africa, however, this is not to substantial.

Significant costs that are unique to the rosehip industry include the cost of purchasing the wild picked rosehips and the cost of fuelling the dryers. The company pays between R8 and R15 per kilogram of rosehip. Therefore, in 2019, the company would have spent between 12 and 22,5 million rand on the 1500 tons of wild rosehips. Fuel cost for operating the dryers that extract the moisture out of the rosehips is expensive regardless of the fuel used (diesel,

coal, electricity or wood). The company does use the waste product from the oil pressing, which they call 'oil cake', as a biomass to help fuel the dyers and reduce costs. Ramos *et al.* (2016) showed the potential of using rosehip extract as a biodiesel.

The company does not face any costs in terms of penalties or permits due to working with an invasive species. The company is required to have a valid import permit from the Department of Agriculture, Forestry and Fisheries. The permitting cost is minimal.

e) Limitations due to Invasive Categorisation

The most significant limitation to the company is that to cultivate *R. rubiginosa* in South Africa is prohibited. Not being legally allowed to cultivate the shrub in South Africa results in a shortage in the amount of rosehips and it has no control over the amount of available rosehips. Not being able to cultivate increases supply risk as the market is almost entirely dependent on the Lesotho harvest, which could significantly vary due to climatic conditions and legislation.

Various other limitations stem from the inability to cultivate. The company has to work within the informal market which by nature is not regulated. Having to source their rosehips in Lesotho adds a significant travel cost. However, in terms of government control and regulation, there is no limitation. The company receives no contact from the government checking to see if the company is treating the potential spread of *R. rubiginosa* adequately. No penalties are placed on the company by the government. There are no additional permits required or import and export costs placed on the company due to its use of an invasive species.

In Lesotho, there is a current issue of state capture. "So far, we have not seen any significant form of this within the rosehip industry" according to the company owner. However, over the last couple of years there has been significant state capture in the wool and mohair industry in Lesotho with the Chinese taking monopolistic control of the industry (Venter, 2019). For many years South Africa played a major role in the industry providing the South African economy with millions of Rands annually. The fear is that the Lesotho government could allow the same thing to happen to the rosehip industry, which would leave the South African company with no supply. This would further impact other South African companies that are

part of the downstream economic benefit associated with rosehip. This is not a current limitation faced by company B; however, it is of significant concern. If cultivation was allowed in South Africa it would alleviate a significant amount of risk for the company.

Another risk and limitation that the company faces is having to move a significant amount of money in cash from South Africa to Lesotho to pay for the rosehips. Transporting large amounts of cash is a risk due to the potential for theft from both within the company and from external sources.

4.4.2 HYPOTHETICAL DOWNGRADE OF *ROSA RUBIGINOSA* L.

If *R. rubiginosa* was downgraded from a category 1b invasive species to a category 2 or lower there would be the opportunity to cultivate the shrub within South Africa. The opening up of cultivation would result in market opportunities for company B and various other stakeholders within the rosehip market. Various limitations faced by company B and other companies in South Africa will be removed. A larger rosehip market would benefit South Africa as a whole in terms of employment and economic growth. A larger southern African supply would further be beneficial to the global market, increasing supply and allowing for further development in the rosehip industry.

a) The Impact of a Downgrade on the Company

Company B and all other wholesale rosehip companies, would no longer be limited to the wild rosehip supply. Companies could cultivate as much of the shrub as they desire, no longer being constrained by the limited wild harvest in Lesotho. Cultivation will allow company B to take a 3-tier approach to the sourcing of the rosehips (wild harvest, import from Chile, and cultivation). A 3-tier approach spreads out the risk of a shortage in supply. Importantly, it will protect against any further state capture in Lesotho which could wipe out almost all of the company's supply at any moment.

Furthermore, cultivation would allow for cultivar selection, use of fertilizers and controlled watering resulting in the best possible rosehip growth. This will allow the company to produce rosehips with the greatest amount of oil and larger, nutrient rich, fruit flesh. The result would be a larger profit margin. Not only will there be more control over the type of cultivar but control over the season length. The ability to control and shorten the picking season will

decrease the risk of environmental factors negatively impacting the rosehips. The rosehips are ready for picking from March with 100% of the rosehips fully matured by June. This will allow for the cultivated season to end several months before the wild picked season. Cultivation of the species would improve both the quality and quantity of rosehips available for market from South Africa.

Cultivation will allow for the rosehips to be grown closer to the company's facilities in South Africa, which will decrease transport costs and reduce the time spent transporting the rosehips from Lesotho to South Africa. The picking of the rosehips will become significantly easier on cultivated land as opposed to the mountainous land of Lesotho, allowing for more rosehips to be picked per worker increasing company productivity.

The downgrade would not provide any benefits in terms of penalties or taxes as in South Africa there are no extra penalties or taxes imposed on companies working with wild Rosa species. The only benefit for the company is that due to being able to cultivate in South Africa they would not need to pay the small price of an import permit that is required when transporting the wild rosehip harvest from Lesotho to South Africa.

The overall benefit of a *R. rubiginosa* downgrade to the company stems from the ability to cultivate the shrub. All other potential benefits, such as decreased transport costs and supply security, are due the cultivation of the shrub. The downgrade would allow company B to reach their production goal of 20 000 tons of rosehip annually, a production increase of over 1300%. A potential turnover increase from R57 million to an estimated R760 million annually.

b) How a Larger Rosehip Market Would Benefit South Africa

A larger South African rosehip market is only possible through cultivation. A growing market will significantly benefit the economy and result in job creation. Jobs will be created as the pickers will be South African employees and paid a formal wage. Further jobs will be created as the company expands needing a larger number of skilled employees to run the business.

A growing market would allow for product development, which, according to Company B's owner, is already happening. There is product development within cosmeceutical, phytocare and food and beverage sectors. The most recent and significant benefit associated with rosehip is its ability to treat osteoarthritis (Chapter 2). Product development will increase

possible output and profits, strengthening the South African economy. The development of the market would allow for pathways into further refining rosehip products in South Africa allowing for value adding which will further build the economy.

The allowing for cultivation will result in the new farming practices which further grow the economy. Not only will the new farming practices benefit the economy in a direct way through sales and employment. It will also benefit the economy as in order to start new farming practices various equipment; piping, pumps and so on need to be purchased. Formal rosehip farming would also increase tax revenue allowing for increased government spending.

c) Benefit to the Global Rosehip Market

There is a growing demand for rosehips globally. The company owner stated that rosehip in Germany is comparable to rooibos in South Africa, emphasising the great demand. There is also growing opportunity for South African companies to export into the Asian market which has recently caught on to the rosehip health trend.

The growth of company B would allow for the company to continue to take over the struggling Chilean supply which is part of an agreement between the South African company and a company in Chile. This gives the company easy access into the European market, which is demanding a large supply.

d) Possible Concerns to a Downgrade

If *R. rubiginosa* is downgraded and cultivation commences in South Africa there are a few possible concerns identified by the researcher. These concerns were presented to the owner of company B.

Firstly, what would happen to the Lesotho communities which are highly dependent on the income gained from the sale of the wild rosehips? The intention would be to continue utilising the wild organic Lesotho market. All the procedures and organic certification pathways are already set up. It would also take a long time to cultivate enough rosehips to saturate demand keeping the need for the wild picked rosehips. Keeping the Lesotho trade would also allow the company to run a 3-tier supply plan, getting supply from cultivation, overseas and

Lesotho. A 3-tier supply plan will further reduce the risk of a shortage in supply. Lastly, buyers like the idea of purchasing a product that has helped a poor rural community.

The second concern was would the cost of cultivation and employing formal pickers increase the cost of supply resulting in cultivation being uneconomical? The owner stated that farmworkers would probably be paid minimum wage which would be a significant cost. However, due to the shrubs being cultivated in rows and on flat land significantly more rosehips would be picked per farmworker. Supply may not be any more expensive even with the various added cost of cultivation. The owner further added that the quality of the cultivated rosehips would be better due to cultivar selection that would make any slight increases in cost worthwhile. Overall, there was no concern about cultivation being unviable and is very much looking into it as an option to increase supply, either outside of South Africa or with a different Rosa species.

The third concern was how difficult it would be to gain organic certification for cultivation. It would be different but not significantly more difficult, according to company B's owner. There are a few complexities when gaining organic certification. For example, the land needs to be fallow for a minimum of 3 years prior to cultivation. The soils would need to be tested. However, these are common practices and have common pathways for all organic farmers. The wild harvest gained from Lesotho are assumed to be organic by organic certification bodies, with the only requirement being a test to see that there is no contamination from neighbouring farms.

4.4.3 CONCLUSION OF THE CASE STUDY

Company B is very much in favour of the idea of downgrading *R. rubiginosa* to allow for cultivation of the invasive shrub. The company has already found itself constrained by supply and would need to look to cultivation in order to reach its supply goal of 20 000 tons. Cultivation could have the potential to grow the company from an annual turnover of R57 million to an estimated R760 million. The global rosehip market has sufficient demand to cope with a growing South African industry. The company in the case study is already in the process of subsidising the Chilean rosehip supply as their industry is decreasing in size due to economic factors in Chile.

There is, however, still the concern about the danger of the shrub spreading further due to cultivation, which will need to be further investigated to understand the dangers and compare them to the benefits.

CHAPTER 5
DISCUSSION AND CONCLUSION

5.1 INTRODUCTION

The following chapter consists of four main sections. The first section (5.2) provides a discussion of the results, putting them into context and identifying what they mean for the rosehip industry in South Africa and the potential spread of the invasive species *Rosa rubiginosa* L. Section (5.3) assessed the broader impact of the research. In section (5.4) the recommendations for future studies will be discussed. The final section (5.5) will be the conclusion of the research.

5.2 DISCUSSION

There are a number of environmental and socio-economic impacts associated with IAPs (see chapter 2). The majority of research associated with IAPs is focused on the negative impacts the plants exhibit (Le Maitre *et al.,* 2000; Richardson & Van Wilgen, 2004; Zimmermann *et al.*, 2004; Pimentel *et al.*, 2005; Chamier *et al.*, 2012; Marbuah *et al.*, 2014). However, there are a number of IAPs that possess economic benefits which receive little attention. A limited number of studies have looked at the benefits associated with IAPs (De Wit *et al.*, 2001; Phillips *et al.*, 2013; Zengeya *et al.*, 2017). A number of IAPs reap benefits that result in the direct monetary benefits creating a significant market for the product (Costanza *et al*., 2014; Strik *et al*., 2007). *Rosa rubiginosa* L. is one such IAP that creates a significant market though the sale of the shrub's rosehips and various by-products. A very limited number of studies have been conducted on the rosehip market (Joublan and Rios, 2005; Censkowsky *et al.*, 2007; Espinoza *et al.,* 2016). None of the studies have directly assessed the rosehip market currently found in southern Africa. The lack of literature on this topic allowed for this study to show that at least this IAP in particular can have significant economic benefits.

5.2.1 ADDITION TO THE LITERATURE

There is a significant gap in the literature surrounding *R. rubiginosa* both in terms of the shrub's beneficial and negative characteristics. As the categorisation of the invasive shrub was originally determined by experts within the field of invasion biology, the study took to experts

in order to gage a better understanding of how invasive *R. rubiginosa* is to South Africa and how the newly discovered benefits associated with the shrub may have influenced their opinions.

The research has shown that there are various negative impacts imposed by the presence of *R. rubiginosa* in South Africa. This comes as no surprise as the shrub is known to be invasive and is categorised as highly invasive in South Africa. The experts expressed that the shrub has a strong negative impact in three key areas; creating impenetrable thickets, reducing cultivated land and grazing land. These three negative impacts and the moderate impact *R. rubiginosa* has on water quantity (Le Maitre *et al*., 2016) would be what convinced the original experts to categorise the shrub as a 1b invasive species in South Africa. Keeping in mind that this was a time when South Africa found no beneficial use for the shrub.

Further research showed that *R. rubiginosa* to have far less negative impact when compared to five other IAPs also found in the highland grass biome of South Africa. This does not mean that *R. rubiginosa* is not invasive however, it does show that there are other invasive species which negatively impact the country to a greater extent. Therefore, the limited available funds being invested into the control of IAPs is better spent reducing the presence of the more invasive species.

The benefits of *R. rubiginosa* were identified by the experts, including both the recently discovered cosmetic benefits and the age-old benefit of the high vitamin C content in tea and jams. Further identification of secondary benefits such as, rural community job creation, was also stated. The increase in the shrubs benefits is what creates the question as to whether the shrub's 1b categorisation should be reassessed, as downgrading the species categorisation, thereby allowing cultivation of the shrub, could lead to even greater benefits to South Africa.

The obvious negative and beneficial impacts of the shrub resulted in a unified agreement that *R. rubiginosa* is a conflict generating species. Only two of the twelve experts agreed with the 1b categorisation of *R. rubiginosa* with the majority being unsure or disagreeing with the categorisation. This is a clear indication that the categorisation of the shrub needs to be reconsidered. The details of the conflict are not well understood due to a lack of research. It is therefore, vital that research like this study and possible additional research, provide the

information required to reassess the categorisation of *R. rubiginosa,* potentially allowing for the cultivation and the expansion of the rosehip industry in South Africa.

5.2.2 *ROSA RUBIGINOSA'S* IMPACT ON LANDOWNERS

The impact *R. rubiginosa* has on landowners in infested *R. rubiginosa* areas showed to a large degree the negative impact the shrub has on South Africa. The shrub is identified as problematic in the highland grass biome in the Eastern Cape and Free State provinces of South Africa. However, the majority of the identified infested areas of South Africa were found to have low coverage, with only areas around Clarens in the Free State having areas with higher densities of the invasive shrub.

The shrub negatively impacts landowners in a number of ways with the most common impact being the choking of fence lines. In extremely infested areas *R. rubiginosa* can block the pathway for livestock to reach water sources. Clearing of *R. rubiginosa* is very important under these circumstances. The cost of clearing varied significantly between landowners. In half the areas surveyed in this study, no clearing was required. The cost of clearing that did occur ranged between R250 and R30 000 annually. Overall, the results show that the average amount spent on clearing per hectare was R4,07 annually. It is clear however that *R. rubiginosa* can require significant control in specific areas, such as parts of Clarens. Further research would need to be done to work out a monetary value for the total cost to landowners in South Africa.

The research identified that *R. rubiginosa* is only significantly invasive in marginal lands as cultivation processes and grazing of livestock outcompete the shrub. Therefore, if the correct farming practices are kept, landowners are not significantly impacted directly. There are several IAPs that are of far greater concern to the landowners surveyed in the study namely; *Robinia pseudoacacia,* Populus species, Rubus species, *Gleditsia triacanthos, Acacia mearnsii, Salix babylonica* and Pyracantha species. It was even found that *Seriphium plumosum* a native plant to South Africa provided more concern to the landowners than *R. rubiginosa*. This being said the shrub was identified as having an increased in spread over the years.

Landowners are slightly impacted by *R. rubiginosa.* However, it is not considered as a serious problem that is in desperate need of control or eradication. The plant is not currently being

controlled in any significant way and there is currently no funding going into the control or eradication of *R. rubiginosa*. This is due to limited government funding and the fact that the shrub is not impacting economic processes in a significant way. Therefore, there is a strong argument against the severity of the shrub's invasive categorisation. If the shrub's benefits are significant enough it would seem that the shrub is not invasive enough to completely disregard the conflict of interest that has arisen in recent years.

5.2.3 ROSEHIP COMPANIES AND THEIR ECONOMIC BENEFIT

The benefits associated with *R. rubiginosa* were assessed by looking at the rosehip market. *Rosa rubiginosa* does have alternative benefits such as being used for hedging and aesthetics but these benefits were not investigated as they were deemed to have little significance. The rosehip market in South Africa is almost entirely made up of *R. rubiginosa's* rosehips. The market is an oligopoly, consisting of four main companies, allowing the study to attempt to saturate the market.

The rosehip companies in South Africa sell the various constituents (shell, seed and oil) of the rosehips. All the hips are sauced from the wild. The majority of the company's sales are to overseas markets, as that is where the demand for rosehip products predominantly comes from. The quantity of rosehips supplied by the South African companies has grown significantly in recent years, from 1000 tons in 2007 to approximately 4600 tons in 2019. However, supply is all by saturated as there is limited wild harvest. The inability to cultivate *R. rubiginosa* is a significant limitation to market supply. The market in 2019 was calculated to have a turnover of approximately R153 million. However, companies within the market are expecting to see significant growth within the rosehip market and have plans to grow the market size to over 22 000 tons of rosehips processed annually in South Africa. To achieve this, supply will need to increase, with cultivation of *R. rubiginosa* being something the companies are very interested in. A downgrade in the invasive statues of *R. rubiginosa* would be needed in order to cultivate the shrub. The growth in the market and cultivation of *R. rubiginosa* would be highly beneficial to a number of stakeholders and would result in job creation. Growth in both employment and the economy are extremely vital to South Africa due to the high levels of unemployment and low GDP growth in the country.

5.2.4 COMPANY BENEFIT OF A HYPOTHETICAL DOWNGRADE OF *ROSA RUBIGINOSA*

The case study conducted with one of the rosehip producing companies to see how the company has managed working with the limitations of an invasive species and how the company would be impacted if the shrub was downgraded allowing for cultivation. The study found that the company had massive growth in the market over the last three years and are now at a point where supply is becoming an issue due to only being able to harvest in the wild. The company has looked to importing rosehips from overseas but this has not resulted in the profits required. The company is very interested in the idea of cultivation. However, with cultivation not being allowed in South Africa, if the shrub is not downgraded, they will have to look to neighbouring countries such as Swaziland where cultivation is not yet illegal. The company is currently supplied with 1500 tons of rosehip. The goal of the company is to increase supply to 20 000 tons. Cultivation would be required to reach this goal. The company would grow from a current annual turnover of R57 million to an estimated R760 million. Such growth would greatly benefit South Africa in terms of economic factors. The underlying question is how much environmental damage the shrub would create if cultivated.

Rosa rubiginosa is only significantly invasive in areas with a high number of frost. Therefore, the shrub is t entirely found in areas which experience over 100 annual frost days (figure 2.4). This indicates the need for cold temperatures in order for the shrub to spread. We are therefore able to see where the shrub could potentially spread. In terms of cultivation this leads to two schools of thought; cultivation could be allowed within frost zones in areas where the shrub is already known to be established and therefore is not a further significant environmental threat. Or cultivation could be legally allowed outside of high frost zones as there is a decreased chance of seed germination in these areas and therefore not a high invasive risk. In areas of fewer to no frost days, seed germination would need to be artificially induced or various other cultivation methods would need to be used.

A similar example is already currently implemented in South Africa. The regulations around *Oncorhynchus mykiss* (rainbow trout) in South Africa allow for the species to be in certain zones and not in others, following the acquisition of a permit (Woodford *et al*., 2017). The zones that the rainbow trout are permitted in is determined by research conducted by the South African National Biodiversity Institute (SANBI) and the South African Institute for

Aquatic Biodiversity (SAIAB). A similar technique could be implemented when categorising *R. rubiginosa,* allowing for the cultivation in certain areas that are not highly susceptible to the shrubs damaging characteristics and where the shrub causes a significant economic and biodiversity loss.

5.3 BROADER IMPACT OF THE RESEARCH

Historically, environmental economic studies have been used to show how biological control of IAPs is less costly than other forms of control (Grundy, 1989; McConnachie *et al.*, 2003; Born *et al.,* 2005; De Lange & van Wilgen, 2010). However, more recently the field of environmental economics has increasingly been used in South Africa to motivate for the management of one invasive species over another (Juliá *et al.*, 2007; Villamagna & Murphy, 2010; Humphrey *et al.*, 2019) or to motivate for continued funding or for the use of a particular control method (Maluleke, 2020). However, one area that has not received much attention in terms of economics is when a serious conflict-of-interest arises where one interest group views the plant as a weed while the other views it as a valued plant (Turpie, 2004; Zengeya *et al*., 2017). The field of environmental economics can play an important role in providing information to assist decision makers on how to proceed in these scenarios. In this study, the conflict generating species, *R. rubiginosa* is shown to have a significant economic benefit, while the cost does not seem to be as severe as originally believed.

The historical economic studies that have focused solely on the negative impacts associated with IAPs is of concern, as the negative connotation associated with IAPs may lead to an unconscious bias. This is seen in the types of research conducted around IAPs, as well as, the legislation and policy being implemented. Researchers and policy makers are very quick to label a non-native species as invasive due to its negative characteristics and often neglect to take into consideration the beneficial characteristics, effectively destroying or limiting any potential benefit before they are realised. However, this study shows that invasive species, such as *R. rubiginosa* have significant beneficial characteristics which seem to be neglected when categorising them. Additional benefits may also be discovered post the categorising of a species. Therefore, there may be other species under the NEM:BA that need their categorisation reconsidered from an unbiased view point. The committee that is tasked with listing IAS, need also to consider the beneficial potential of species. An economic assessment

would allow for a better understanding of whether species are categorised correctly. It would therefore be wise to conduct studies on various species which have clear economic benefits, in order to determine if it is categorised correctly.

Being able to downgrade or remove various beneficial species from the Alien and Invasive Species List could significantly benefit South Africa economically. To date, no IAP has been downgraded or removed from the NEM:BA list. The NEM:BA provides clear instructions as to how a species should be assessed to determine if they should be listed as invasive (NEM:BA, 2004). However, there is no process laid out in the NEM:BA to follow in order to downgrade an invasive species. The legislation may be too focused on listing and upgrading species and not flexible enough to allow for downward change. The Centre for Biological Control, a research centre at Rhodes University South Africa, have made a proposal to the Department of Environmental Affairs that *Azolla filiculoides* Lam. be removed from the NEM:BA list of restricted species on the basis that it is no longer a threat due to the successful biological control which has nullified the water weeds invasive potential (Hill, per comm, 2020). The suggestion was sent to authorities in 2018 but there has yet to be a decision. If *A. filiculoides* is removed from NEM:BA list, it will be the first invasive plant to be removed. Being able to change a species legislation once it has shown to have an incorrect categorisation could create industries and jobs resulting in GDP growth. Economic growth is very important to South Africa as unemployment and GDP growth are of great concern. It is therefore highly recommended that academics and professional in the invasive species field take more consideration of the potential benefits an invasive species possesses.

There are various risks to downgrading an invasive. If a species is downgraded or removed because it is believed to be under control, as in the case of *A. filiculoides*, and it turned out to be the wrong decision it would be relatively easy to reverse the change. However, if a species is downgraded for the purpose of its economic benefit and large million-rand companies are created which rely on the species, would it be so easy to reverse the change if the species started spreading excessively? *Acacia mearnsii* (black wattle) is an example of an invasive species that was categorised with the benefits the species possesses taken into account. It was therefore categorised to allow for cultivation, so as to create, what is now a relatively large black wattle industry in South Africa. However, it has become a bigger and bigger problem and potentially should be considered for an upgrade in its invasive status. Is a change

to black wattle a realistic possibility with there being a large industry attached? A change in the categorisation would result in job losses, many of whom are from low income households, and reduced economic growth.

This specific study has shown how a downgrade to *R. rubiginosa* would create a far larger rosehip industry which would significantly benefit South Africa. Experts and landowners were used to provide understanding of the negative impacts of *R. rubiginosa,* which indicated that the shrub was not as invasive as many other category 1b IAPs. However, it is vital that extensive ecological studies are conducted to understand the possible risks associated with the downgrade. Various questions need to be answered, such as, is the shrub outcompeting other plants, stealing pollinators, using extensive amounts of water and various others, before a major decision is made to downgrade the species. Once these impacts are understood a comparison can be made between the benefits and the costs and an educated decision can be made for the benefit of future South African generations.

In most cases with IAS the principle of guilty until proven innocent is taken. It makes sense that an invasive species is initially viewed this way as they pose a serious threat to non-native environments. However, in some cases the beneficial characteristics of a species are of such significance that the principle of innocent until proven guilty may be a better viewpoint. *Rosa rubiginosa* in South Africa is one such species that seemingly has great economic potential and minimal negative impacts. If more information comes to light depicting the shrubs invasive characteristics, processes and mechanisms can be put in place to protect the environment while still allowing for the beneficial rosehip market.

5.4 RECOMMENDATIONS FOR FUTURE RESEARCH

It would be beneficial to conduct further research that would saturate the market for rosehips allowing for an exact assessment of the market size and the benefit it has on the economy. It would also be highly beneficial to conduct a study to assess what the exact negative impacts of *R. rubiginosa* and the extent of their monetary impact. A risk analysis would be highly beneficial as no assessment has been done in South Africa. Having monetary values for both the benefits and costs associated with *R. rubiginosa* would allow for a cost:benefit analysis to be completed on the invasive shrub which would give a clear indication if the benefit of *R.*

rubiginosa outweighs the shrub's costs. A cost-benefit analysis would further aid in the reassessment of the shrubs invasive status.

A rather unique and fascinating aspect to the rosehip market in southern Africa is the informal market that is created. A socioeconomic study on the informal market, specifically in Lesotho where it is of significant size, would provide interesting insights into the livelihoods of the informal workers. Both Lesotho and South Africa have high unemployment rates and therefore the informal sector is seen as a very important aspect to the livelihoods of the poor as it provides them with an income the formal sector cannot provide. A number of stakeholders within the rosehip market have coined the phrase "guns and rosehip" when referring to the informal rosehip market in Lesotho, alluding to the complexities found within.

It is further recommended that an in-depth analysis comparing various other highland invasive species, found within South Africa, to *R. rubiginosa.* This could provide valuable information as to where the greatest externalities lie. Furthermore, it will aid in the legislative processes and the determination of where private and government funds are made available to help minimise negative economic consequences. Funds are very limited in South Africa and thus the economic valuation of such projects provide the necessary motivation for the allocation of the limited funds (Turpie, 2004). Economic evaluations of IAPs, such as cost:benefit analyses, help shape policy decision. Thus, economic evaluations are essential in determining the viability of a project and attracting potential investors.

The study could be added to by conducting an in-depth MAXENT analysis of *R. rubiginosa.* An analysis to show where the shrub has potential to spread would provide an understanding as to how much of the invasive range the shrub has covered. This will allow experts to know where the shrub could potentially be cultivated so as not to be an invasive risk. It will also allow an understanding of how great the potential spread of the shrub is.

5.5 CONCLUSION

Creating economic growth is of vital importance to South Africa. IAPs are often only seen as having negative externalities. However, IAPs are normally introduced for their perceived beneficial characteristics. A number of invasive alien species are conflict-generating and it therefore becomes the responsibility of experts to establish if the costs associated are too

great to allow for the use of the species benefits. *Rosa rubiginosa* L. is one such conflict-generating species in South Africa.

There is clear evidence that *R. rubiginosa* is invasive in areas which experience a large number of annual frost days. However, there is limited area in South Africa which experience the required climatic conditions, limiting the invasive potential of the shrub. The shrub has very limited impact on economic factors as the shrub does not have any significant impact even on farms within areas of high annual frost days. The shrub seems to only be significantly invasive within marginal land areas. Experts in the field of invasion biology showed that they were not convinced *R. rubiginosa* should be categorised as a 1b invasive species, highlighting the shrubs conflict of interest.

There is clear evidence of growth within the rosehip industry in South Africa. However, due to supply being limited to wild collected rosehips, the market is reaching saturation while the demand from overseas markets is still significantly larger than the current supply. It would be highly beneficial in terms of economic growth and job creation to downgrade *R. rubiginosa* to allow for cultivation and the expansion of the rosehip market. The rosehip market in South Africa has the potential to grow into a multi-billion-rand market, with one company looking to achieve an estimated annual turnover of R760 million if cultivation is permitted.

The finding within this research shows that the invasive species *R. rubiginosa* is not believed to be as invasive to South Africa as originally believed. The research also showed that the shrub is limited to specific regions of South Africa and that it has little impact on economic activities. The global market for the shrub's fruit (rosehips) has significantly grown in size over the last few years due to the discovery of various medicinal and cosmetic benefits. The South African suppliers of rosehips have thus increased their production and profits. However, the market has become saturated due to only being supplied by wild picked rosehips. The only way for the market in South Africa to expand is through cultivation which is only possible following a downgrade of *R. rubiginosa*. The expansion of the market in South Africa would benefit the struggling economy and provide a number of people with employment. As the market grows more opportunities will be created within the rosehip market in South Africa.

Based on the information currently available surrounding *R. rubiginosa* in South Africa, it is suggested that *R. rubiginosa* should be downgraded working on the principle of innocent until

proven guilty, rather than guilty until proven innocent principle. Therefore, it is suggested that *R. rubiginosa* should be removed from the Alien and Invasive Species List of South Africa or downgraded allowing for the cultivation of the economically beneficial shrub. If further research proves that the shrub is more invasive than believed, the required actions can be put in place in order to protect the environment while still allowing for the beneficial rosehip market.

REFERENCES

AGUIRRE, G., LOZA, M., GASQUEZ, J., FUSCO, M., SOSA, A., CIUFFO, G., & CIUFFO, L. (2016). The Potentiality of Non Timber Forest Products. Fruit Availability, Phytochemical Properties of *Rosa rubiginosa* L. Rose Hips. *American Journal of Plant Sciences*, 07(15): 2272–2287.

AKHTAR, N., & HAQQI, T. M. (2012). Current nutraceuticals in the management of osteoarthritis: A review. *Therapeutic Advances in Musculoskeletal Disease*, 4(3): 181–207.

ALLISON, S. D., & VITOUSEK, P. M. (2004). Rapid nutrient cycling in leaf litter from invasive plants in Hawai'i. *Oecologia*, 141(4): 612–619.

ALLRED, S. B., & ROSS-DAVIS, A., (2011). The drop-off and pick-up method: an approach to reduce nonresponse bias in natural resource surveys. *Small-Scale Forestry*, 10: 305-318.

ANDREO, V., NETELER, M., ROCCHINI, D., PROVENSAL, C., LEVIS, S., PORCASI, X., POLOP, J. (2014). Estimating hantavirus risk in Southern Argentina: A GIS-based approach combining human cases and host distribution. *Viruses*, 6(1): 201–222.

ASHMEAD, W. (2011). On the Cynipidous Galls of Florida , with Descriptions of New Species and Synopses of the Described Species of North America. *Transactions of the American Entomological Society and Proceedings of the Entomological Section of the Academy of Natural Science*, 14(1887): 125–158.

BAKER, H. G. (1967). Support for Baker's Law – As a rule. *Evolution,* 21(4): 853-856.

BAKER, H. G. (1955). Self-compatibility and establishment after 'long-distance' dispersal. *Evolution,* 9(3): 347-349.

BANGSUND, D A, LEISTRITZ, F. L., & LEITCH, J. A. (1999). Assessing economic impacts of biological control of weeds: The case of leafy spurge in the northern Great Plains of the United States. *Journal of Environmental Management*, 56: 35–43.

BANGSUND, DEAN A, & LEISTRITZ, F. L. (1991). Economic impacts of leafy spurge on grazing lands in the northern Great Plains. NDSU Agriculture Economic Report.

BARRY, R., SANDERSON, K., & FILLMORE, S. (2008). Establishment of wild roses for commercial rose hip production in Atlantic Canada. *International Journal of Fruit Science*, 8(4): 266–281.

BOOTH, T. H., NIX, H. A., BUSBY, J. R., & HUTCHINSON, M. F. (2014). Bioclim: The first species distribution modelling package, its early applications and relevance to most current MaxEnt studies. *Diversity and Distributions*, 20(1): 1–9.

BORN, W., RAUSCHMAYER, F., & BRÄUER, I. (2005). Economic evaluation of biological invasions - A survey. *Ecological Economics*, 55(3): 321–336.

BROOKS, M. L., D'ANTONIO, C. M., RICHARDSON, D. M., GRACE, J. B., KEELEY, J. E., DiTOMASO, J. M., HOBBS, R.J., PELLANT, M., & PYKE, D. (2004). Effects of Invasive Alien Plants on Fire Regimes. *BioScience*, 54(7): 677-688.

BRUUN, H. H. (2006). Prospects for biocontrol of invasive Rosa rugosa. *BioControl*. 51: 141-181.

CARBUTT, C. (2012). The emerging invasive alien plants of the Drakensberg Alpine Centre, southern Africa. *Bothalia*, 85: 71–85.

CENSKOWSKY, U., HELBERG, U., NOWACK, A., & STEIDLE, M. (2007). Overview of World Production and Marketing of Organic Wild Collected Products. *International Trade Centre*, 1–96.

CHAMIER, J., SCHACHTSCHNEIDER, K., LE MAITRE, D. C., ASHTON, P. J., & VAN WILGEN, B. W. (2012). Impacts of invasive alien plants on water quality, with particular emphasis on South Africa. *Water SA*, 38(2): 345–356.

CHENGZHANG, L., RONGHAO, P., YIQI, L., XUHUI, Z., XIAOWEN, W., CHANGMING, F., JIAKUAN, C., & BO, L. (2007). Altered ecosystem carbon and nitrogen cycles by plant invasion: a meta-analysis. *New Phytologist*, 177(3): 706–714.

COHEN, M. (2012). Rosehip: An evidence based herbal medicine for inflammation and arthritis. *Australian Family Physician*, 41(7): 495–498.

CORORATON, C. B., ORDEN, D., & PETERSON, E. (2009). A review of literature on the economics of invasive species, (September), 1-57.

COSTANZA, R., DE GROOT, R., SUTTON, P., VAN DER PLOEG, S., ANDERSON, S. J., KUBISZEWSKI, I., FARBER, S., & TURNER, R. K. (2014). Changes in the global value of ecosystem services. *Global Environmental Change*, 26(1) : 152–158.

CULLINEY, T. (2005). Benefits of Classical Biological Control for Managing Invasive Plants. *Critical Reviews in Plant Sciences*, 24(2): 131–150.

CURTIS, A. N., & BIDART, M. G. (2017). Effects of chemical management for invasive plants on the performance of Lithobates pipiens tadpoles. *Environmental Toxicology and Chemistry*, 36(11): 2958–2964.

DASSONVILLE, N., VANDERHOEVEN, S., VANPARYS, V., HAYEZ, M., MEERTS, P. (2008). Impacts of alien invasive plants on soil nutrients are correlated with initial site conditions in NW Europe. *Oecologia*, 157(1): 131–140.

DE LANGE, W. J., & VAN WILGEN, B. W. (2010). An economic assessment of the contribution of biological control to the management of invasive alien plants and to the protection of ecosystem services in South Africa. *Biological Invasions*, 12(12): 4113–4124.

DE PIETRI, D. E. (1992). Alien shrubs in a national park: can they help in the recovery of natural degraded forest? *Biological Conservation*, 62(2), 127–130.

DE WIT, M. P., CROOKES, D. J., & VAN WILGEN, B. W. (2001). Conflicts of interest in environmental management: estimating the costs and benefits of a tree invasion. *Biological Invasions*, 3: 167–178.

DEPARTMENT OF TRADE AND INDUSTRY (2012). Cosmetic Sector Desk. [Online]. Accessed: https://www.thedti.gov.za/industrial_development/cosmetics.jsp [Acessed 27 May 2019]

DILLMAN, D. A., (2016). Moving survey methodology forward in our rapidly changing world: A commentary. *Journal of Rural Social Sciences,* 31(3): 160-174.

DWA (Department of Water Affairs) (2011). Water Resource Planning Systems: Water Quality Planning. Resource Directed Management of Water Quality. Planning Level Review of Water Quality in South Africa. Department of Water Affairs, Pretoria, South Africa.

DYE, P. & JARMAIN, C. (2004). Water use by black wattle (Acacia mearnsii): implications for the link between removal of invading trees and catchment streamflow response: working for water. *South African Journal of Science*, 100(1 & 2): 40-44.

EAGLE, A. J., EISWERTH, M. E., JOHNSON, W. S., SCHOENIG, S. E., & CORNELIS VAN KOOTENS, G. (2007). Society for Range Management Costs and Losses Imposed on California Ranchers by Yellow Starthistle Costs and Losses Imposed on California Ranchers by Yellow Starthistle. *Rangeland Ecology & Management*, 6021(4): 369-377.

EARLY, R., BRADLEY, B. A., DUKES, J. S., LAWLER, J. J., OLDEN, J. D., BLUMENTHAL, D. M., GONZALEZ, P., GROSHOLZ, E., IBANEZ, I., MILLER, L. P., SORTE, C. J. B., & TATEM, A. J. (2016). Global threats from invasive alien species in the twenty-first century and national response capacities. *Nature Communications*, 7: 1–8.

EARTHOIL. (2017). Rosehip. [Online]. Accessed: https://www.earthoil.com/grower-projects/rosehip [Accessed 11 May 2018].

EHRENFELD, J. G. (2003). Effects of Exotic Plant Invasions on Soil Nutrient Cycling Processes. *Ecosystems*, 6(6): 503–523.

EPSTEIN, A. H., & HILL, J. H. (1999). Status of Rose Rosette Disease as a Biologcial Control for Multiflora Rose. *The American Phytopathological Society*, 83(2): 92–101.

ESPINOZA, T., VALENCIA, E., QUEVEDO, R., & DIAZ, 0. (2016). Physical and chemical properties importance of rose hip (*R. canina, R. rubiginosa*): A review. *Scientia Agropecuaria,* 7: 67-78.

FINDLAY, R., & O'ROURKE, K. (2007). Power and Plenty. Princeton University Press.

FORSETH, I. N., & INNIS, A. F. (2004). Kudzu (Pueraria montana): History, physiology, and ecology combine to make a major ecosystem threat. *Critical Reviews in Plant Sciences*, 23(5): 401–413.

FRANCO, D., PINELO, M., SINEIRO, J., & NÚÑEZ, M. J. (2007). Processing of Rosa rubiginosa: Extraction of oil and antioxidant substances. *Bioresource Technology*. 98: 3506-3512.

FRASER, G. C. G., HILL, M. P., & MARTIN, J. A. (2016). Economic evaluation of water loss saving due to the biological control of water hyacinth at New Year's Dam , Eastern Cape province , South Africa. *African Journal of Aquatic Science*, 41(2): 227–234.

GORDON, D. 2001. CRONK, Q. C. B., & J. L. FULLER. 2001. Plant invaders: the threat to natural ecosystems. Earthscan Publications, London, UK. *Conservation Ecology* 5(2): 3. [online] URL: http://www.consecol.org/vol5/iss2/art3/

GORDON, D. R. (1998). Effects of invasive, non-indigenous plant species on ecosystem processes: Lessons from Florida. *Ecological Applications*, 8(4): 975–989.

GORGENS A and VAN WILGEN B. (2004). Invasive alien plants and water resources in South Africa: current understanding, predictive ability and research challenges. *South Africa Journal of Science* 100: 27-33.

GREN, I. M. (2008). Economics of alien invasive species management - Choices of targets and policies. *Boreal Environment Research*, 13: 17–32.

GRUNDY, T. P. (1989). An economic evaluation of biological control of Hieracium, (202), 1-41.

GRUNDY, T. P., Bushnell, P. G., & Clarke, R. T. J. (1989). An economic evaluation of biological control of sweet briar. 1-37.

GUJARATI, D.N. (2009). Basic econometrics. Tata McGraw-Hill education, New Delhi

HAO, J.H., QIANG, S., CHROBOCK, T., VAN KLEUUEN, M., & LIU, Q. Q. (2011). A test of baker's law: breeding systems of invasive species of Asteraceae in China. *Biol Invasions,* 13: 571-580.

HENDERSON, L. (1991). Invasive alien woody plants of the Orange Free State. *Bothalia*, 21(2): 73–89.

HENDERSON, L. (1992). Invasive alien woody plants of the Eastern Cape. *Bothalia*, 21(2): 119–143.

HENDERSON, L. (1998). South African Plant Invaders Atlas (SAPIA). *Appl. Plant Sci.* 12: 31-32.

HENDERSON, L. (2001). Alien Weeds and Invasive Plants. Cape Town: Paarl Printers.

HENDERSON, L. (2007). Invasive, naturalized and casual alien plants in southern Africa: a summary based on the Southern African Plant Invaders Atlas (SAPIA). *Bothalia*, 248(37.2): 215–248.

HENDERSON, LESLEY. (2011). Rubus species - brambles, blackberries and others. SAPIA News, (19), 1–9.

HIGHT, S. D., CARPENTER, J. E., BLOEM, K. A., BLOEM, S., PEMBERTON, R. W., & STILING, P. (2002). Expanding Geographical Range of Cactoblastis Cactorum (Lepidoptera: Pyralidae) in North America. *Florida Entomologist*, 85(3): 527–529.

HIJMANS, R. J., CAMERON, S. E., PARRA, J. L., JONES, P. G., & JARVIS, A. (2005). Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology*, 25(15): 1965–1978.

HILL, M. P., & COETZEE, J. (2017). The biological control of aquatic weeds in South Africa: Current status and future challenges. *Bothalia*, 47(2): 1–12.

HILLS, S., (2008). Rosehip extract developed for new product opportunities. *Food navigator.com.* [Online]. Accessed https://www.foodnavigator.com/Article/2008/11/27/Rosehip-extract-developed-for-new-product-opportunities [Accessed 10 Feb 2019].

HILLIER, A., CANNUSCIO, C. C., GRIFFIN, L., THOMAS, N., & GLANZ, K., (2014). The value of conducting door-to-door surveys. *International Journal of Social Research Methodology,* 17(3): 285-302.

HIRSCH, H., ZIMMERMANN, H., RITZ, C. M., WISSEMANN, V., VON WEHRDEN, H., RENISON, D., WESCHE, K., WELK, E., & HENSEN, I. (2011). Tracking the Origin of Invasive Rosa rubiginosa Populations in Argentina. *International Journal of Plant Sciences*, 172(4): 530–540.

HOLGATE, G. (1987). Sweet brier control with goats. Proceedings of the New Zealand Grassland Association, 161(May 1984): 157–161.

HOWELL, C. (2008). Consolidated list of environmental weeds in New Zealand. Science & Technical Publishing.

HUGHES, R. F., ARCHER, S. R., ASNER, G. P., WESSMAN, C. A., MCMURTRY, C., NELSON, J., & ANSLEY, R. J. (2006). Changes in aboveground primary production and carbon and nitrogen pools accompanying woody plant encroachment in a temperate savanna. *Global Change Biology*, 12(9): 1733–1747.

HULME, P. E. (2009). Trade, transport and trouble: Managing invasive species pathways in an era of globalization. *Journal of Applied Ecology*, 46(1): 10–18.

HUMPHREY, L., FRASER, G., & MARTIN, G. (2019). The Economic Implications of Robinia pseudoacacia L. (black locust) on Agricultural Production in South Africa. *Agrekon*, 58(2): 216–228.

HUNTER, I. (2014). Declared Plant Policy under the Natural Resources Management Act 2004.

ICWE (1992). The Dublin Statement and Report of the Conference. International Conference on Water and the Environment: Development issues for the 21st century, Dublin.

IMPSON, F. A. C., KLEINJAN, C. A., HOFFMANN, J. H., POST, J. A., & WOOD, A. R. (2011). Biological Control of Australian Acacia Species and Paraserianthes lophantha (Willd.) Nielsen (Mimosaceae) in South Africa. *African Entomology*, 19(2): 186–207.

ISRAEL, G. D., & LAMM, A. J. (2012). Item non-response in a client survey of the general public. *Survey practice,* 5(2): 1-6.

JANAKIRAM, T., & DEBNER, T. (2008). Variability in hip characters in Rosa species. *J. Hortl. Sci,* 3(2): 169–171.

JENSEN, R. (2012). Economic policy for invasive species. Working paper 007, University of Notre Dame, Department of Economics.

JIMÉNEZ-LÓPEZ, J., RUIZ-MEDINA, A., ORTEGA-BARRALES, P., & LLORENT-MARTÍNEZ, E. J. (2017). Rosa rubiginosa and Fraxinus oxycarpa herbal teas: characterization of phytochemical profiles by liquid chromatography-mass spectrometry, and evaluation of the antioxidant activity. *New J. Chem*., 41(15): 7681–7688.

JO, I., FRIDLEY, J. D., & FRANK, D. A. (2017). Invasive plants accelerate nitrogen cycling: evidence from experimental woody monocultures. *Journal of Ecology*, 105(4): 1105–1110.

JOHNSON, D. M., & STILING, P. D. (1998). Distribution and Dispersal of Cactoblastis cactorum (Lepidoptera : Pyralidae), an Exotic Opuntia-Feeding Moth , in Florida. *The Florida Entomologist*, 81(1): 12–22.

JOUBLAN, J. P., & RIOS, D. (2005). Rose Culture and Industry in Chile. *In Acta Horticulture,* 65–70.

JULIÁ, R., HOLLAND, D. W., & GUENTHNER, J. (2007). Assessing the economic impact of invasive species: The case of yellow starthistle (Centaurea solsitialis L.) in the rangelands of Idaho, USA. *Journal of Environmental Management*, 85(4): 876–882.

KETTENRING, K. M., & ADAMS, C. R. (2011). Lessons learned from invasive plant control experiments: A systematic review and meta-analysis. *Journal of Applied Ecology*, 48(4): 970–979.

KHARAZMI, A., & WINTHER, K. (1999). Rose hip inhibits chemotaxis and chemiluminescence of human peripheral blood neutrophils in vitro and reduces certain inflammatory parameter in vivo. *Inflammopharmacology*, 7: 377-386.

KISSEL, R. M., BASTOW WILSON, J., BANNISTER, P., & MARK, A. F. (2018). Water Relations of some Native and Exotic Shrubs of New Zealand. *The New Phytologist*, 107(1): 29–37.

LARSEN, E., KHARAZMI, A., CHRISTENSEN, L. P., & CHRISTENSEN, S. B. (2003). An antiinflammatory galactolipid from rose hip (Rosa canina) that inhibits chemotaxis of

human peripheral blood neutrophils in vitro. *Journal of Natural Products*, 66(7): 994–995.

LE MAITRE D, VAN WILGEN B, CHAPMAN R and MCKELLY D. (1996). Invasive plants and water resources in the Western Cape province, South Africa: Modelling the Consequences of a lack of management. *British Ecological Society* 33(1): 161-172.

LE MAITRE D, VERSFELD D and CHAPMAN R. (2000). The impact of invading alien plants on surface water resources in South Africa: A preliminary assessment. *Water SA* 26(3): 397-407.

LE MAITRE, D. C., VERSFELD, D., & CHAPMAN, R. (2000). The impact of invading alien plants on surface water resources in South Africa: a preliminary assessment. *Water SA*, 26(3): 397–408.

LE MAITRE, D., FORSYTH, G. G., DZIKITI, S., & GUSH, M. B. (2016). Estimates of the impacts of invasive alien plants on water flows in South Africa. *Water SA*, 42(4): 659–672.

LESSER, V. M., YANG, D. K., NEWTON, L. D. (2011). Assessing Hunters' opinions based on a mail and a mixed-mode survey. *Human Dimensions of Wildlife*, 16(3): 164-173.

MALAN H and DAY J. (2002). Linking Discharge, Water Quality and Biotic Response in Rivers: a Literature Review. WRC Report No. 956/2/02. Water Research Commission, Pretoria.

MALULEKE, M. (2020). Evaluating the cost-effectiveness of control on selected aquatic weeds in South Africa. Unpublished M Com thesis, Rhodes University, Grahamstown.

MARAIS C, and WANNENBURGH A. (2008). Restoration of water resources (natural capital) through the clearing of invasive alien plants from riparian areas in South Africa – cost and water benefits. *South African Journal of Botany,* 74: 526-537.

MARBUAH, G., GREN, I. M., & MCKIE, B. (2014). Economics of Harmful Invasive Species: A Review. *Diversity*, 6(3): 500–523.

MÁRMOL, I., SÁNCHEZ-DE-DIEGO, C., JIMÉNEZ-MORENO, N., ANCÍN-AZPILICUETA, C., & RODRÍGUEZ-YOLDI, M. (2017). Therapeutic applications of rose hips from different Rosa species. *International Journal of Molecular Sciences*, 18(6): 1–37.

MASTERS, G., & NORGROVE, L. (2010). Climate Change and Invasive Alien Species. CABI Working Paper 1, 30.

MAZZOLARI, A. C., MARRERO, H. J., & VÁZQUEZ, D. P. (2017). Potential contribution to the invasion process of different reproductive strategies of two invasive roses. *Biological Invasions*, 19(2): 615–623.

MCCONNACHIE, A. J., DE WIT, M. P., HILL, M. P., & BYRNE, M. J. (2003). Economic evaluation of the successful biological control of *Azolla filiculoides* in South Africa. *Biological Control*, 28(1): 25–32.

MCGEOCH, M. A., BUTCHART, S. H. M., SPEAR, D., MARAIS, E., KLEYNHANS, E. J., SYMES, A., CHANSON, J., & HOFFMANN, M. (2010). Global indicators of biological invasion: Species numbers, biodiversity impact and policy responses. Diversity and Distributions, 16(1): 95–108.

MCNEELY, J.A. 2000. The future of alien invasive species: changing social views. In Invasive species in a changing world. Edited by H.A. Mooney and R.J. Hobbs. Island Press, Washington, D.C. pp. 171–190

MOLLOY, B. (1976). An analysis of sweet briar on Molesworth. In the Changing Vegetation of Molesworth Station, New Zealand, 1944 to 1971. (DSIR Bulletin 217) (ed. L.B. Moore), pp. 90-110. Department of Scientific and Industrial Research, Wellington.

MOODLEY, D., GEERTS, S., RICHARDSON, D., & WILSON, J. R. U. (2016). The importance of pollinators and autonomous self-fertilisation in the early stages of plant invasions: Banksia and Hakea (Proteaceae) as case studies. *Plant Biology*, 18(1): 124–131.

MORAN, V. C., HOFFMANN, J. H., & ZIMMERMANN, H. G. (2013). 100 years of biological control of invasive alien plants in South Africa: History, practice and achievements. *South African Journal of Science*, 109(9): 1–6.

MOURE, A., SINEIRO, J., & DOMÍNGUEZ, H. (2001). Extraction and functionality of membrane-concentrated protein from defatted Rosa rubiginosa seeds. *Food Chemistry*, 74: 327-339

NEM:BA. (2004). National Environmental Management Biodiversity Act. Department of Environmental Affairs: Pretoria

NOWAK, R. (2005). Fatty acids composition in fruits of wild rose species. *Acta Societatis Botanicorum Poloniae*, 74(3): 229–235.

PEJCHAR, L., & MOONEY, H. (2009). Invasive species, ecosystem services and human well-being. *Trends in Ecology and Evolution*, 24(9): 497–504.

PERRINGS, C., WILLIAMSON, M., BARBIER, E., DELFINO, D., SILVANA, D., SHOGREN, J., SIMMONS, P., & WATKINSON, A. (2002). Biological invasion risks and the public good: an economic perspective. *Conservation Ecology*, 6(1): 1-7.

PHILLIPS, C. J., MARDEN, M., LAMBIE, S., WATSON, A., ROSS, C., & FRASER, S. (2013). Observations of below-ground characteristics of young redwood trees (Sequoia sempervirens) from two sites in New Zealand - implications for erosion control. *Plant and Soil*, 363(1–2): 33–48.

PIMENTEL, D., MCNAIR, S., JANECKA, J., WIGHTMAN, J., SIMMONDS, C., O'CONNELL, C., WONG, E., RUSSEL, L., ZERN, J., AQUINO., & TSOMONDO, T. (2001). Economic and environmental threats of alien plant, animal, and microbe invasions. *Agriculture, Ecosystems and Environment*, 84: 1–20.

PIMENTEL, D., ZUNIGA, R., & MORRISON, D. (2005). Update on the environmental and economic costs associated with alien-invasive species in the United States. *Ecological Economics*, 52: 273-288.

POONA, N. (2008). Invasive alien plant species in South Africa: impacts and management options. *Alternation,* 15(1): 160-179.

POPAY, I., & FIELD, R. (1992). Grazing animals as biological control agents.

PRATER, M. R., OBRIST, D., ARNONE, J. A., & DELUCIA, E. H. (2006). Net carbon exchange and evapotranspiration in postfire and intact sagebrush communities in the Great Basin. *Oecologia*, 146(4): 595–607.

PRESCHA, A., GRAJZER, M., DEDYK, M., & GRAJETA, H. (2014). The antioxidant activity and oxidative stability of cold-pressed oils. *Journal of the American Oil Chemists' Society*, 91(8): 1291–1301.

PRESTON, C. D., PEARMAN, D. A., & HALL, A. R. (2004). Archaeophytes in Britain. *Botanical Journal of the Linnean Society*, 145(3): 257–294.

RAMOS, P. M., RAMOS, P. M., GIL, J. M., SÁNCHEZ, M. C. R., GRACIA, M. N., NAVARRO, S. H., & GIL, J. M. (2016). Vibrational and Thermal Characterization of Seed, Pulp, Leaves and Seed Oil of Rosa Rubiginosa. *Boletín de La Sociedad Argentina de Botánica*, 51(3) : 429–439.

REIN, E; KHARAZMI, A; WINTHER, K. (2004). A herbal remedy, hyben vital (stand. Powder of a subspecies of Rosa canina fruits), reduces pain and improves general wellbeing in patients with osteoarthritis – a double-blind, placebo controlled, randomised trial. *Phytomedicine*. 11: 383-391.

RICHARDSON, D. M., & REJMÁNEK, M. (2011). Trees and shrubs as invasive alien species - a global review. *Diversity and Distributions*, 17(5): 788–809.

Richardson, D. M., PYSEK, P., Rejmánek, M., Barbour, M. G., Panetta, F. D., & West, C. J. (2000). Naturalization and invasion of alien plants: concepts and definitions. *Diversity and Distributions,* 6: 93–107.

RICHARDSON, D., & VAN WILGEN, B. W. (2004). Invasive alien plants in South Africa: How well do we understand the ecological impacts? *South African Journal of Science*, 100(1–2): 45–52.

RICHARDSON, D., MORAN, V. C., LE MAITRE, D. C., ROUGET, M., & FOXCROFT, L. C. (2004). Recent developments in the science and management of invasive alien plants : connecting the dots of research knowledge, and linking disciplinary boxes : working for water. *South African Journal of Science*, 100(1 & 2): 126-128.

ROGERS P, DE SILVA R and BHATIA R. (2002). Water is an economic good: How to use prices to promote equity, efficiency, and sustainability. *Water Policy* 4: 1-17.

SERBESOFF-KING, K. (2003). Melaleuca in Florida: A literature review on the taxonomy, distribution, biology, ecology, economic importance and control measures. *Journal of Aquatic Plant Management*, 41: 98–112.

SCHULZE, R. E. (1997). South African atlas of agrohydrology and climatology. Report TT82/96, *Water Research Commission*. Pretoria.

SIGER, A., NOGALA-KALUCKA, M., & LAMPART-SZCZAPA, E. (2008). The content and antioxidant activity of phenolic compounds in cold-pressed plant oils. *Journal of Food Lipids,* 15(2): 137-149.

SIMONSEN, T. J., BROWN, R. L., & SPERLING, F. A. H. (2008). Tracing an invasion: Phylogeography of Cactoblastiscactorum (Lepidoptera: Pyralidae) in the United States based on mitochondrial DNA. *Annals of the Entomological Society of America*, 101(5): 899–905.

SMITH H, SHERIDAN G, LANE P, SNYMAN P and HAYDON S. (2011). Wild fire effects on water quality in forest catchments: A review with implications for water supply. *J. Hydrol*., 396(1-2): 170-192.

SMITH, A. L., HEWITT, N., KLENK, N., BAZELY, D. R., YAN, N., WOOD, S., … LIPSIG-MUMMÉ, C. (2012). Effects of climate change on the distribution of invasive alien species in Canada: a knowledge synthesis of range change projections in a warming world. *Environmental Reviews*, 20(1): 1–16.

SMULDERS, M. ARENS, P. KONING-BOUCOIRAN, C. GITONGA, V. KRENS, F. ATANASSOV, A. ATANASSOV, I. RUSANOV, K. BENDAHMANE, M. DUBOIS, A. RAYMOND, O. CAISSARD, J. BAUDINO, S. CRESPEL, L. GUDIN, S. RICCI, S. KOVATCHEVA, N. VAN HUYLENDROECK, J. LEUS, L. WISSEMANN, V. ZIMMERMANN, H. HENSEN, I. WERLEMARK, G. & NYBOM, H. (2011). Rosa. In: Kole C. (eds) Wild crop relatives: genomic and breeding resources. Springer, Berlin, Heidelberg.

SMYTH, J. D., DILLMAN, D. A., CHRISTIAN, L. M., & O'NEILL, A. C. (2010). Using the internet to survey small towns and communities: Limitations and possibilities in the early 21st century. *American Behavioural Scientist*, 53(9): 1423-1448.

SNYMAN, H. A. (2009). Germination potential of Seriphium plumosum (bankrupt bush, slangbos or vaalbos). *Grassroots*, 9(1): 43–48.

SOUTHERN AFRICAN PLANT INVADERS ATLAS (SAPIA). (2019). database, Plant Protection and Research Institute, Agricultural Research Council. [Online]. Accessed: http://www. agis.agric.za/agisweb/agis.html

SPEAR, D., MCGEOCH, M. A., FOXCROFT, L. C., & BEZUIDENHOUT, H. (2011). Alien species in South Africa's national parks. *Koedoe*, 53(1).

STATISTA (2019). Annual growth of the global cosmetics market from 2004 to 2018*. [Online]. Accessed: https://www.statista.com/statistics/297070/growth-rate-of-the-global-cosmetics-market/ [Accessed 27 May 2019].

STRIK, B. C., CLARK, J. R., FINN, C. E., & BAN, M. P. (2007). Comprehensive Crop Reports Worldwide Blackberry Production. *HortTechnology*, 17(2): 205–213.

SYRETT, P. HILL, R. & JESSEP, C. (1985). Conflict of interest in Biological Control of Weeds in New Zealand. *Entomology department, DSIR, Christchurch, New Zealand*. 391-397.

THE WORLD BANK. (2018). Unemployment, total (% of total labor force) (modelled ILO estimate). [Online].Accessed: https://data.worldbank.org/indicator/SL.UEM.TOTL.ZS?end=2018&locations=ZA&most_recent_value_desc=true&start=1991&view=chart [Accessed 22 July 2019].

TURPIE, J. (2004). The role of resource economics in the control of invasive alien plants in South Africa. *South African Journal of Science*, 100: 87–93.

TURPIE, J. K., MARAIS, C., & BLIGNAUT, J. N. (2008). The working for water programme: Evolution of a payments for ecosystem services mechanism that addresses both poverty and ecosystem service delivery in South Africa. *Ecological Economics*, 65(4): 788–798.

VAN DER BERG, N. (2014). The Informal Economy : A literature review.

VAN DER ZAAG P and SAVENIJE H. (2006). Water as an economic good: the value of pricing and the failure of markets. *Institute for water education.* 7-23.

VAN WILGEN, B W, DE WIT, M. P., ANDERSON, H. J., LE MAITRE, D. C., KOTZE, I. M., NDALA, S., BROWN, B., RAPHOLO, M. B. (2004). Costs and benefits of biological control of invasive alien plants: case studies from South Africa. *South African Journal of Science*, 100: 113–122.

VAN WILGEN, B., RICHARDSON, D., & HIGGINS, S. (2001). Integrated control of invasive alien plants in terrestrial ecosystems. *Land Use and Water Resources Research*, 1(5): 1–6.

VAN WILGEN, BRIAN W, WILSON, J. R. U., FAULKNER, K., MORAPI, T., MNIKATHI, Z., MUNYAI, T., & RAHLAO, S. (2017). The status of biological invasions and their management in South Africa in 2017 Draft for review only.

VAN WILGEN, BRIAN W., & RICHARDSON, D. (2014). Challenges and trade-offs in the management of invasive alien trees. *Biological Invasions*, 16(3): 721–734.

VAN WILGEN, BRIAN W., FORSYTH, G. G., LE MAITRE, D. C., WANNENBURGH, A., KOTZÉ, J. D. F., VAN DEN BERG, E., & HENDERSON, L. (2012). An assessment of the effectiveness of a large, national-scale invasive alien plant control strategy in South Africa. *Biological Conservation*, 148(1): 28–38.

VAN WILGEN, BRIAN W., RICHARDSON, D., LE MAITRE, D. C., MARAIS, C., & MAGADLELA, D. (2001). THE ECONOMIC CONSEQUENCES OF ALIEN PLANT INVASIONS: EXAMPLES OF IMPACTS AND APPROACHES TO SUSTAINABLE MANAGEMENT IN SOUTH AFRICA. *Environment, Development and Sustainability*, 3, 145–168.

VENTER, C. (2019). Wool and mohair farmers at the Lesotho crossroads. *FarmBiz*, 5(4): 10-11

VILLAMAGNA, A. M., & MURPHY, B. R. (2010). Ecological and socio-economic impacts of invasive water hyacinth (Eichhornia crassipes): A review. *Freshwater Biology*, 55(2): 282–298.

WALLACE, K. J. (2007). Classification of ecosystem services: Problems and solutions. *Biological Conservation*, 139(3–4): 235–246.

WANG, C., XIAO, H., LIU, J., WANG, L., & DU, D. (2015). Insights into Ecological Effects of Invasive Plants on Soil Nitrogen Cycles. *American Journal of Plant Sciences*, 06(01): 34–46.

WARD, M., JOHNSON, S. D., & ZALUCKI, M. P. (2012). Modes of reproduction in three invasive milkweeds are consistent with Baker's Rule. *Biol Invasions,* 14: 1237-1250.

WARHOLM, O; SKAAR, S; HEDMAN, E; MOLMEN, H; EIK, L. (2003). The effects of a standardized herbal remedy made from a subtype of Rosa canina in patients with osteoarthritis: A double-blind, randomized, placebo-controlled clinical trial. *Curr. Ther*. Res. 64: 21-31.

WESTPHAL, M.I., BROWNE, M., MACKINNON, K., & NOBLE, I. (2008), The link between international trade and the global distribution of invasive alien species. *Biol Invasions,* 10: 391-398.

WILLSON, A. (1984). Managing mountain veld for water. *Veld & Flora*, 35-38.

WILLICH, S. N., ROSSNAGEL, K., ROLL, S., WAGNER, A., MUNE, O., ERLENDSON, J., KHARAZMI, A., SORENSEN, H., & WINTHER, K. (2010). Rose hip herbal remedy in patients with rheumatoid arthritis – a randomised controlled trial. *Phytomedicine*, 17: 87-93.

WINDHAM, M., WINDHAM, A., HALE, F., & AMRINE, J. (2014). Observations on Rose Rosette Disease. *American Rose*, 1–10.

WINTHER, K., APEL, K., & THAMSBORG, G. (2005). A powder made from seeds and shells of a rose-hip subspecies (Rosa canina) reduces symptoms of knee and hip osteoarthritis: a randomized, double-blind, placebo-controlled clinical trial. *Scand J Rheumatol*, 34: 302–308.

WISE, R. M., VAN WILGEN, B. W., & LE MAITRE, D. C. (2012). Costs, benefits and management options for an invasive alien tree species: The case of mesquite in the Northern Cape, South Africa. *Journal of Arid Environments*, 84: 80-90.

WITT, A. B. R., KIAMBI, S., BEALE, T., & VAN WILGEN, B. W. (2017). A preliminary assessment of the extent and potential impacts of alien plant invasions in the Serengeti-Mara ecosystem, East Africa. *Koedoe*, 59(1): 1–16.

WOODFORD, D. J., IVEY, P., JORDAAN, M. S., KIMBERG, P. K., ZENGEYA, T., & WEYL, O. L. F. (2017). Optimising invasive fish management in the context of invasive species legislation in South Africa. *Bothalia*, 47(2): 1–9.

ZENGEYA, T., IVEY, P., WOODFORD, D. J., WEYL, O., NOVOA, A., SHACKLETON, R., RICHARDSON, D., & VAN WILGEN, B. (2017). Managing conflict-generating invasive species in South Africa: Challenges and trade-offs. *Bothalia*, 47(2): 1–11.

ZIMMERMANN, H. (2012). Causes for the invasion success of Rosa rubiginosa L . in Argentina.

ZIMMERMANN, H. G., MORAN, V. C., & HOFFMANN, J. H. (2004). Biological control in the management of invasive alien plants in South Africa, and the role of the Working for Water programme, 100(1–2:, 34–40.

ZIMMERMANN, H., VON WEHRDEN, H., DAMASCOS, M. A., BRAN, D., WELK, E., RENISON, D., & HENSEN, I. (2011). Habitat invasion risk assessment based on Landsat 5 data, exemplified by the shrub Rosa rubiginosa in southern Argentina. *Austral Ecology*, 36(7): 870–880.

APPENDIX

1. Expert opinion questionnaire

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INFORMED CONSENT DECLARATION

Expert Opinion Questionnaire

Project Title: **The Potential Conflict of Interest Associated with the Management of *Rosa rubiginosa* in South Africa**

Timothy Westwood from the Department of Economics and Economic history, Rhodes University has requested my permission to participate in the above-mentioned research project.

The nature and the purpose of the research project and of this informed consent declaration have been explained to me in a language that I understand.

I am aware that:

1. The purpose of the research project is to determine the costs and benefits of invasive species *Rosa rubiginosa* in South Africa from the perspective of farmers, landowners and other stakeholders in the relevant geographical areas. The project will also determine the market for rosehips in South Africa and its potential growth.

2. The Rhodes University has given ethical clearance to this research project and I have seen/may request to see the clearance certificate.

3. By participating in this research project, I will be contributing towards a furthering of the socio-economic impacts of a category 1b IAP in SA. This research will aid in understanding the impacts of a little researched species of IAP, provide much needed knowledge on that species, inform management decisions in terms of prioritization of IAP species and provide clarity on cost-benefit status of the species.

4. I will participate in the project by undertaking a questionnaire that will seek to ascertain what the benefits and costs are of the species and provided informed opinions on the invasive statues and characteristics of *Rosa rubiginosa*.

5. My participation is entirely voluntary and should I at any stage wish to withdraw from participating further, I may do so without any negative consequences.

6. I will not be compensated for participating in the research, but my out-of-pocket expenses will be reimbursed.

7. There may be risks associated with my participation in the project. I am aware that

   a. the following risks are associated with my participation: Embarrassment caused by not knowing responses to some questions or exposure by results becoming open to public assessment.
   b. the following steps have been taken to prevent the risks: Questions are phrased in such a way that respondents may give a response without feeling like they have inadequate knowledge. Personal details and information will not be published or made available in any of the published work and all stored data will be done so without the personal details of the participants.
   c. there is a <1% chance of the risk materialising

8. The researcher intends publishing the research results in the form of a masters thesis as well as several subsequent academic papers. However, confidentiality and anonymity of records will be maintained and that my name and identity will not be revealed to anyone who has not been involved in the conduct of the research.

9. I will not receive feedback/will receive feedback in the form of an email with the thesis attached regarding the results obtained during the study.

10. Any further questions that I might have concerning the research or my participation will be answered by Timothy Westwood – timpaulwestwood@gmail.com ; 0726043468.

11. By signing this informed consent declaration, I am not waiving any legal claims, rights or remedies.

12. A copy of this informed consent declaration will be given to me, and the original will be kept on record.

I, …….. have read the above information / confirm that the above information has been explained to me in a language that I understand and I am aware of this document's contents. I have asked all questions that I wished to ask and these have been answered to my satisfaction. I fully understand what is expected of me during the research.

I have not been pressurised in any way and I voluntarily agree to participate in the above-mentioned project.

…… ……

Participant's signature **Date**

Any queries should be directed to Timothy Westwood, available at timpaulwestwood@gmail.com or on 0726043468.

Any complaints should be directed to the Chair of the Human Ethics Sub-Committee Prof Jo Dames, available at j.dames@ru.ac.za

A. Personal Details (for administrative purposes and in case follow-up for clarification is required)

NAME (first and surname)	
CONTACT DETAILS (optional)	Number: _____ Email: _____
OCCUPATION	
TITLE	

B. Plant Identification

According to the Alien and Invasive Species List of South Africa, *Rosa rubiginosa* is the only invasive rose species. However, there are a number of closely related Rosa species in Southern Africa. The images below are simply to provide you with a visual representation of

Rosa rubiginosa.

Rosa rubiginosa

1. **Do you feel confident in being able to identify the Rosa species (*Rosa rubiginosa*) in the above pictures?**

   ☐ - Yes ☐ - No ☐ - Only with flower

C. *Rosa rubiginosa*

2. **Are you aware that *Rosa rubiginosa* is a 1b invasive species in South Africa?**

   ☐ - Yes ☐ - No

---

3. **Do you agree with the 1b categorisation?**

   ☐ - Yes ☐ - No ☐ - Unsure

---

4. **Do you believe *Rosa rubiginosa* to be a Conflict Generating Species (CGS)?**

☐ - Yes ☐ - No ☐- Unsure

Please detail your thoughts on the topic:

_____

_____

_____

_____

5. **Please complete the following table:**
   a. **Please indicate whether you believe *Rosa rubiginosa* has more or less of a negative impact in comparison to other highland invasive species.**

[* - MI = More invasive, SI = Same invasiveness, LI = Less invasive]

	MI	SI	LI
1. *Rubus fruticose* (Blackberry)			
2. *Pyracantha angustifolia* (Firethorn)			
3. *Cotoneaster* species			
4. *Robinia pseudoacacia* (Black locust)			
5. *Cirsium* species (Thistles)			

6. **Please complete the following table**:
   a. International studies have suggested that this plant has the following negative impacts: please indicate what your sentiments towards the following statements are.

[* - SD = Strongly disagree, D = Disagree, NA = Not aware, A = Agree & SA = Strongly agree**]**

	SD*	D	NA	A	SA
a. The plant alters the fire regime of the natural vegetation (changes the fire season).					
b. The plant significantly reduces water quantity.					
c. The plant creates fire hazards.					

d. The plant creates impenetrable thickets that impede human and animal movement.					
e. The plant reduces the yields of farming land by encroaching on cultivated land.					
f. The plant reduces the grazing land available to livestock.					

b. Can you think of any other negative impacts derived from the plant that are not covered by the above statements? If so, please detail these impacts below.

_____

_____

_____

_____

7. Please complete the following table:

a. Please indicate what your sentiments towards the following statements are.

[* - SD = Strongly disagree, D = Disagree, NA = Not Aware, A = Agree & SA = Strongly agree**]**

	SD*	**D**	**NA**	**A**	**SA**
a. The plants fruit (rosehips) can be processed to provide basic constituents of anti-inflammatory drugs. (Medicinal)					
b. Rosehips can be processed to deliver ingredients that are used to develop modern cosmetics.					
c. Rosehips can be processed into teas and jams.					
d. Rosa species can be used to facilitate natural forest regeneration.					
e. Rosehip contains high levels of vitamin C.					
f. The rosehips can be used as fodder for livestock.					

b) Can you think of any other benefits associated with rosehips that are not provided in the above statements? If so, please detail these benefits bellow.

D. Conclusion

Your assistance, time and input is greatly appreciated.

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

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

May I please remind you that none of this information will be shared publicly without your prior consent and that if you have any issues, queries or otherwise wish to get hold of me my email address is timpaulwestwood@gmail.com and I am available on 0726043468.

Thank you for your time and all the best in all your endeavours.

Additional Notes:

2. Landowner questionnaire

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INFORMED CONSENT DECLARATION

Landowner Questionnaire

Project Title: **The Potential Conflict of Interest Associated with the Management of *Rosa rubiginosa* in South Africa**

Timothy Westwood from the Department of Economics and Economic history, Rhodes University has requested my permission to participate in the above-mentioned research project.

The nature and the purpose of the research project and of this informed consent declaration have been explained to me in a language that I understand.

I am aware that:

13. The purpose of the research project is to determine the costs and benefits of invasive species *Rosa rubiginosa* in South Africa from the perspective of farmers, landowners and other stakeholders in the relevant geographical areas. The project will also determine the market for rosehips in South Africa and its potential growth.

14. The Rhodes University has given ethical clearance to this research project and I have seen/may request to see the clearance certificate.

15. By participating in this research project, I will be contributing towards a furthering of the socio-economic impacts of an IAP in SA. This research will aid in understanding the impacts of a little researched species of IAP, provide much needed knowledge on that species, inform management decisions in terms of

prioritization of IAP species and provide clarity on cost-benefit status of the species.

16. I will participate in the project by undertaking a questionnaire that will seek to ascertain what the benefits and costs are of the species and provided informed opinions on the invasive statues and characteristics of *Rosa rubiginosa*.

17. My participation is entirely voluntary and should I at any stage wish to withdraw from participating further, I may do so without any negative consequences.

18. I will not be compensated for participating in the research, but my out-of-pocket expenses will be reimbursed.

19. There may be risks associated with my participation in the project. I am aware that

    a. the following risks are associated with my participation: Embarrassment caused by not knowing responses to some questions or exposure by results becoming open to public assessment.
    b. the following steps have been taken to prevent the risks: Questions are phrased in such a way that respondents may give a response without feeling like they have inadequate knowledge. Personal details and information will not be published or made available in any of the published work and all stored data will be done so without the personal details of the participants.
    c. there is a <1% chance of the risk materialising

20. The researcher intends publishing the research results in the form of a masters thesis as well as several subsequent academic papers. However, confidentiality and anonymity of records will be maintained and that my name and identity will not be revealed to anyone who has not been involved in the conduct of the research.

21. I will not receive feedback/will receive feedback in the form of an email with the thesis attached regarding the results obtained during the study.

22. Any further questions that I might have concerning the research or my participation will be answered by Timothy Westwood – timpaulwestwood@gmail.com ; 0726043468.

23. By signing this informed consent declaration, I am not waiving any legal claims, rights or remedies.

24. A copy of this informed consent declaration will be given to me, and the original will be kept on record.

I, …….. have read the above information / confirm that the above information has been explained to me in a language that I understand and I am aware of this document's contents. I have asked all questions that I wished to ask and these have been answered to my satisfaction. I fully understand what is expected of me during the research.

I have not been pressurised in any way and I voluntarily agree to participate in the above-mentioned project.

……. …….

Participant's signature **Date**

Any queries should be directed to Timothy Westwood, available at timpaulwestwood@gmail.com or on 0726043468.

Any complaints should be directed to the Chair of the Human Ethics Sub-Committee Prof Jo Dames, available at j.dames@ru.ac.za

C. Personal Details (for administrative purposes and in case follow-up for clarification is required)

NAME (first and surname)	
CONTACT DETAILS (optional)	Number: _____ Email: _____
PREFERRED NAME OF PROPERTY	
DISTRICT PROPERTY LIES WITHIN	
YEARS UNDER YOUR OWNERSHIP/LEASE	
SIZE OF PROPERTY (HA)	
OPERATIONS ON PROPERTY (e.g. farming, private property, etc)	

D. Plant Identification

According to the Alien and Invasive Species List of South Africa, *Rosa rubiginosa* is the only invasive rose species. However, there are a number of closely related Rosa species in Southern Africa. The images below are simply to provide you with a visual representation of *Rosa rubiginosa*.

1a. Rosa rubiginosa plant

1b. Rosa rubiginosa hips

1c. Rosa rubiginosa plant with flower

2. **Do you feel confident in being able to identify the Rosa species (*Rosa rubiginosa*) in the above pictures?**

   ☐ - Yes ☐ - No

3. **If you answered "No" to question 1. Do you identify all wild Rosa species as "rosehips"?**

   ☐ - Yes ☐ - No

E. Containment:

Please recall that the information provided is private and will not be shared without prior consent of yourself.

4. **Is *Rosa rubiginosa* on your land?**

   ☐ - Yes ☐ - No

5. **Please indicate the extent of *Rosa rubiginosa* on your land.**

☐ - Low ☐ - Medium ☐ - High

6. **Do you regard *Rosa rubiginosa* as problematic?**

   ☐ - Yes ☐ - No ☐ - Unsure

   _____

   _____

7. **What are the negative impacts of *Rosa rubiginosa* that you have experienced?**

   ☐ - chokes fence lines

   ☐ - reduces water

   ☐ - blocks access

   ☐ - decreases available farming land

   ☐ - other (indicate on the line below)

   _____

   _____

8. **Have you attempted to control the spread of *Rosa rubiginosa* on your land?**

   ☐ - Yes ☐ - No

9. **What control techniques do you implement to stop/reduce the spread of *Rosa rubiginosa* on your land?**

   ☐ - **Mechanical** (Physical removal of plants)

   ☐ - **Chemical** (Use of herbicides)

   ☐- **Biological** (The use of animals or insects to control the patches)

   ☐- **Fire**

10. **How often do you implement control techniques?**

    _____

11. **Could you please indicate how much money you spend annually on controlling *Rosa rubiginosa.* (An estimate will suffice)**

R

12. **Could you please indicate how much money you lose due to *Rosa rubiginosa's* negative impacts on your land. (An estimate would suffice)**

R

13. **Have you found any beneficial properties of *Rosa rubiginosa* on your property?**

_____

_____

_____

_____

14. **Have you ever thought about the possibility of cultivating rosehips?**

☐ - Yes ☐ - No

15. **How would you compare the presence of *Rosa rubiginosa* with other invasive species within the area?**

_____

_____

_____

_____

16. **How has the shrub population change over the years?**

☐ - Increased and still increasing at a very high rate.

☐ - Increased but of late the rate has slowed down.

☐ - Not increasing

☐ - Decreasing

F. Legislation:

Please recall that the information provided is private and will not be shared without prior consent of yourself.

17. **Do you have an understanding of the National Environmental Management: Biodiversity Act and the Alien Invasive Species list of 2014? Specifically, the legislations covering *Rosa rubiginosa*.**

☐ - Yes ☐ - No

_____

_____

_____

18. **Do you believe the legislation regarding *Rosa rubiginosa* is reasonable?**

☐- very reasonable ☐ - reasonable ☐ -neutral ☐ - unreasonable ☐ -very unreasonable

_____

_____

_____

___

G. Conclusion

Your assistance, time and input is greatly appreciated.

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

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

_____

May I please remind you that none of this information will be shared publically without your prior consent and that if you have any issues, queries or otherwise wish to get hold of me my email address is timpaulwestwood@gmail.com and I am available on 0726043468.

Thank you for your time and all the best in all your endeavours.

Additional Notes:

_____

_____

_____

_____

_____

_____

3. Company Questionnaire

INFORMED CONSENT DECLARATION

Company Questionnaire

Project Title: **The Potential Conflict of Interest Associated with the Management of *Rosa rubiginosa* in South Africa**

Timothy Westwood from the Department of Economics and Economic history, Rhodes University has requested my permission to participate in the above-mentioned research project.

The nature and the purpose of the research project and of this informed consent declaration have been explained to me in a language that I understand.

I am aware that:

25. The purpose of the research project is to determine the costs and benefits of invasive species *Rosa rubiginosa* in South Africa from the perspective of farmers, landowners and other stakeholders in the relevant geographical areas. The project will also determine the market for rosehips in South Africa and its potential growth.

26. The Rhodes University has given ethical clearance to this research project and I have seen/may request to see the clearance certificate.

27. By participating in this research project, I will be contributing towards a furthering of the socio-economic impacts of an IAP in SA. This research will aid

in understanding the impacts of a little researched species of IAP, provide much needed knowledge on that species, inform management decisions in terms of prioritization of IAP species and provide clarity on cost-benefit status of the species.

28. I will participate in the project by undertaking a questionnaire that will seek to ascertain what the benefits and costs are of the species and provided informed opinions on the invasive statues and characteristics of *Rosa rubiginosa*.

29. My participation is entirely voluntary and should I at any stage wish to withdraw from participating further, I may do so without any negative consequences.

30. I will not be compensated for participating in the research, but my out-of-pocket expenses will be reimbursed.

31. There may be risks associated with my participation in the project. I am aware that

    a. the following risks are associated with my participation: Embarrassment caused by not knowing responses to some questions or exposure by results becoming open to public assessment.
    b. the following steps have been taken to prevent the risks: Questions are phrased in such a way that respondents may give a response without feeling like they have inadequate knowledge. Personal details and information will not be published or made available in any of the published work and all stored data will be done so without the personal details of the participants.
    c. there is a <1% chance of the risk materialising

32. The researcher intends publishing the research results in the form of a masters thesis as well as several subsequent academic papers. However, confidentiality and anonymity of records will be maintained and that my name and identity will not be revealed to anyone who has not been involved in the conduct of the research.

33. I will not receive feedback/will receive feedback in the form of an email with the thesis attached regarding the results obtained during the study.

34. Any further questions that I might have concerning the research or my participation will be answered by Timothy Westwood – timpaulwestwood@gmail.com ; 0726043468.

35. By signing this informed consent declaration, I am not waiving any legal claims, rights or remedies.

36. A copy of this informed consent declaration will be given to me, and the original will be kept on record.

I, ……..…….. have read the above information / confirm that the above information has been explained to me in a language that I understand and I am aware of this document's contents. I have asked all questions that I wished to ask and these have been answered to my satisfaction. I fully understand what is expected of me during the research.

I have not been pressurised in any way and I voluntarily agree to participate in the above-mentioned project.

…… ……

Participant's signature **Date**

Any queries should be directed to Timothy Westwood, available at timpaulwestwood@gmail.com or on 0726043468.

Any complaints should be directed to the Chair of the Human Ethics Sub-Committee Prof Jo Dames, available at j.dames@ru.ac.za

H. Personal Details (for administrative purposes and in case follow-up for clarification is required)

NAME (first and surname)	
CONTACT DETAILS (optional)	
NAME OF COMPANY	
DISTRICT PROPERTY LIES WITHIN	
WHEN WAS THE COMPANY FOUNDED?	
OPERATIONS OF COMPANY (e.g. essential oils, cosmetics, food, etc)	

I. Rosehip

Please recall that the information provided is private and will not be shared without prior consent of yourself.

1. **Is rosehip the main product your company deals with?**

   ☐ - Yes ☐ - No

   _____

   _____

2. **How long have you been exporting/selling rosehips?**

   _____

3. **Are you aware of what plant species the rosehips come from? (or are all your rosehips grouped as one)**

   ☐ - Yes ☐ - No ☐-Partly

   Please provide the name of the plant/s (scientific or common name).

_____

_____

_____

4. **Where do you source your rosehips from?**

☐ - Eastern Cape ☐ - Free State ☐ - Gauteng ☐ - Kwa-Zulu Natal ☐ - Limpopo

☐ - Mpumalanga ☐ - Northern Cape ☐ - North-West ☐ - Western Cape

☐ - Lesotho ☐ - Other

5. **Are the rosehips grown commercially or picked in the wild?**

   ☐ - Grown commercially ☐ - Picked in the wild

   _____

6. **Are the rosehip products you sell marketed as organic?**

   ☐ - Yes ☐ - No

   _____

7. **How important is the organic label to your company?**

   _____

   _____

8. **Please complete the following table:**

   a. **Please indicate what your sentiments towards the following statements are.**

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

	SD*	D	N	A	SA
g. Rosehips are cold-pressed to produce rosehip oil which is beneficial to damaged skin.					
h. Rosehips can be processed to deliver ingredients that are used to develop modern cosmetics.					
i. Rosehips can be processed into teas and jams.					
j. Rosehips can be used as fodder for animals.					
k. Rosehip contains high levels of vitamin C.					

   b. **Can you think of any other benefits associated with rosehips that are not provided in the above statements? If so, please detail these benefits bellow.**

_____

_____

_____

9. **Are you aware that some *Rosa* species are invasive in South Africa?**

☐ - Yes ☐ - No

10. **Do you take any precautionary measures when handling rosehips to avoid the spreads of the species?**

_____

_____

_____

J. Production

Please recall that the information provided is private and will not be shared without prior consent of yourself.

11. **How many tons of rosehips go through your production annually?**

12. **How much have you paid per ton of raw rosehips over the last 10 years? (Or as far back as possible)**

Year	Price (R)
2019	
2018	
2017	
2016	
2015	
2014	
2013	
2012	
2011	
2010	

13. **What has been your company's turnover for each of the last 10 years?**

Year	Turnover (R)
2019	
2018	
2017	
2016	
2015	

2014	
2013	
2012	
2011	
2010	

Projection for this year if sell 300 tons on just shell and oil = R8,64 mil

14. **What type of rosehip products does your company sell?**

☐ - Raw Product (hips) ☐ - Refined Products (seeds, shells…) ☐- Final Products (packaged products)

15. **Please provide your companies rosehip quantity of sales, profits generated and what percentage is sold locally vs overseas. Please provide any other product categories and their details in the spaces provided.**

Product Category	Quantity Sold Annually	Turnover (R)	Local sales (%)	Overseas sales (%)
1) Rosehip Seed Oil				
2) Whole Rosehips				
3) Rosehip Shells				
4) Rosehip Seeds				
5) Teas and Jams				
6)				
7)				
8)				
9)				
10)				

16. **Please provide your company's employment numbers?**

Full-time employees: _____

Seasonal employees: _____

Informal employees: _____

D. Rosehip Market

Please recall that the information provided is private and will not be shared without prior consent of yourself.

17. Where do you sell/export your rosehip products to?

☐ - Eastern Cape ☐ - Free State ☐ - Gauteng ☐ - Kwa-Zulu Natal ☐ - Limpopo

☐ - Mpumalanga ☐ - Northern Cape ☐ - North-West ☐ - Western Cape

Please provide the company names:

_____

_____

Sub-Saharan Africa:

☐ - Yes ☐ - No

Please state which countries and companies:

_____

_____

_____

Africa:

☐ - Yes ☐ - No

Please state which countries:

_____

Europe:

☐ - Yes ☐ - No

Please state which countries:

_____

Other (Please elaborate):

_____

_____

_____

18. **How has the sale of rosehips and rosehip products changed over the years, both locally and overseas? (Quantities) Why?**

    Locally:

    _____

    _____

    _____

    Overseas:

    _____

    _____

    _____

19. **Do you believe there is the potential for market expansion in the rosehip market?**

    ☐ - Yes ☐ - No ☐ - Unsure

    Please provide a short description for your answer:

    _____

    _____

    _____

    _____

20. **Can you provide any rosehip market details that indicate the size of the market in South Africa?**

    _____

    _____

    _____

21. **Can you provide any rosehip market details that indicate the size of the market Overseas?**

    _____

    _____

    _____

22. **What are the restrictions you face dealing with rosehips?** (supply, demand, harvesting, production…)

    _____

    _____

23. **Do you believe it would be economically beneficial to allow the cultivation of Rosa species, such as *Rosa rubiginosa,* by downgrading the shrubs invasive status?**

☐ - Yes ☐ - No

_____

_____

E. Conclusion

Your assistance, time and input is greatly appreciated.

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

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

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May I please remind you that none of this information will be shared publically without your prior consent and that if you have any issues, queries or otherwise wish to get hold of me my email address is timpaulwestwood@gmail.com and I am available on 0726043468.

Thank you for your time and all the best in all your endeavours.

Additional Notes: